

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

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**Förutsägande av intensivvårdsinläggning hos traumapatienter i Indien med quick sequential organ failure assessment score (qSOFA)**

*Bakgrund:* Trauma är ett globalt problem som påverkar ett stort antal människor varje år. Majoriteten av dödsfallen från trauma sker kort tid efter skadetillfället och det är därför viktigt att snabbt kunna gradera och prioritera patienter med trauma. Quick sequential organ failure assessment score (qSOFA score) har visats kunna användas för att förutsäga dödligheten hos patienter med trauma men det är ännu inte visat att qSOFA score kan användas för att predicera intensivvårdsinläggning och därmed vara till hjälp i kliniskt beslutfattande. *Syfte:* Syftet med detta projekt var att bedöma validiteten av qSOFA för att förutsäga intensivvårdsinläggning hos traumapatienter vid sjukhus med begränsade resurser. *Material och Metoder:* Towards Improved Trauma Care Outcomes in India (TITCO) kohorten och complete case analysis användes för att beräkna ny optimala gränsvärden för parametrarna som ingår i qSOFA score med hjälp av logistisk regression. Nya oddskvoter räknades ut efter de uppdaterade gränsvärdena och prestandan jämfördes mellan originalmodellen och den uppdaterade modellen. Bootstrap metoden användes för att estimera konfidensintervall. *Resultat:* Totalt 6601 patienter inkluderades. Den uppdaterade modellen presterar bättre än originalmodellen både med avseende på diskriminering och kalibrering. AUC för originalmodellen 0,577 och den uppdaterade modellen 0,624 med en skillnad på 0,047(95%CI 0,025–0,063). ICI för originalmodellen 0,363 och den uppdaterade modellen 0,038 med en skillnad på -0,325 (95%CI -0,356 – -0,274). *Slutsats:* En uppdaterad qSOFA score kan användas för att uppskatta den övergripande risken för intensivvårdsinläggning hos traumapatienter vid urbana indiska sjukhus men mer forskning behövs innan en uppdaterad qSOFA ska kunna användas i kliniskt beslutfattande.

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

*Introduction:* Trauma is a global problem affecting many patients. Most deaths occur shortly after the injury. It is therefore important to quickly assess and prioritize patients with severe injuries. The quick sequential organ failure assessment (qSOFA) score has been shown to predict mortality in trauma patients, but it has not been shown that qSOFA can be used to predict intensive care unit (ICU) admission and aid clinical practice. *Aims:* The aim of this project was to assess the validity of qSOFA in predicting ICU admission in trauma patients admitted to hospitals in a low resource setting. *Material and Methods:* The Towards Improved Trauma Care Outcomes in India (TITCO) cohort and a complete case analysis was used to calculate new optimal cutoffs for the parameters in the qSOFA score using logistic regression. New odds ratios were calculated using the updated cutoffs and the performance was compared between the original and the updated model using area under the receiver operating characteristics curve (AUC) and integrated calibration index (ICI). Bootstrapping was used to estimate the confidence intervals. *Results:* 6601 patients were included. The updated model performed better than the original model both in terms of discrimination and calibration. AUC for the original model was 0.577 and 0.624 for the updated, with a difference of 0.047 (95%CI 0.025-0.063). ICI for the original model was 0.363 and 0.038 for the updated, with a difference of -0.325 (95%CI -0.356 - -0.274). *Conclusions:* An updated qSOFA score can be used to estimate the risk for ICU admission in trauma patients in urban India hospitals but more research is needed before qSOFA can be implemented and used in clinical decision making.

*Keywords:* Trauma, qSOFA, Intensive care

# Abbreviations

AUC –Area Under the receiver operating characteristics Curve

CI – Confidence Interval

DALY - Disability Adjusted Life Years

GCS – Glasgow Coma Scale

ICI - Integrated Calibration Index

ICU – Intensive Care Unit

OR – Odds Ratio

qSOFA – quick Sequential Organ Failure Assessment

RR – Respiratory Rate

RTS – Revised Trauma Score

SBP – Systolic Blood Pressure

SD – Standard Deviation

SOFA - Sequential Organ Failure Assessment

TITCO – Towards Improved Trauma Care Outcomes in India

T-RTS – Triage Revised Trauma Score

# Introduction

Trauma is defined as the clinical entity composed of both physical injury and the body’s associated response. Trauma patients are a heterogenous group with wide range of different causes where some of the most prominent ones are traffic related injuries, falls, self-harm, interpersonal violence and burns. Trauma is a global health problem and the total number of injuries worldwide is estimated to be at least 520 million cases per year (1).

