Predicting intensive care unit admission in trauma patients in India using the quick sequential organ failure assessment score (qSOFA)

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Introduction

Trauma is a global health problem affecting at least 520 million people per year [1]. Trauma accounts for 13% of total disability adjusted life years lost and 8% of deaths globally with the majority in low and middle income countries [2, 3]. Most deaths from trauma occur shortly after the injury and reducing mortality in patients with severe trauma requires early intervention[4]. This includes knowing how to sort which patients to prioritize in the emergency room and which patients that need to be admitted to an intensive care unit (ICU), as intensive care in many cases can be necessary to maintain adequate physiological functions.

Because of the urgency and complexity of trauma care it is important to early assess trauma severity to guide further management, including the need for care in the ICU. Several trauma severity scores have been developed for this purpose, of which the Revised Trauma Score (RTS) is the most well known [5]. The RTS includes Glasgow come scale (GCS), systolic blood pressure (SBP) and respiratory rate (RR), and is rated 0-4 points on each parameter. Because of the multiple cutoffs involved for each parameter the RTS can be too complex for routine use, especially in low resource settings with high trauma loads. The quick Sequential Organ Failure Assessment score (qSOFA score) was developed in 2016 and includes the same variables as RTS but with just one cutoff for each parameter. Introduced as a screening tool coupled with the already existing Sequential Organ Failure Assessment score (SOFA score). The qSOFA score was meant to be used bedside to identify patients with high-risk of organ dysfunction due to infections [6, 7] and the SOFA score to more precisely evaluate the level of organ dysfunction [8]. The qSOFA score has lately been able to predict mortality in trauma patients [9, 10].

The majority of the research done on trauma and trauma care is from high income countries including the studied predictive power of qSOFA on mortality. Because low resource settings are disproportionately affected by trauma and have limited resources a simple scoring system to help prioritize resources such as ICU beds is important. The qSOFA is easy to perform and because of its singular cutoffs it is easy to calculate. Therefore we aimed to asses the validity of qSOFA in predicting ICU admission in trauma patients admitted to hospitals in a low resource setting and to investigate whether the qSOFA model could be updated to increase its performance. If successful qSOFA could be used as a tool to help practicing clinicians sort patients and in faster way decide the lever of care needed.

Methods

Source of data

We analysed the Towards Improved Trauma Care Outcomes (TITCO) in India cohort [11]. The TITCO cohort data was collected between July 2013 and December 2015 and includes patients admitted to four public university hospitals. The hospitals included were; Jai Prakash Narayan Apex Trauma Center, connected to the All India Institute of Medical Sciences in New Delhi, a large center solely dedicated to trauma care; King Edward Memorial hospital in Mumbai, a tertiary level hospital but without dedicated trauma wards;

Lokmanya Tilak Municipal General Hospital in Mumbai, a tertiary level public university hospital with a smaller dedicated trauma ward; and Seth Sukhlal Karnani Memorial Hospital in Kolkata, connected to The Institute of Post Graduate Medical Education and Research, a tertiary level public university hospital without a ward dedicated solely to trauma.

All data was collected using one dedicated data collector at each site that rotated between day, evening, and night shifts. The data collectors were not employed by the hospitals to ensure nonbiased reporting, and all collectors had a master's degree in health science as well as they got continuous training and supervision throughout the study. Data was gathered retrospectively within days from patients' case files when not directly observed by a data collector on site. To ensure consistency the data was reviewed against patients' files.

Participants

The TITCO cohort includes patients with a history of trauma who either got admitted to one of the participating hospitals or who died between arrival and admission. Patients were not included if they presented with isolated limb injuries without associated vascular damage or if they were dead upon arrival. The exclusion criteria for this study where patients below the age of 18, patients who died before admission to a participating hospital, patients who arrived with a surgical airway or who were intubated before arriving to a participating hospital.

Outcome

The outcome of interest was admission to the ICU during hospitalization as recorded in the TITCO database. This was recorded as hours in intensive care in the TITCO database and was for this study converted into a binary variable representing the presence or absence of ICU admission.

Predictors

The predictors used in qSOFA are RR, GCS and SBP. Data on these predictors were collected on arrival to hospital. In the original qSOFA these predictors were dichotomized using the cutoffs higher than or equal to 22 for respiratory rate, less than 15 for the Glasgow coma scale, and less than 100 for systolic blood pressure. Using these dichotomized predictors qSOFA can be expressed as either a model, in which the coefficients associated with each predictor are used to estimate patient specific probabilities of the outcome, or a score equal to the sum of the dichotomized predictors ranging from 0 to 3. For this study we used the predictors as dichotomized in the original qSOFA publication [7] but also as continuous variables to identify new optimal cutoffs and associated coefficients, see Statistical analysis methods below.

