Kathmandu University Medical Journal (2007), Vol. 5, No. 4, Issue 20, 475-483

Original Article

Application of "the Sequential Organ Failure Assessment (SOFA) score" in predicting outcome in ICU patients with SIRS

Acharya SP[1], Pradhan B[2], Marhatta MN[3]

[1]Lecturer, [2]Asstant Professor, [3]Associate Professor and Head, Department of Anesthesiology, Tribhuban University Teaching Hospital, Maharajgunj, Kathmandu, Nepal

Abstract

Background: Various scoring systems have been developed to prioritize patient admission and management in ICU. The objective of this prospective, observational cohort study was to evaluate application of one such system, the Sequential Organ Failure Assessment (SOFA) Score in predicting outcome in ICU patients with SIRS. Patients and

Methods: Fifty patients admitted to a six bed multidisciplinary ICU with SIRS were consecutively enrolled in the study and SOFA scores were calculated at zero hour, after 48 hrs, and after 96 hrs and patients followed till discharge from hospital.

Results: When compared to outcome, the non survivors had high initial, mean and highest SOFA scores as compared to survivors. (p value = 0.002, <0.001, <0.001 respectively). Delta SOFA was not significantly associated with outcome. (p value= 0.117). The initial SOFA score > 11 predicted a mortality of 90%. (OR 23.72, 95%CI2.68-209.78, *p*=0.004). Similarly, mean SOFA score of > 7 predicted a mortality of 73.9% (OR 22.7, 95%CI 5.0 – 103.5, *p*<0.001) and high SOFA score > 11 predicted a mortality of 87.5% (OR 32.66, 95%CI 5.82-183.179, *p*< 0.001). Area under receiver operating characteristic (ROC) curve for mean SOFA was 0.825, for high SOFA was 0.817 and for initial SOFA was 0.708. Thus mean, high and initial SOFA scores were helpful in predicting between the survivors and the non survivors.

Conclusion: The SOFA scoring system is useful in predicting outcomes in ICU and thus help in proper utilization of ICU resources.

Key words: Sequential Organ Failure Assessment (SOFA) Score, Systemic Inflammatory Response Syndrome (SIRS), Intensive Care Unit (ICU).

Critical care medicine is a complex, multidisciplinary specialty, designed to care all sort of patients with critical illnesses. Even in developed countries, concerns about the high costs in the ICU are increasing.[1] Thus, illness severity scoring systems have been devised depending on therapeutic, anatomical and physiological basis.[1] If ICU admissions could be prioritized based on scoring systems, the use of limited financial, medical and human resources can be optimized and will allow the best usage in the ICU. Such studies are very few in the developing countries, and in particular no studies have been done with the SOFA score (Table 1) in Nepal. Thus this study was conducted to predict the outcome in ICU patients with SIRS with the SOFA score. The Sequential Organ Failure Assessment (SOFA) Score [2, 3] has been developed by European Society of Critical Care Medicine (ESCCM), in 1994, as a system for measuring the status of the patient in the ICU. It basically evaluated the six different organ systems separately. Different variables and parameters are included in each of the organ system and a definite score is given to that state varying from 0 - 4, all of which is later added to calculate the SOFA score, (out of a maximum of 24). The score increases as the organ system functioning worsens, thus assessment of individual organ dysfunction or failure can be done along with evaluation of patient as a whole. SOFA score can be used to evaluate all patients in the ICU; we limited our cohort to those patients who met the criteria of Systemic Inflammatory Response Syndrome (SIRS) with the aim to study the outcome of these patients with SIRS in the ICU and see whether SOFA score will be able to predict the outcome or not. The SIRS criteria was based on 1992 consensus conference, conducted by the American College of Chest Physicians (ACCP) and the Society of Critical Care Medicine (SCCM), where definitions and terminology associated with sepsis and its sequelae were clarified.[4] In December 2001, a second conference was organized by the ACCP, SCCM, the American Thoracic Society, and the European Society of Critical Care Medicine to update the original definitions. After that, an expanded list of signs and symptoms was outlined to facilitate recognition of sepsis.[4]