The effects of trauma on patients and their families can be divided into non-fatal and fatal trauma. The effects of non-fatal trauma can be further subdivided into Disability Adjusted Life Years (DALY) lost and economic effects. DALY is a measurement using both the mortality, in years lost between death and local life expectancy, and morbidity, as in years lived with reduced function due to the disease both physical and psychological. In 2017 trauma accounted for 10.1% of total DALY lost. This is about the same as all neoplasms, 9.4 %, and can be compared to that of cardiovascular diseases accounting for 14.6 % (2).

Whereas the physical disabilities depend on the type of injury, the psychological effects include depression, anxiety and post traumatic distress and are often long lasting after an injury. A study from the United Kingdom showed that patients who had experienced an unintentional injury had elevated levels of depression, anxiety and post traumatic distress scores up to at least a year after the injury. The same study also showed that patients with lower socioeconomic status, lower pre-injury quality of life, and higher pre-injury depression and anxiety scores were associated with a higher rate of psychological effects after the injury (3).A multinational study of the association between depression and injuries could also show that although differing slightly depending on the country income there was an increased risk of depression in patients who had suffered traffic or other injuries (4).

The economic effects in turn regards both the out-of-pocket expenses for treatments as well as reduced productivity due to reduced ability after the injury. A study in northern India from 2019 calculated that 22% of patients who presented with traumatic injuries afterward had catastrophic health expenditure defined as 30% or more of their total expenditure on healthcare related costs and 12 % were pushed below the international poverty line as a consequence of their injury (5).

Regarding fatal trauma and the mortality associated with trauma in 2017 trauma accounted for 8% of total global deaths (2). According to calculations done by Mock et al. (6) 90% of all deaths due to trauma were in low- and middle-income countries which also had a mortality rate 60-80% higher than that of high-income countries. Mock et al. also calculated that an improvement in trauma care globally to the level of that in high-income countries could save about 1.7 million lives annually, or about one third of the global deaths due to trauma, not including possible injury prevention.

It is known that most fatalities in response to trauma occur shortly after the injury. In order to reduce the mortality in patients with severe trauma it is vital with early intervention, often surgical. The higher mortality is often because of patients suffering from internal and external bleeding where surgery is an important part of the hemorrhage control (7). It is evident that in parts of the world with fewer hospitals, reduced access to healthcare and a less developed ambulance networks the time parameter is one of the contributing factors to the increased mortality in trauma patients in low- and middle-income countries.

For patients with severe infections the Sequential Organ Failure Assessment (SOFA) score was developed in 1994 to grade the level of organ dysfunction in critically ill patients. The SOFA score is based on the reduced function scored 0-4 for each of the respiratory, cardiovascular, neurological, hepatic, coagulation, and renal systems. Initially the focus was mainly patients suffering from severe infections and sepsis, but it was early recognized to be applicable in a wide range of critical illnesses such as severe trauma (8).

Alongside the last revision of the sepsis definition in 2016 the quick Sequential Organ Failure Assessment score (qSOFA score) was developed. The qSOFA score includes three parameters: Systolic blood pressure (SBP) below 100 mmHg, a respiratory rate (RR) above 22 min and an altered consciousness, measured with a Glasgow Coma Scale (GCS) score below 15. One point is awarded for each parameter yielding a total score of 0-3. The qSOFA score was introduced as a screening tool, to be performed bedside to identify patients with high-risk of organ dysfunction due to infections (9,10). The qSOFA score has also been shown to be able to predict mortality in patients with traumatic injuries when used both in prehospital care (11) as well as repeated evaluation during hospitalization (12).

Another tool to assess the severity of a patient’s condition due to trauma is the Revised Trauma Score (RTS) and the Triage Revised Trauma Score (T-RTS) composed of the same parameters as qSOFA, that is SBP, RR and GCS, but with a score of 0-4 for each parameter instead of a single criterion. The scores can either be presented individually as used in RTS or added together to a total of 0-12 used in the T-RTS. The RTS is devised to be used in outcome evaluation and assessment of injury severity and the T-RTS for triage and finding patients a prehospital or initial setting in most need of specialized trauma care (13). However, there are some articles raising concerns about the sensitivity and specificity of the T-RTS as it both overtriages some patients and undertirages other (14) as well as fails to predict mortality in patients suffering from blunt or penetrating trauma (15).