Sample size

We included all eligible patients from the TITCO cohort

Missing data

A complete case analysis was conducted.

Statistical analysis methods

We used R for all statistical analyses . We described the sample characteristics using counts and percentages for qualitative variables and mean and standard deviations (SD) for quantitative variables. We use model to denote the combination of predictor values and coefficients that can be used to estimate patient specific outcome probabilities and score to denote the sum of dichotomized predictor values.

The study sample was randomly split into three parts called the training sample, validation sample, and test samples with 60%, 20%, and 20% of the observations in each sample respectively. To update qSOFA we first used the training sample to identify new optimal cutoffs for each predictor. To identify optimal cutoffs we calculated the Youden index for all possible cutoffs for each predictor. We then defined the optimal cutoff for each predictor as the cutoff that maximized the Youden index. We then used lostistic regression in the validation sample to estimate coefficients associated with the new optimal cutoffs.

We used the test sample to assess and compare the performances of the original and the updated qSOFA models. We assessed performance in terms of discrimination, as the area under the receiver operating characteristics curve (AUC), and calibration, as the integrated calibration index (ICI). For AUC, an acceptable performance is above 0.7 where higher AUCs correspond to better discrimination and values below 0.7 show poor discrimination. Regarding ICI no standard for performance exists, but a lower index close to 0 corresponds to a better calibration. We compared the performances of the original and updated qSOFA models by calculating the absolute differences in performance estimates.

We also compared the performance of original and updated qSOFA scores. In the original qSOFA publication [12], odds ratios were only presented for the individual dichotomized predictors. We used those odds ratios together with the presented mortality for patients with a score of 0 to construct a model and calculate the odds ratios for each of the scores (i.e. 0, 1, 2 and 3). This was done by averaging the predicted probabilities of the outcome for all patients in the validation sample with the same score regardless of which parameters gave the total score. We calculated the odds ratios associated with each score of the updated qSOFSA score using the same method and tabulated the odds ratios of the original and updated scores side by side.

To estimate 95% confidence intervals (CIs) associated with new optimal cutoffs, performance estimates, differences in performance estimates, and odds ratios for score levels we used an empirical bootstrap procedure with 1000 iterations. During each iteration, the entire study process – from splitting of the sample into training, validation, and test samples to the calculation of score level odds ratios – was repeated in a bootstrap sample of the same size as the original sample drawn with replacement.

Results

The TITCO cohort included 16000 patients (Figure 1). We excluded 3373 patients because they were under the age of 18 and 98 patients because they died between arrival and admission. Patients with on arrival externally controlled breathing, such as intubation or surgical airway, were also excluded accounting for 493 patients. We further excluded 5435 patients due to missing data in either admission to the ICU (33), systolic blood pressure (2109), respiratory rate (4870), or GCS (1499). The final sample included 6601 patients.

The mean age was 37.55 with predominantly male participants (83%). The most common type of injury was road traffic injurys with 51% followed by falls and assault accounting for 26 % and 10 % respectively. 61% of patients were transported to a participating hospital from another health care facility. Overall 41% of patients had to be treated in the ICU. The data is presented in @ref(tab:table1) with corresponding standard deviations and percentages.