Correspondence
Dr. Subhash Pd Acharya,
Kaushaltar-15, Madhyapur, Thimi, Bhaktapur, Nepal.
PO BOX: 10211 Kathmandu, Nepal.
Email: drsuvash@gmail.com

Table 1. The Sequential Organ Failure Assessment (SOFA) Score*

Variables	SOFA Score 0	1	2	3	4
Respiratory Pao_2/Fio_2, mm Hg	>400	≤400	≤300	≤200†	≤100†
Coagulation Platelets $\times 10^3/\mu L$‡	>150	≤150	≤100	≤50	≤20
Liver Bilirubin, mg/dL‡	<1.2	1.2-1.9	2.0-5.9	6.0-11.9	>12.0
Cardiovascular Hypotension	No hypotension	Mean arterial pressure <70 mm Hg	Dop ≤5 or dob (any dose)§	Dop >5, epi ≤0.1, or norepi ≤0.1§	Dop >15, epi >0.1, or norepi >0.1§
Central nervous system Glasgow Coma Score Scale	15	13-14	10-12	6-9	<6
Renal Creatinine, mg/dL or urine output, mL/d‖	<1.2	1.2-1.9	2.0-3.4	3.5-4.9 or <500	>5.0 or <200

*Norepi indicates norepinephrine; Dob, dobutamine; Dop, dopamine; Epi, epinephrine; and Fio_2, fraction of inspired oxygen.
†Values are with respiratory support.
‡To convert bilirubin from mg/dL to µmol/L, multiply by 17.1.
§Adrenergic agents administered for at least 1 hour (doses given are in µg/kg per minute).
‖To convert creatinine from mg/dL to µmol/L, multiply by 88.4.

Objectives

The main objective of the study is to determine the usefulness of the measurement of Sequential Organ Failure Assessment (SOFA) scores for prediction of outcome (mortality) in the intensive care unit (ICU) in patients with SIRS.

Materials and methods

With permission from the Institutional ethical committee and department of anaesthesiology, a prospective, observational cohort study was conducted from 15th June 2005 for a period of four months at a six bed Multidisciplinary Intensive Care Unit (ICU) at a University Hospital in Kathmandu, Nepal. Fifty patients consecutively admitted to the ICU, of any specialties, who fulfilled the SIRS criteria, Age between 15 and 70 years and an informed consent given by the patient or immediate relative (first degree). Paediatric and Geriatric age group were excluded to avoid controversy in the study due to influence of age on mortality in critically ill patients in these extreme of ages. Patients taken out from ICU against medical advice, whose investigations could not be done or lost, and loss of patient follow up, after discharge from ICU were also excluded from the study.

All patients meeting the inclusion criteria, any time after admission into the ICU were consecutively included in the study. This time is noted as the 0 hr, when SIRS was diagnosed and patient was included in the study. Relevant clinical examinations and measurements were recorded and blood investigations sent. Arterial Blood Gas Analysis was done in the ICU with heparinised arterial blood sample with the blood gas analyzer nova biomedical UK. (Model: Stat Profile® pHOX). All the reports of investigations and clinical measurements were recorded and the score was assigned according to the score for individual organ system of the SOFA, (Table 1) and a final SOFA score of that time (0 hr) recorded. The same investigations, measurements were done and SOFA score was calculated after 48 hrs and after 96hrs and recorded. Then after, all patients were followed up and outcome recorded till they were discharged from the hospital. The outcomes of the patient were classified as non survivors and survivors. Only SOFA score inside ICU was recorded and outcome recorded. The different SOFA scores were compared to outcome of the patient in ICU with SIRS using independent sample t tests and the paired sample t tests. Odds ratio with 95% confidence interval was computed

using univariate logistic regression analysis with ICU outcome as the dependent variable. A Chi square test (with Yates correction when applicable) and Fisher's exact test (when chi square test was not applicable) was used to evaluate statistical significance of categorical variables. Receiver operating characteristic curves were also studied to analyze between different SOFA variables. Patient outcome was compared also with the Age, Sex, Length of ICU stay, Duration of Mechanical Ventilation, using independent sample t test. p value < 0.05 was considered significant statistically. Statistical analysis was done with the computer software SPSS for windows.