Because of the inherent urgency and complexity of trauma care it is vital to have an initial scoring system that is both simple to perform and that does not need laboratory nor other advanced measuring equipment. For this reason, the SOFA score can be said to use too advanced techniques and the T-RTS with its many cutoffs to be too complicated, even though the latter is widely used in trauma care today. The choice of using qSOFA is thus because of its promising signs in other studies and because of the possible clinical advantage in its simplicity.

It should also be noted that the majority of the research done on the topic of trauma and trauma care has been performed in high-income countries. To the knowledge of the author no similar studies have been conducted in regard to initial trauma care in low-income countries. It is thus not clear if the results are also applicable in low resource settings, which arguably stand to benefit the most of a scoring system to be able to prioritize the limited resources at hand, in hope of improving patient outcome. Furthermore, most studies report the predictive power of different scoring systems on mortality and it has not yet been sufficiently studied whether an initial qSOFA score can be used to predict admissions to an intensive care unit (ICU) and thus aid in the direct clinical treatment for trauma patients.

## Healthcare in India

The Indian healthcare is of now severely underfunded, the national healthcare expenditure is about 3.5% of national GDP, or about 70 USD per person in 2017, compared to a national healthcare expenditure of 5900 USD in Sweden for the same year. Out of these 70 USD per person 27 % is government expenditure and 72% is private expenditure, mostly out of pocket expenditures. The remaining expenditure is for external sources such as international aid. (16) This makes the unregulated private healthcare sector almost 3 times as large as the public providing 80% of outpatient care and 60% of inpatient care in India. India also lacks healthcare personnel and in many cases complete medical training, especially regarding trauma care. (17, 18)

Besides the deficient monetary aspects of India’s healthcare system, it can also be said that there is a lack of sufficiently enforced safety policies and regulations, for example road traffic and workplace safety. Although it should be noted that in the new national health policy from 2017 one of the primary focuses are preventing rail and road traffic accidents. The national health policy also aims at expanding the number of hospital beds dedicated to trauma care across the country reducing the time between injury and care as discussed above. (17, 18)

## Aim

To assess the validity of qSOFA in predicting ICU admission in trauma patients admitted to hospitals in a low resource setting. A secondary aim was to compare the discrimination and calibration between the original qSOFA model and an updated model based om the same predictors as qSOFA.

# Method

## Source of data

This is a registry-based study using data from the Towards Improved Trauma Care Outcomes (TITCO) in India which is a prospective observational registry (19). The data in the TITCO cohort 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.

Regarding data quality, all data was collected using one 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 weekly against patients’ files and against a data set collected in duplicate once in 3 months.

## Participants

The TITCO cohort include 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 excluded from the database if they presented with isolated injuries to limbs without associated vascular damage as well as patients who were dead upon arrival.

The additional 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 as well as patients 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 represented 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 were respiratory rate, Glasgow coma scale and systolic blood pressure. Data on these predictors were collected on arrival to hospital. In the original qSOFA these predictors were dichotomized using the cutoffs > 22 for respiratory rate, < 15 for the Glasgow coma scale, and < 90 for systolic blood pressure. Using these dichotomized predictors qSOFA can be expressed as either a model, in which the coefficients or odds ratios 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 but also as continuous variables to identify new optimal cutoffs and associated coefficients, see Statistical analysis methods below.

## Missing data

A complete case analysis was conducted.

## Statistical analysis methods

We used R for all statistical analysis. 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 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 the validation sample to estimate coefficients associated with the new optimal cutoffs with logistic regression.

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 scoreindex 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 original and updated qSOFA scores. In the original qSOFA publication, the odds ratios associated with each level of the score (i.e. 0, 1, 2, and 3) were calculated using the mean estimated probabilities of the outcome in all patients with the same score. We calculated the odds ratios associated with each level of the updated score using the same method and tabulated the odds ratios of the original and updated scores side by side.

To estimate 95% confidence intervals associated with new optimal cutoffs, performance estimated, 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.

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# Ethical consideration

This study was performed on the open and anonymized Towards Improved Trauma Care Outcomes (TITCO) in India observational cohort dataset composed of data collected at several hospitals. (19) Ethics committees at all participating centers approved the collecting of data. (Lokmanya Tilak Municipal General Hospital, IEC/11/13; King Edward Memorial Hospital, IEC(I)/OUT/222/14; Seth Sukhlal Karnani Memorial Hospital, IEC/279; All‐India Institute of Medical Sciences, IEC/NP‐279/2013 RP‐01/2013).