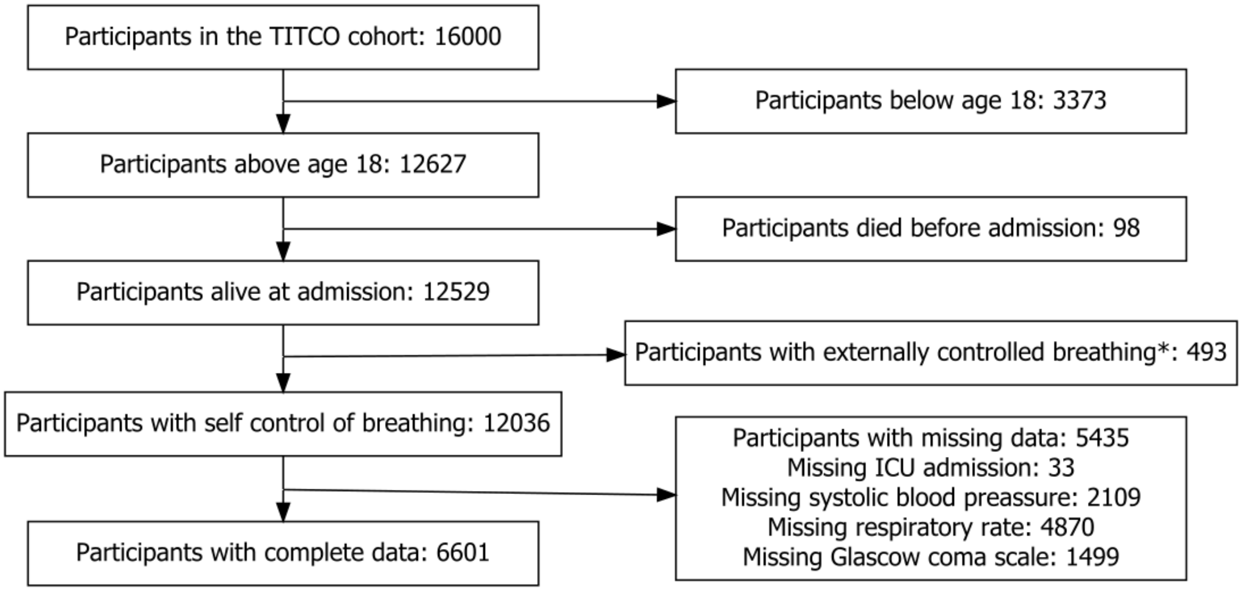


Figure 1: Flowchart showing the exclussion criteria andthe number of study participants. /n *Externally controlled breathing includes intubation orsurgical airway before arrival to a participating hospital

Table 1: Characteristics of the study population, both overall and stratified by ICU admission where 'Yes' and 'No' stands for whether or not the patients was admitted to the ICU. SD- Standard deviation.

	Overall	No	Yes
n	6601	3877	2724
Age (mean (SD))	37.55 (15.18)	38.14 (15.45)	36.71 (14.74)
Sex = Male (%)	5480 (83.0)	3082 (79.5)	2398 (88.0)
Transported = Yes (%)	4005 (60.7)	2459 (63.4)	1546 (56.8)
Mode of injury (%)			
Assault	627 (9.5)	411 (10.6)	216 (8.0)
Burn	134 (2.0)	133 (3.4)	1 (0.0)
Fall	1703 (25.9)	1080 (27.9)	623 (23.1)
Other	307 (4.7)	209 (5.4)	98 (3.6)
Railway injury	439 (6.7)	99 (2.6)	340 (12.6)
Road traffic injury	3364 (51.2)	1944 (50.2)	1420 (52.6)
Admitted to the ICU = Yes (%)	2724 (41.3)	0 (0.0)	2724 (100.0)
Died after admission = Yes (%)	1342 (20.3)	551 (14.2)	791 (29.0)
SBP (mean (SD))	116.34 (23.91)	117.87 (19.10)	114.16 (29.30)
RR (mean (SD))	18.85 (4.97)	18.99 (4.94)	18.64 (4.99)
GCS (mean (SD))	12.21 (4.00)	12.97 (3.52)	11.13 (4.38)

We identified the following revised optimal cutoffs: 97 for SBP, 30 for RR and 14 for GCS. We also identified corresponding ORs where GCS had the highest OR and SBP had the lowest OR. Table 2 presents the cutoffs and ORs as well as corresponding confidence intervals for the updated model together with the cutoffs, ORs and confidence intervals for the original model as taken from the original qSOFA publication.

Table 2: Table 2 Overview of the cutoff values and Odds ratios for the individual parameters in the original and updated model. Abbreviations: OR-Odds ratio, CI-Confidence interval, SBP-Systolic blood pressure, RR-Respiratory rate, GCS-Glasgow coma scale. * OR for the original model refers to mortality. ** OR for the updated model refers to ICU admissions.

	Original cutoff	Original OR*	Updated OR(95%CI)**	Optimal cutoffs (95%CI)
Intercept	-	0.01*	0.466 (0.377 - 0.485)	-
SBP	<100	2.61(2.40-2.85)	2.024 (1.021 - 3.449)	97 (97 - 117)
RR	>22	3.18(2.89-3.50)	1.042 (0.818 - 2.408)	30 (8 - 32)
GCS	<15	4.31(9.96-4.69)	2.522 (1.745 - 2.721)	14

The predicted probability of ICU admission and corresponding OR for each score level given the OR from Table 2 is presented in Table 3 and 4 for the original and the updated models respectively. The presented ORs are weighted according to the distribution of the individual parameter scores for each total score as present in the study population. For the original model, the probability ranges from 1% to 26% and for the updated model, the predicted probability ranges from 32% to 71% for a score of 0-3.