Results

Mean age of the patient admitted to ICU with SIRS was 34 yrs ±14.4 yrs. There were 29 males (58%) and 21 females (42%). In the study group, the longest duration of stay in ICU was 69 days and the minimum duration of ICU stay was 1 days. The averaged duration of ICU stay was 9days. Regarding different specialties, 20 patients were admitted by Internal Medicine (40%), 10 by Neurology (20%), 8 by General Surgery (16%), 7 by Neurosurgery (14%), 3 by Obstetrics & Gynaecology (6%), and 2 by Cardiothoracic and Vascular Surgery (4%). 68% required mechanical ventilator support while 32% did not require. Mean duration of mechanical ventilation was 9.5 days. Regarding procedures, among 50 patients, central venous monitoring line was inserted in 68% patients and invasive arterial blood pressure monitoring line was inserted in 18%. Tracheostomy was done in 10%, Haemodialysis in 4%, and Bronchoscopy was performed in 2% of patients.

Analyzing outcome, 20 patients (40%) expired in the ICU (Non- survivors, while 30 patients (60%) survived and were transferred out of ICU and then discharged home subsequently, with a good recovery. Residual deficit was noticed in 8 patients (16%). The common residual deficit noticed was tracheotomy (and thus temporary loss of speech) in 10%, hemiparesis in 4%, aphasia in 4% and dyskinetic movements in 2%.

Mean age was 35.7 yrs in non-survivors while it was 32.4 yrs in survivors. In the non-survivors, 13 (65%) were males and 7 (35%) were females while in survivors 16 (53.34%) were males and 14 (46.67%) were females. The mean length of ICU stay was 4.85 days in non-survivors while it was 11.3 days in survivors. The mean duration of mechanical ventilation was 4.7 days in non-survivors while it was 16.35 days in survivors.

Analysis of sofa score

Initial SOFA Score ranged from 1 to 17, average Initial SOFA score was 7.9. Non-survivors (M1) were significantly associated with the Initial SOFA score of 10.3. (p value 0.002). Initial SOFA score of more than 11 had a predicable mortality of 90 %.(p value = 0.001) But 27.5% of patients who had initial SOFA score of less than 11 also expired.

Mean SOFA Score ranged from 1 to 19, average of mean SOFA score was 7.8. Non-survivors (M1) were also significantly associated with the Mean SOFA score of 11.5. (p value < 0.001). Mean SOFA score more than 7 had a predicable mortality of 73.9%. (p value < 0.001). But 11.1% of patients who expired also had mean SOFA score of less than 7.

Highest SOFA Score ranged from 1 to 21, average highest SOFA score was 9.5. Non-survivors (M1) were significantly associated with the Highest SOFA score of 13.5. (p value < 0.001). Highest SOFA score more than 11 had a predicable mortality of 87.5% (p value = 0.00002). But 17.6% of patients who expired also had highest SOFA score of less than 11.

Delta-SOFA Score ranged from 0 to 7, average Delta-SOFA Score was 2.8. However there was no significant association of Delta-SOFA Score with the outcome. Delta-SOFA in Non-survivors was 3.5 while it was 2.4 in Survivors. (p value = 0.117). And in predicting mortality also, Delta SOFA score was not able to predict mortality significantly by both Fisher's exact test (p value = 0.67) and univariate logistic regression analysis. (p value = 0.40).

The area under the ROC curve (Fig 1) shows that Mean SOFA of > 7 has the highest correlation with mortality followed by High SOFA of > 11, and then Initial SOFA of > 11. The equivalence of areas under ROC curve for mean and high SOFA score also suggests that they are similarly effective in predicting outcome (mortality).