No participant can be said to have been harmed by the study because of its purely observational nature. One could reason about the possible Hawthorne effect of observing healthcare workers or delay while collecting data could have a negative effect on the patients care. Although this could not be eliminated completely it was thought to be mitigated after the first few weeks of data collection.

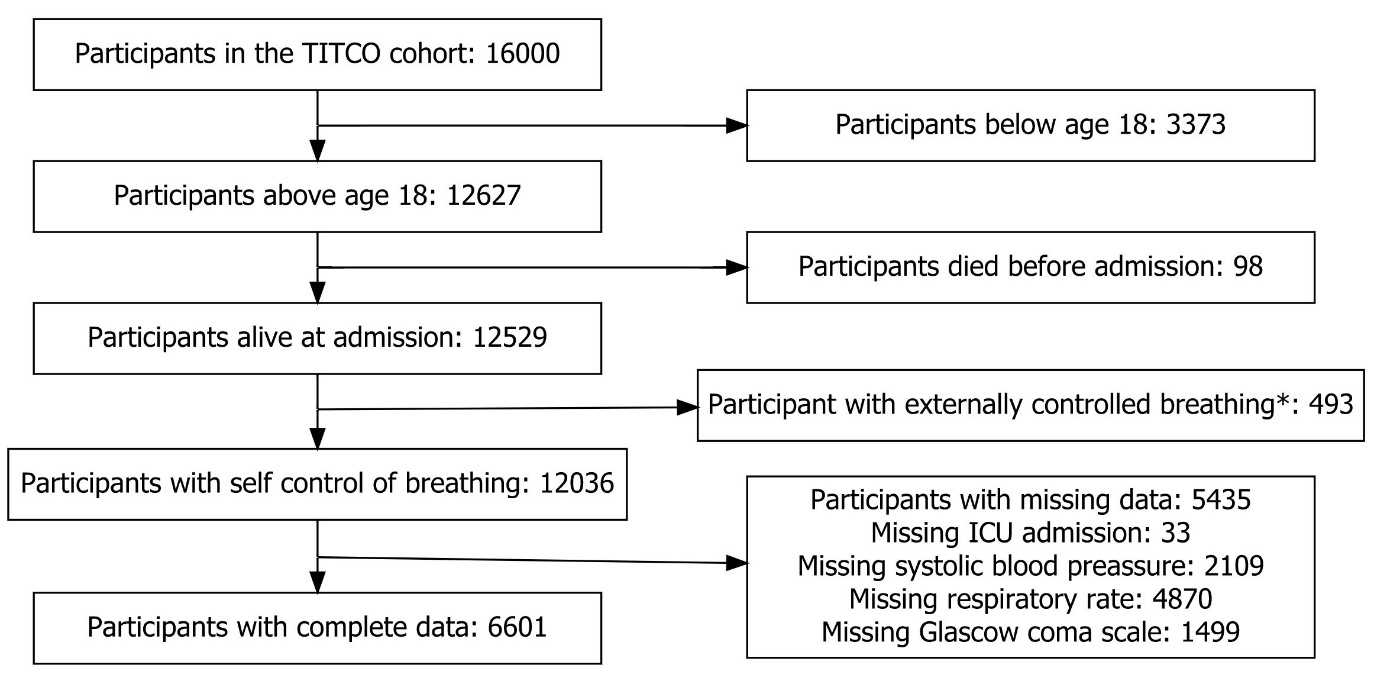
Furthermore, because of the lack of harm due to it being an observational cohort and because of the physical and psychological distress already present for the patient and their relatives, the ethics committees reasoned that obtaining individual informed consent from the patients or their relatives would be an unnecessary burden and individual consent was therefore not gathered. The data was gathered in such a way to minimize the negative effects the study could have on the patients or their relatives. The data was anonymized to preserve the integrity of the patients involved, and no personal details such as names, addresses, social security, or insurance numbers were ever collected.

India has an overall underfunded public healthcare and most of the trauma care happen in public hospitals exacerbating this problem. However, because of the wide range of traumas and that trauma care mostly happens at public hospitals, a patient’s socioeconomic status cannot be said to have an effect on the care received during hospitalization and is not thought of to be a contributing factor in the make-up of this study. It should be noted that because of the lack of enforced safety regulations, economic compensation and injury rehabilitation in India, socioeconomic status does influence incidence and longtime outcome for the patients. But this angle is outside the scope of this study.