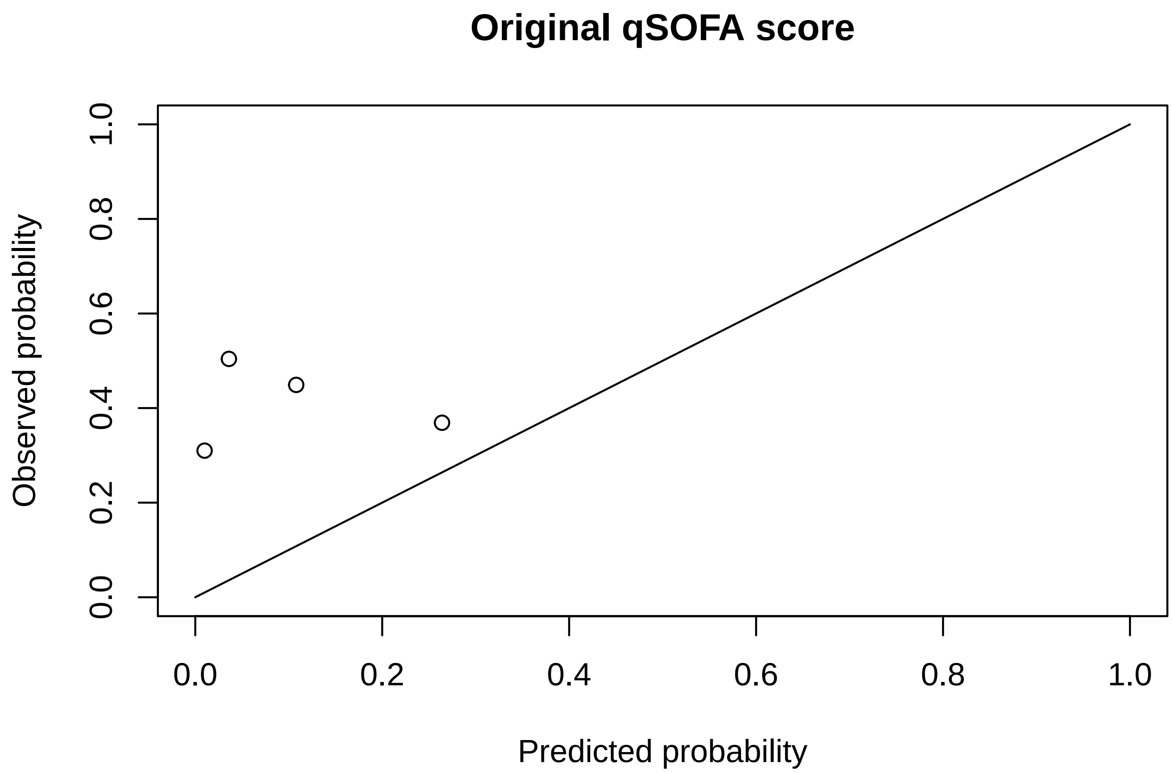
Table 3: Predicted probabilities of intensive care unit (ICU) admission given an original qSOFA score of 0-3 and corresponding odds ratios using 0 as reference.

Original score	Estimated probability of ICU admission(95%CI)	Odds ratio(95% CI)
0	0.01	1
1	0.036 (0.035 - 0.036)	3.683 (3.603 - 3.728)
2	0.108 (0.106 - 0.108)	12 (11.799 - 12.067)
3	0.264	35.772

Table 4: Predicted probabilities of intensive care unit (ICU) admission given an updated qSOFA score of 0-3 and corresponding odds ratios using 0 as reference.

Updated score	Predicted probability of ICU admission(95%CI)	Odds ratio(95% CI)
0	0.318 (0.274 - 0.327)	1
1	0.531 (0.347 - 0.524)	2.432 (1.095 - 2.597)
2	0.684 (0.524 - 0.737)	4.651 (2.366 - 6.859)
3	0.712 (0.502 - 0.848)	5.315 (2.273 - 12.683)

Figures 2 and 3 shows comparisons between the estimated and observed probabilities for the new and updated model and table 5 compares the performance in terms of Integrated calibration index (ICI) and Area under the curve (AUC) for the receiver operating characteristics for the original and updated model.