Table 2: Univariate logistic analysis for SOFA score variables

SOFA SCORE	ODDS RATIO	95% CI FOR OR	p VALUE
INITIAL>11	23.72	2.684 – 209.78	0.004
MEAN>7	22.7	5.0 – 103.5	<0.001
HIGH>11	32.667	5.825 – 183.179	< 0.001
DELTA>4	4.84	1.075 – 21.84	0.40

Table 3: Prediction of mortality

SOFA	**Score**	**TOTAL Number**	**EXPIRED Number**	**PREDICTED (% OF EXPIRED)**	**p VALUE**	**TEST APPLIED**
INITIAL	> 11	10	9	90%	0.001	Fisher's Exact
	≤ 11	40	11	27.50%		
MEAN	> 7	23	17	73.91%	0.00002	Chi square (Yates correction applied).
	≤ 7	27	3	11.11%		
HIGH	> 11	16	14	87.5%	0.00001	Chi square (Yates correction applied).
	≤ 11	34	6	17.6%		
DELTA	> 4	10	7	70%	0.67	Fisher's Exact
	≤ 4	40	13	32.5%		

Analysis of the Receiver Operating Characteristic (ROC) Curve

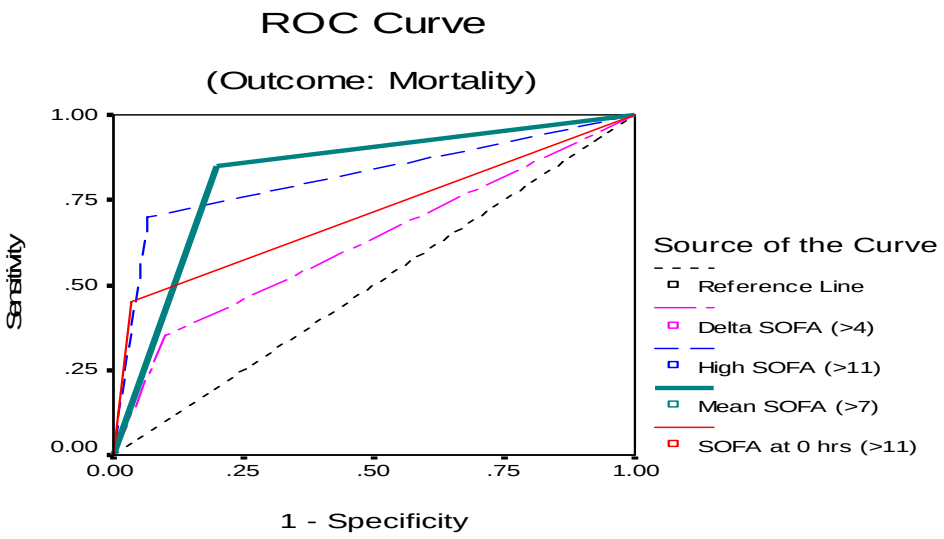

Fig 1: Area under ROC Curve

Test Result Variable(s)	Area
SOFA at 0 hrs (>11)	.708
Mean SOFA (>7)	.825
High SOFA (>11)	.817
Delta SOFA (>4)	.625