It can also be said that the resources needed to perform this study are small since no new data need to be gathered and thus the benefit of improved trauma care and health for trauma patients in low resource settings is sufficient to merit this project.

# Results

The TITCO cohort included 16 000 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 to the hospital. Patients with 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.



**Figure 1 Study flowchart.** Flowchart showing the exclusion criteria and the number of study participants.   
\* Externally controlled breathing includes intubation or surgical airways before arrival to a participating hospital.

The mean age was 38 years with predominantly male participants (83%). The most common type of injury was road traffic injuries with 51% followed by falls and assaults accounting for 26 % and 10 % respectively. Furthermore 61 % of patients were transported to a participating hospital from another health care facility. In the study population 41 % of patients had to be treated for some time in the ICU. The data is presented both overall and stratified by ICU admission in table 1 with corresponding standard deviations.

**Table 1 Study characteristics**. Characteristics of the study population both overall and stratified by ICU admission. SD- Standard deviation.

|  |  |  |  |
| --- | --- | --- | --- |
|  | Overall | No ICU | ICU |
| **Total participants** | 6601 | 3877 | 2724 |
| **Age (mean (SD))** | 37.6 (15.18) | 38.1 (15.45) | 36.7 (14.74) |
| **Male (%)** | 5480 (83.0) | 3082 (79.5) | 2398 (88.0) |
| **Transported (%)** | 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) |
| **Railway injury** | 439 (6.7) | 99 (2.6) | 340 (12.6) |
| Road TRAFFIC  **INJURY** | 3364 (51.2) | 1944 (50.2) | 1420 (52.6) |
| **Other** | 307 (4.7) | 209 (5.4) | 98 (3.6) |
| **ICU admission (%)** | 2724 (41.3) | 0 (0.0) | 2724 (100.0) |
| **Died after admission (%)** | 1342 (20.3) | 551 (14.2) | 791 (29.0) |
| **SBP (mean (SD))** | 116.3 (23.91) | 117.9 (19.10) | 114.2 (29.30) |
| **RR (mean (SD))** | 18.9 (4.97) | 19.0 (4.94) | 18.6 (4.99) |
| **GCS (mean (SD))** | 12.2 (4.00) | 13.0 (3.52) | 11.1 (4.38) |

We identified the following revised optimal cutoffs: 117 for SBP, 30 for RR and 14 for GCS. The corresponding confidence intervals and updated odds ratios can be seen in Table 2 together with the original OR from Seymour et al. (20).

**Table 2** Original and updated odds ratios (OR) for the logistic regression models as well as the revised optimal cutoffs for the updated model.   
Abbreviations: OR-Odds ratio, CI-Confidence interval, SBP-Systolic blood pressure, RR-Respiratory rate, GCS-Glasgow coma scale.

|  |  |  |  |
| --- | --- | --- | --- |
|  | **Original OR** | Updated OR  (95%CI) | **Optimal cutoffs (95%CI)** |
| **BASELINE** | 0.01 | 0.45 (0.15 - 0.51) | - |
| **SBP** | 2.61(2.40-2.85) | 1.20 (1.16 - 3.48) | < 117 (97 - 117) |
| **RR** | 3.18(2.89-3.50) | 2.05 (0.56 - 13.13) | > 30 (8 - 34) |
| **GCS** | 4.31(9.96-4.69) | 2.34 (1.89 - 3.02) | < 14 (11 - 14) |

The predicted probability of ICU admission and corresponding OR given the OR from Table 2 and the distribution of the individual parameters in the study sample are presented in Table 3 and 4 for the original and the updated model. For the updated model, the predicted probability ranges from 31% to 72% for a score of 0-3 and for the original model the probability ranges from 1% to 26%.