Original qSOFA score
Observed probability
0.0
0.2
0.4
0.6
0.8
1.0
Predicted probability
0.0
0.2
0.4
0.6
0.8
1.0

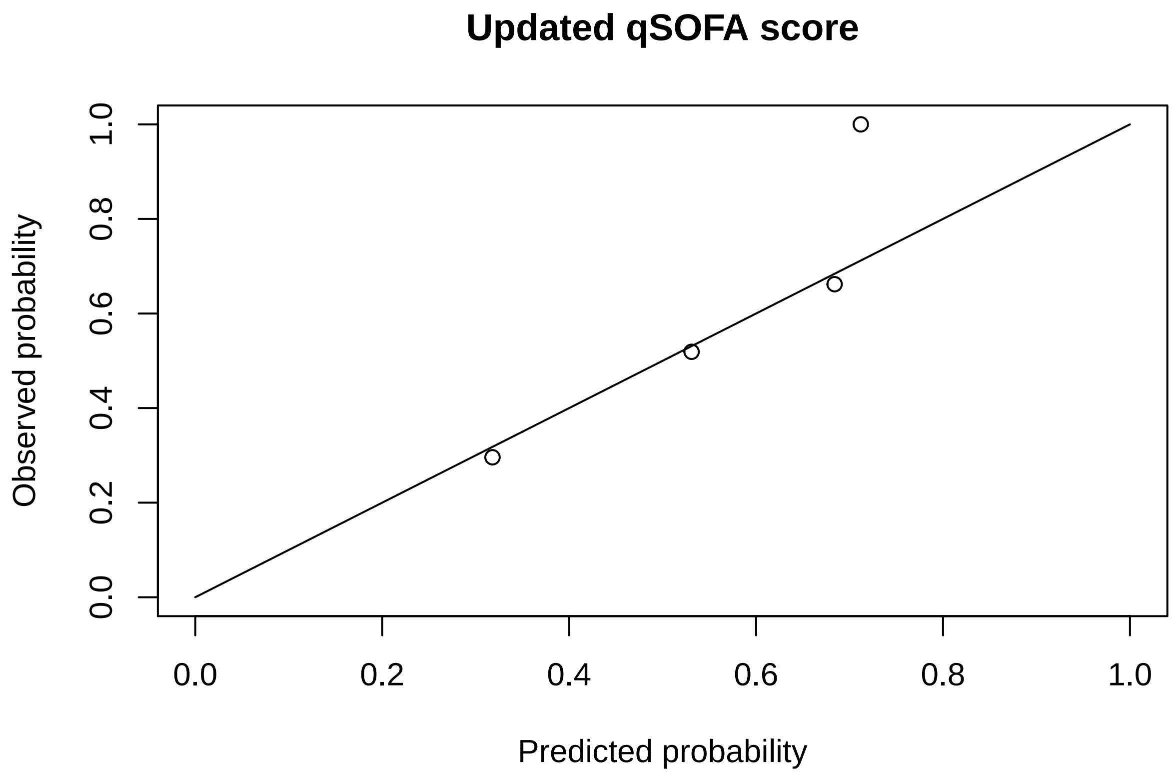


Table 5: Table 5. Comparison of performance, in terms of ICI and AUC, between the original and the updated qSOFA model as well as the ICI off the combined score for the original and the updated model. Abbreviations: AUC Area under the curve, ICI Integrated calibration index

	ICI(95% CI)	Diff ICI (95% CI)	AUC (95%CI)	Diff AUC
Original qSOFA model	0.368 (0.364 - 0.399)	-	0.577 (0.569 - 0.611)	-
Updated qSOFA model	0.027 (0.024 - 0.057)	-0.341 (-0.36 - -0.307)	0.632 (0.596 - 0.664)	0.056 (0.026 - 0.06)
Original qSOFA score	0.363 (0.349 - 0.394)	-	0.562 (0.556 - 0.599)	-
updated qSOFA score	0.019 (0.019 - 0.054)	-0.344 (-0.348 - -0.303)	0.635 (0.592 - 0.659)	0.073 (0.03 - 0.065)

Discussion

Our aim was to assess the validity of the original qSOFA in predicting ICU admission in trauma patients admitted to hospitals in a low resource setting. We found that in the context of urban Indian hospitals the original qSOFA score, with its original cutoffs and coefficients, did not accurately predict ICU admission. The original model underestimated the probability of ICU admission and a max score of 3 did not result in an increased rate of ICU admission compared to a score of 0. The AUC for the original and updated model remained below 0.7 and both models discriminated ICU admission poorly. The updated model performed only slightly better. The ICI was high for the original and lower for the updated model and score wich indicates improved calibration when updating both the model and the score.