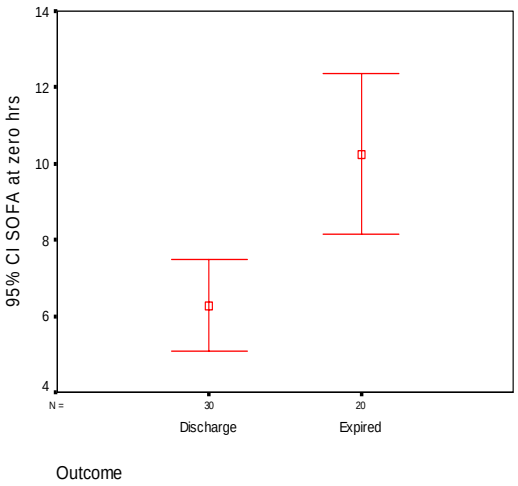

Fig 2a. Initial SOFA

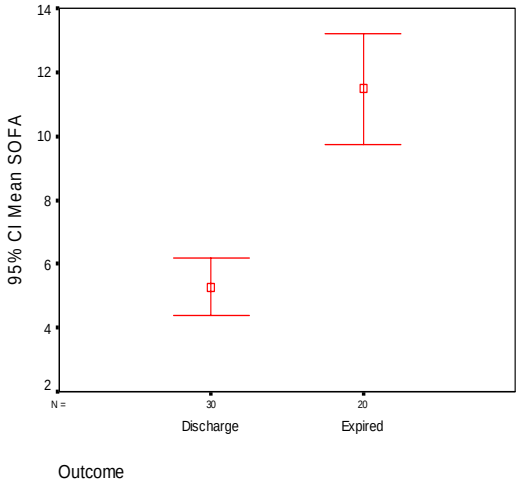

Fig 2b. Mean SOFA

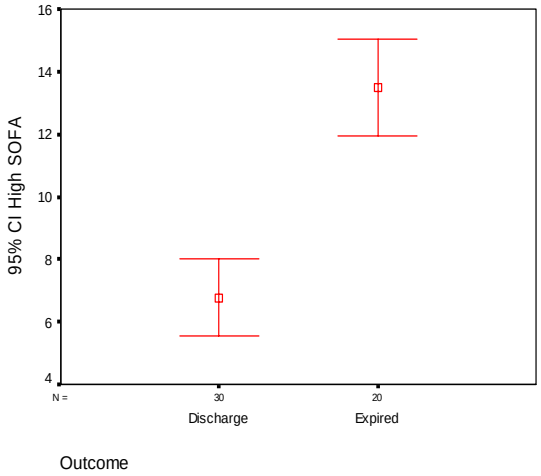

Fig 2c. High SOFA

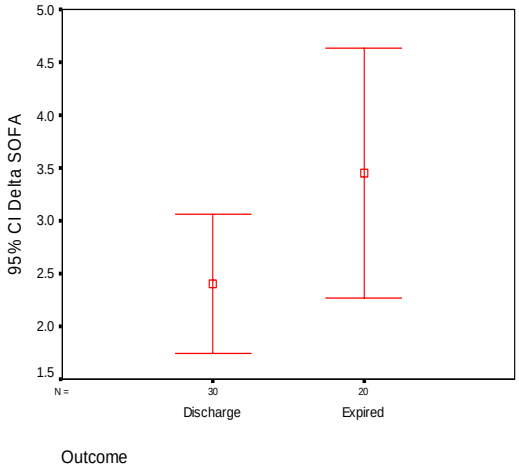

Fig 2d. Delta SOFA.

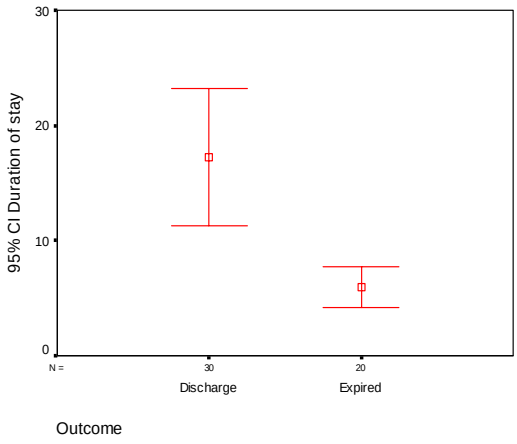

Fig 2e. Duration of Stay

Fig 2: 95% Confidence Intervals for different SOFA scores and duration of stay amongst the survived and the expired...