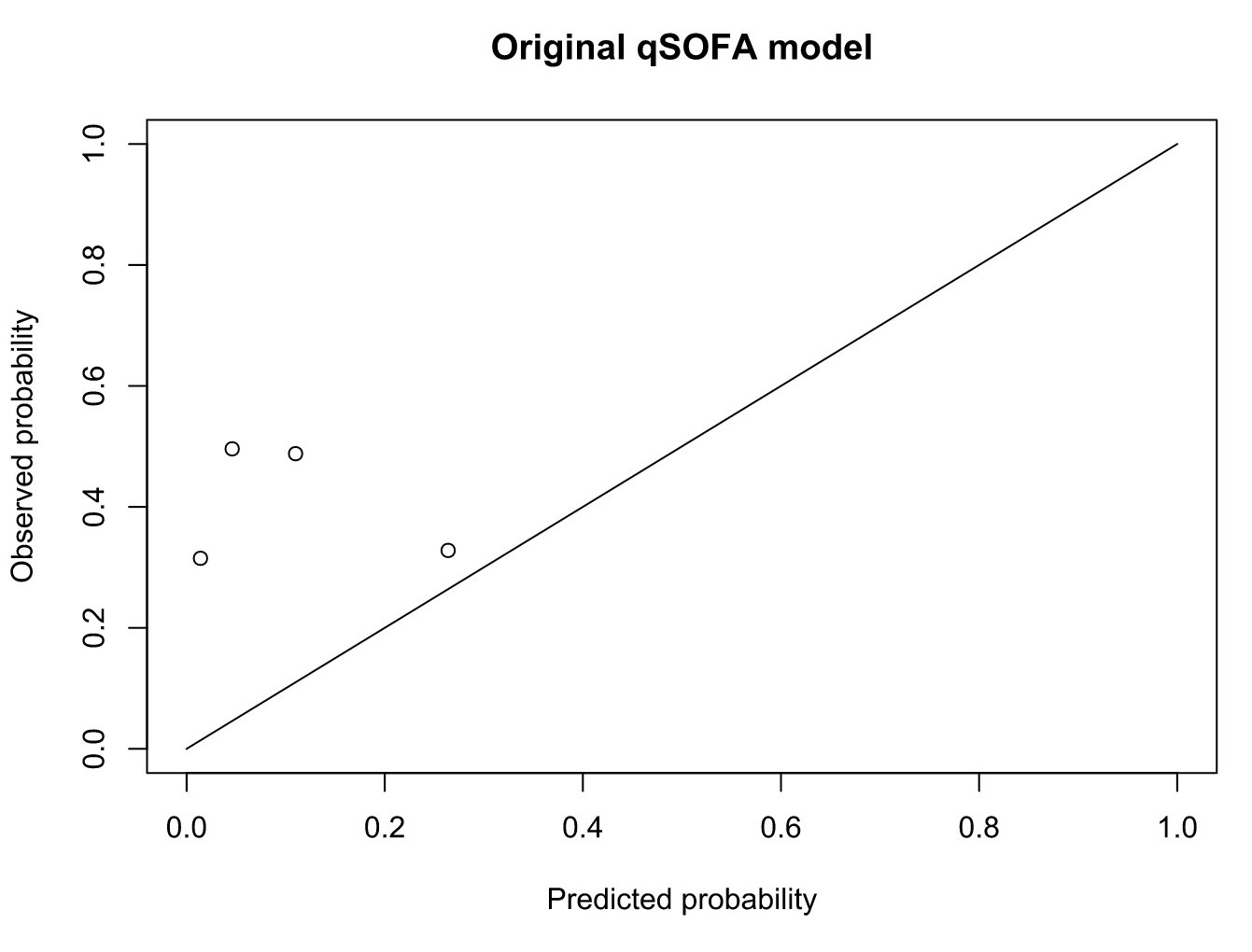
**Table 3** Predicted probabilities of intensive care unit (ICU) admission given an original qSOFA score of 0-3 and corresponding odds ratios using 0 as a reference.

|  |  |  |
| --- | --- | --- |
| **Original score** | **Predicted probability of ICU admission (95%CI)** | **Odds ratio (95% CI)** |
| **0** | 0.014 (0.01 - 0.029) | 1 |
| **1** | 0.046 (0.015 - 0.082) | 3.367 (1.273 - 5.37) |
| **2** | 0.11 (0.051 - 0.162) | 8.587 (3.267 - 12.612) |
| **3** | 0.264 | 25.057 (15.937 - 35.772) |