While developing the original qSOFA score as a screening tool for patients with an increased risk of dying from severe infection it was shown that a low score of 0-1 corresponded to a mortality of approximately 1-2 percent and that a high score of 2-3 corresponded to a significantly higher mortality of 7-20 %. When using the predetermined cutoff value of 2 points this result made the original qSOFA a useful tool to identify patients with a low risk of dying. On the other hand the results also allowed for that patients with a higher score could be more closely monitored and get access to treatment before they potentially deteriorated.

In contrast, with our updated qSOFA for predicting ICU admission in trauma patients a low score of 0-1 corresponded to a probability for ICU admission of 32-53% and a high score of 2-3 corresponded to a probability of 68-71 %. This shows that regardless of the score the patients still have a relatively high risk for ICU admission. Our data showed that a higher score correlates with a higher risk of ICU admission. However, it is not clear what clinical relevance this difference would have in the process of deciding the adequate level of care for patients with traumatic injuries.

Although no other studies have been done correlating qSOFA to ICU admission in low resource settings studies have explored the association between qSOFA and mortality in high resource settings, both regarding patients with risk for sepsis [12] and trauma patients [10, 13]. These studies show that there is a clear association between qSOFA and mortality. Comparing these results to ours the ORs are higher, and the AUC shows a slightly better discrimination for mortality than ICU admission.

It can be argued that both ICU admission and mortality results from a more severe patient condition, and thus should be correlated. However, in this cohort mortality was high also in patients who were not admitted to the ICU. This indicating that the association between trauma severity and ICU admission may be less straightforward in this setting compared with many high resource settings. This could be partly because these patients were so severely injured that they either died before they could be transferred to the ICU or it was decided that intensive care was deemed futile and not in the patients best interest. But it could also be due to a lack of ICU beds in the participating hospitals such that patients had to be prioritized for intensive care and not all patients who would benefit from it got admitted to the ICU. For context, the number of ICU beds per 100 000 people is 2.3 in India compared with for example 7.3 in Japan [14]. To be able to explore this question more thoroughly further research is needed.

Our results also showed that out of the three parameters, the association between respiratory rate and a higher risk of ICU admission was not statistically significant. In contrast the associations for SBP and GCS were statistically significant. This can be partially explained by that a new cutoff was calculated for each bootstrap resulting in different cutoffs being used while evaluating the model widening the confidence intervals. It also shows that in some bootstraps, a higher RR above the cutoff was associated with a lower risk for ICU admission, suggesting that the connection between RR and ICU admission is not strictly positive, as assumed in the construction of the qSOFA model. One possible explanation is that the non-linear association between RR and poor outcomes is not captured when a single cutoff is used. More research is needed to further explore the connection between RR and ICU admission before the original, or an updated qSOFA score as presented in this study, can be used in clinical decision making in this context.

The study had several limitations. First the data collected for the TITCO database came from a homogeneous group of participating hospitals all in urban India. Because of this it is unclear if the results are generalizable to for example rural hospitals.

Secondly it should be noted that 61 percent of the patients where for an unspecified time first treated at another hospital or health care facility and then later transferred to one of the participating hospitals. Because of this the parameters used in this study only show the first ones taken at arrival to the participating hospital and not always the first ones taken after the injury. Furthermore, the results in this study do not take into account any interventions performed before arrival or between arrival and admission to the ICU.

Lastly the TITCO database had a significant amount of missing data, about 45% of the 12 thousand participants fulfilling the inclusion criteria were excluded due to missing data. Since we do not know the distribution, the cause of this missing data nor whether it can be assumed to have any particular distribution this further increases the uncertainty. The largest contributor of missing data was respiratory rate and since this was manually calculated by hospital staff it is possible that it was not prioritized for patients with the most severe trauma where other interventions where of greater importance and thus excluding them from this study. It is unknown if this had any effect on this study and for more certain result more research is needed.

Conclusion

This study indicates that qSOFA should not be used to predict ICU admission in trauma patients in this context. Although an updated qSOFA score can be used to estimate the overall risk for ICU admission in trauma patients in urban Indian hospitals and the updated model had a good calibration on group level, the discrimination was shown to be too low to merit any use in clinical decision making for the individual patient and thus more research is needed.

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