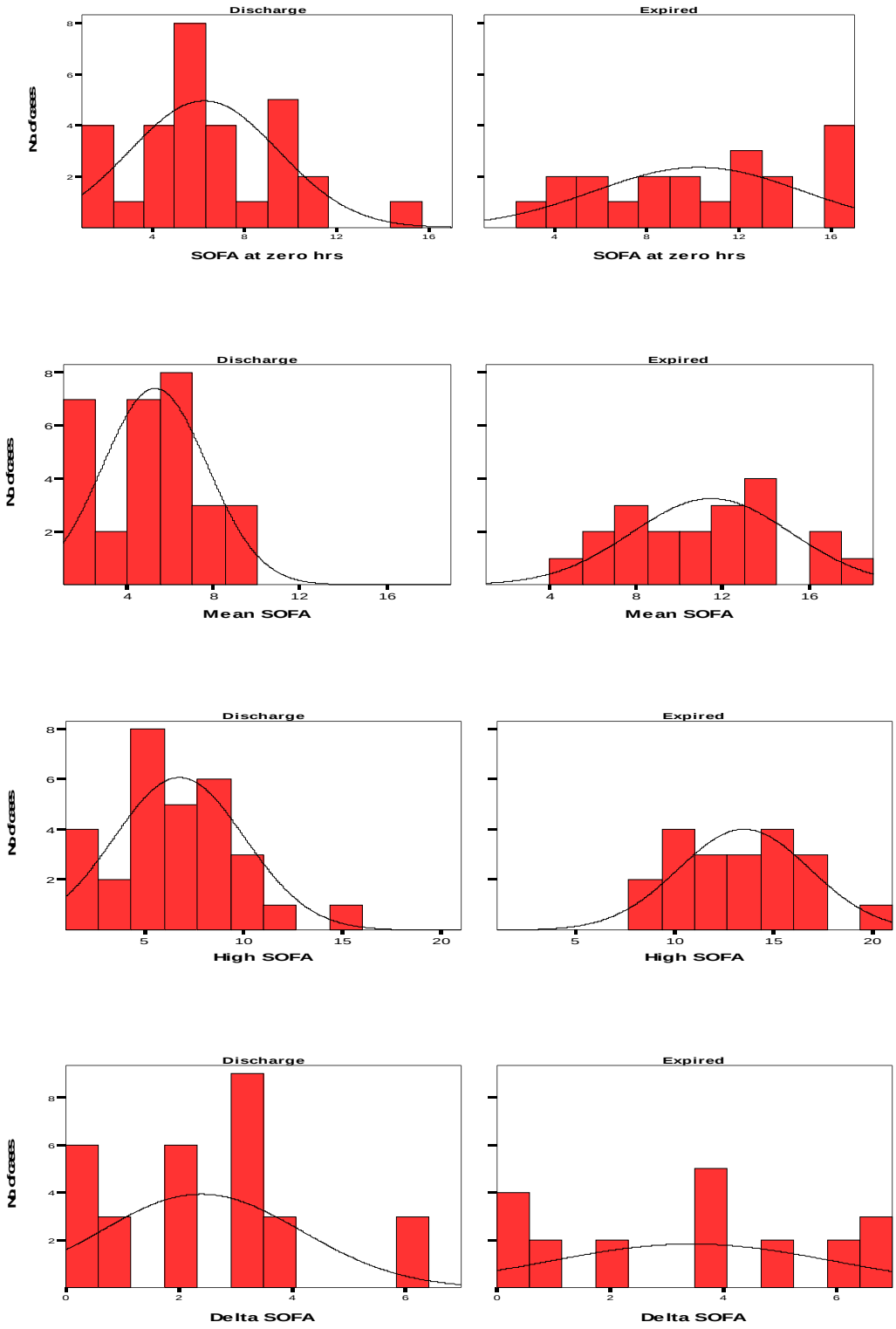

Fig 3: Histograms comparing between discharged/survivors (Left Panel) and non survivors/expired (Right Panel) among various SOFA, SOFA at 0 hrs, Mean, high, Delta SOFA respectively.