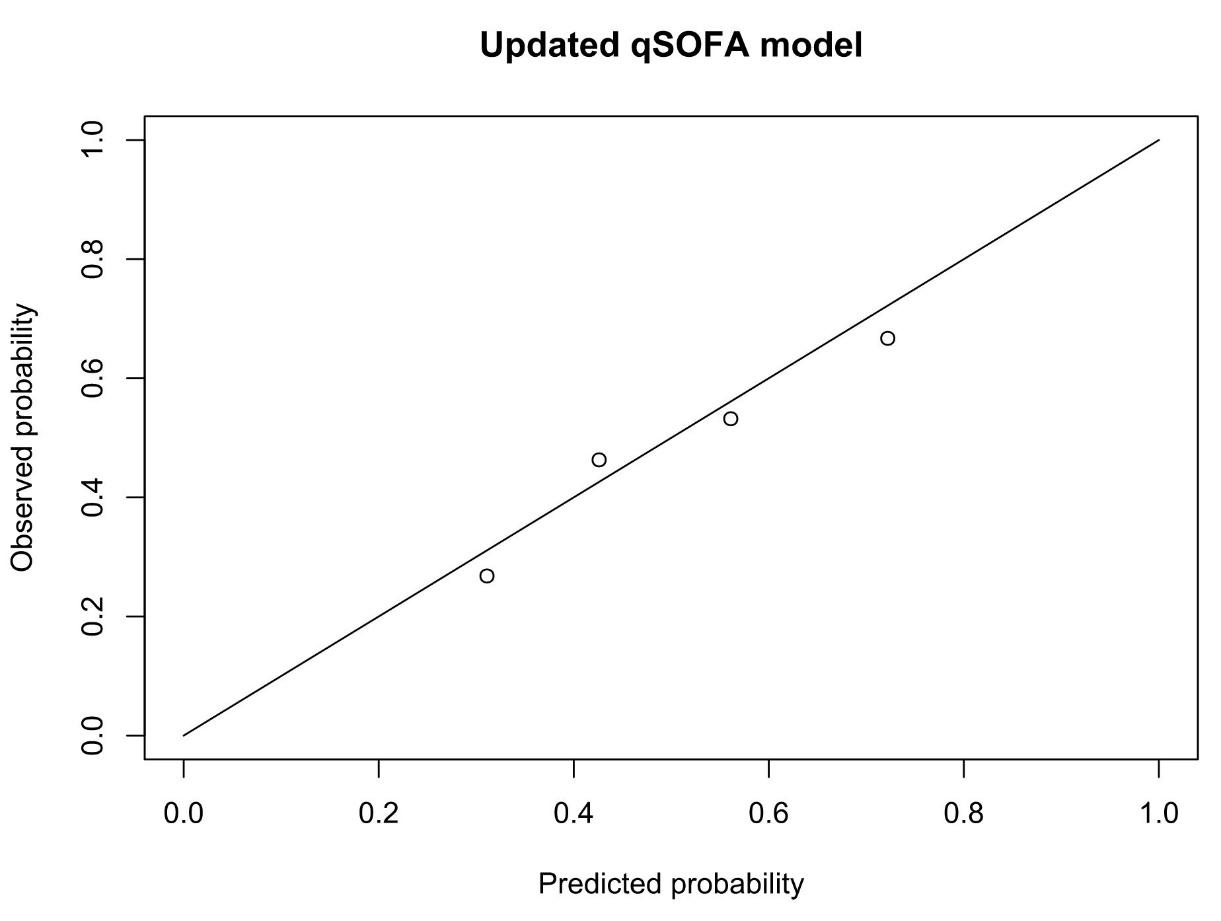
**Table 4** Predicted probabilities of intensive care unit (ICU) admission given an updated qSOFA score of 0-3 and corresponding odds ratios using 0 as a reference.

|  |  |  |
| --- | --- | --- |
| **Updated score** | **Predicted probability of ICU admission (95%CI)** | **Odds ratio (95% CI)** |
| **0** | 0.311 (0.075 - 0.336) | 1 |
| **1** | 0.426 (0.294 - 0.538) | 1.642 (1.109 - 5.411) |
| **2** | 0.561 (0.44 - 0.766) | 2.829 (2.121 - 13.689) |
| **3** | 0.722 (0.492 - 0.97) | 5.765 (2.216 - 21960742.293) |

Figure 2 and Figure 3 show a comparison between the predicted and observed probabilities for the original and the updated model respectively. The points corresponding to the original model underestimate the probability of ICU admission and the points corresponding to the updated model fall closer to the diagonal line representing perfect calibration. Table 5 compares the performance in terms of ICI and AUC for the original and the updated model. The differences in performance are significant both in terms of individual parameters as well as combined to a 0-3 points score.