Discussion

Among the various scoring systems for predicting outcomes in ICU, SOFA score is easy as the variables measured are easily available and routinely measured in the ICU and can be measured in various cohorts of patients. Patients with sepsis usually presents with SIRS in the initial phase and later progress to sepsis and then to septic shock, as mentioned in the Sepsis occurrence in acutely ill patients (SOAP) study by Sprung CL et al.[5] We thus narrowed our cohort of patients to those patients with SIRS. We also found through our Medline search that there are very few studies with the SOFA score in patients with SIRS, thus we planned to take SIRS patients as our cohort for our observational study.

Ideally SOFA scores should have been measured daily for all the patients but, as progression of SIRS is usually more progressive and delayed, so it was measured every 48 hrs. Thus to see the gradual change in SOFA score along with the change in the patient clinical status, 48 hrs interval was chosen, and this interval of 48 hrs, is equally relevant and was also chosen in other studies of SOFA score.[6,7]

In this study, mean age of the patient was 34 yrs, whereas the mean age was 59 in the study of Ferreira et al[3] while mean age was 61.2 yrs in the study of Rocker G et al.[8] In our study 58% were males and 42% were females. These differences may be because those studies have included all patients in ICU while our cohort included only those patients with SIRS. Among these, 68% of patient's required mechanical ventilatory support and 68% required invasive monitoring.

In this study, 60% patients survived while 40% patients with SIRS died in the ICU. Overall mortality of ICU in our cohort of patients was 40% compared to overall ICU mortality of 35.7% in the study of Rocker G et al[8], 34.3% in the study of Mhamed SM et al[7], and ICU mortality of only 22% in study of Vincent et al.[9] This difference may also be because of the same reason that the calculated mortality in our study included only those patients with SIRS while the given mortality in other studies are the overall ICU mortality in all groups of patients.

In our study, mean length of ICU stay was 9 days, non survivors had a shorter stay of 4.85 days, but survivors stayed in the ICU for a longer duration of 11.3 days. (p value = 0.06). Schuster also reported shorter length of ICU stay in patients who died.[10] But this result is also contrary to some disease specific studies done by Shaughnessy in post CABG patients and by Williams in patients with acute pancreatitis where longer duration of ICU stay was associated with increase mortality.[11, 12]

The study population had a mean duration of hospital stay of 12.5 days, with the range of 2 to 83 days. In non-survivors mean duration of hospital stay was only 5.95 days while it was 17.23 days in survivors. (p value = 0.001) This shows that survivors are significantly associated with a longer duration of hospital stay than the non survivors.

Mean age of patient among the non survivors was 35.7 yrs while that among the survivors was 32.6 yrs. (p value = 0.429) Thus age was not significantly associated with outcome in these patients with SIRS. Among the non survivors, 65% were males, while among the survivors only 53.4% were males, and similarly 35% of non survivors were females and 46.6% of non survivors were females. (p value = 0.41) Thus in our study sex was also not associated with outcome. This was similar to most of the studies.[5, 7, 13]

All of the non survivors (100%) required mechanical ventilation while only 14 patients (46.67%) of survivors required mechanical ventilation. The requirement of mechanical ventilation was thus also not associated with outcome. (p value = 0.253)

Analyzing the SOFA scores, when Initial SOFA, Mean SOFA, Highest SOFA, and Delta SOFA scores were compared to outcome, the non survivors had high initial, mean and highest SOFA scores as compared to survivors. (p value = 0.002, <0.001, <0.001 respectively). These results were similar to the study of Ferreira et al.[3] But correlation of Delta SOFA with outcome was not significant. (p value = 0.117) which was in contrast to study of Ferreira et al.[3] where Delta SOFA was also significantly associated with outcome. This may be because of the different way of calculating the Delta SOFA score. Ferreira et al.[3] calculated the difference between SOFA at 48hr and SOFA at 0 hr and mentioned this value as Delta SOFA 48 – 0. Similarly they calculated the difference in SOFA at 96 hr and 0 hr and mentioned as Delta SOFA 96 - 0. They calculated the change in SOFA score with reference to the initial SOFA score (at 0 hr). However, Machado et al[6] assigned Delta SOFA as the variation of SOFA score day 1 and day 3, and did not consider any value then after. In another study, Hiroshi et al[15] assigned Delta SOFA as the difference between maximum SOFA and baseline SOFA score. But in our study we calculated the greatest score among the two values; Delta SOFA 48 - 0 and Delta SOFA 96 –

48 (that is the change in every 48hr with comparison to the previous score, either increase or decrease in the score.) and designate that value as the Delta SOFA Score. This is probably the reason why Delta SOFA was not associated to outcome in our study while it was significantly associated with outcome in the study of Ferreira et al, [3] Vincent et al, [2] Machado et al[5] and Hiroshi et al.[15] This value assigned as Delta SOFA score in our study has been taken in few other studies as Delta-max SOFA but this variable has also been associated with outcome.[16]

Regarding prediction of mortality, the initial SOFA, i.e. SOFA scores at diagnosis of SIRS, when > 11, predicted mortality of 90%, which was similar to the study of Ferreira et al.[3] when initial SOFA > 11 predicted a mortality of 95%. In our study, the mean SOFA, i.e. the average SOFA score during the stay in ICU, when > 7, predicted mortality of 73.9%. Highest SOFA, among the SOFA score up to 96 hrs of admission to ICU, if > 11, predicted mortality of 87.5% which was comparable to >80% mortality in the study of Ferreira et al.[3]

But the Delta SOFA score did not correlate to mortality. (p value = 0.117). In our study, initial, mean and highest SOFA score were the reliable predictors of ICU outcome throughout the ICU stay which was similar to the study of Ferreira et al,[3] Vincent JL et al, [2] Saulius V et al,[17] and Machado RL et al.[5]

Analyzing the area under the Receiver operating characteristic curve (AuROC), it was seen that the mean SOFA of > 7 has the highest correlation with mortality (AuROC: 0.825), followed by high SOFA of > 11 (AuROC: 0.817), and then initial SOFA of > 11 (AuROC<0.708). These were comparable to the study of Ferreira et al,[3] Ceriani et al.[16] But in their study area under ROC was largest for high SOFA followed by mean and initial SOFA. But the area under Delta SOFA > 4 was lesser (AuROC: 0.625) as compared with other studies. The equivalence of areas under ROC curve for mean and high SOFA score also suggests that they are similarly effective in predicting outcome (mortality).

As the scoring systems are not always 100% accurate, ICU physicians must learn to integrate data into clinical decision making. These scoring human systems do not dehumanize the decision making process but rather aid to eliminate physicians reliance on emotional, poorly calibrated, over pessimistic subjective estimates.[18]

As with all studies, our study also has some limitations. The study population was very small and will need larger multicentric studies with large number of patients (e.g. Ferriera et al[3], Vincent JL et al [2]) and should be compared to other scoring systems also as done by Saqib ID[19] and Silva E et al.[20] The SOFA scores was calculated every 48 hrs only, ideally it should have been measured every 24 hrs and thus monitoring the progression of the disease and would have been more informative if compared to other scoring systems in the ICU like APACHE, MODS, etc.

Conclusion

The SOFA score was able to predict outcome in ICU patients with SIRS. Initial SOFA, Mean SOFA and Highest SOFA, all correlated well with the mortality. The SOFA scoring system can help the ICU physicians in admitting patients, monitoring the clinical course, assessment of organ dysfunction, predicting mortality, and for transferring patients out from the ICU and thus in proper utilization of ICU resources also in developing countries like ours, where the resources are limited. However, further studies with greater number of patients, more frequent measurement of variables and comparison between different scoring systems is required to improve the accuracy.

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