**Figure 2** Integrated Calibration Index plot for the original qSOFA score. BYT TILL SCORE I FIGUREN



**Figure 3** Integrated Calibration Index plot for the updated qSOFA score. BYT TILL SCORE I FIGUREN

**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 (95%CI)** |
| **Original qSOFA model** | 0.385 (0.347 - 0.409) | - | 0.577 (0.563 - 0.623) | - |
| **Updated qSOFA model** | 0.045 (0.014 - 0.083) | -0.339 (-0.375 - -0.281) | 0.624 (0.605 - 0.664) | 0.047 (0.025 - 0.063) |
| **Original qSOFA score** | 0.363 (0.329 - 0.388) | - | - | - |
| **Updated qSOFA score** | 0.038 (0.01 - 0.076) | -0.325 (-0.356 - -0.274) | - | - |

# Discussion

The aim of this project 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. When updating the model adjusting the cutoffs and coefficients the new model performs significantly better both in terms of ICI and AUC. The AUC for the updated modelremained below 0.7 and both models had discriminated ICU admission poorly - the updated model performs only slightly better. The low ICI for the updated model indicates good calibration which cannot be said about the original model.

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 percent (20). When using the predetermined cutoff value of 2 points this result made a low score of the original qSOFA to also indicate a low risk of death. 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 more severe symptoms developed.

In contrast, with our updated qSOFA for predicting ICU admission in trauma patients a low score of 0-1 correspond to a probability for ICU admission of 31 - 43 percent and a high score of 2-3 correspond to a probability of ICU admission of 56 – 72 percent. This shows that regardless of the score the patients still have a relatively high risk for ICU admission. Although a higher score is shown to correlate with a higher risk of ICU admission it is not clear what clinical relevance this score would have in the process of deciding the adequate level of care for patients with severe injuries.

The 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. However, this association was statistically significant both in regard to SBP and GCS. 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 would be that both a high and a low RR is associated with higher risk of ICU admission, however this was not explored in this study. 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.

Although no other studies have been done correlating qSOFA to ICU admission in low resource settings studies have explored the correlation between qSOFA and mortality in high resource settings, both regarding patients with risk for sepsis (10, 20) and trauma patients (12). All these studies show that there is a clear association between the qSOFA score 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, 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 would not be of use for the patients. 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. (21) To be able to explore this question more thoroughly further research is needed.

## Strengths and limitations

The strengths of this study were the large number of patients in the TITCO database and that no previous studies have been done with a similar aim looking at ICU admission. Furthermore, the statistical analysis using bootstrap was rigorous and sound yielding trustworthy results for 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 settings in India. Because of this it is not clear that the results presented here are generalizable to for example hospitals with a rural location or a different economic level.

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 contained 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 injuries 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.

## Clinical applications

The results from this study are not significant enough to merit direct clinical use of the original nor the updated model in the context of predicting ICU admission as discussed above. This project should rather be considered as a basis for future research aimed to construct a more exact model to predict ICU admission in trauma patients, see future studies below.

### Equity

When a patient suffers a severe injury, the basic physiological responses measured for this study are not thought to be affected in a meaningful way by sex, socioeconomic status, age, or race and therefore no application or result in regard to equity should follow from this study. However, this study population contains an overwhelming majority of men in working age, 18-65, and due to societal factors, there is thought of to be a larger portion of patients with a lower socioeconomic status in this sample. This population is the one most likely to suffer from trauma and the one where the results most likely has the best application. Although there is no evidence to suggest it should not be generalizable to other populations in similar hospital settings.

The way to improve equity in trauma care is not by implementing the results from this or similar studies but rather through other programs and political incentives aimed to reduce the total number of trauma patients and the long-term effect of trauma, such as improved work safety protocols for high-risk jobs that are most likely to be occupied by men, increased road safety, economic stability, injury compensation, overall healthcare spending and access to rehabilitation.

## Future studies

A way for future research to investigate the usage of qSOFA in ICU admission would be to look at ICU admission, qSOFA score and mortality combined. This in order to investigate whether patients, depending on their qSOFA score, who were admitted to the ICU had a lower morality compared to patients with the same qSOFA score not admitted to the ICU. The aim of this would be to decide which patients would be the most helped by intensive care to better allocate the resources on hand.

However, if the goal is to have a model to predict ICU admission the author would suggest developing an entirely new model using more predictors than used in this paper. The one-time values of our parameters are thought of to be too simplistic when assessing the need for intensive care. For future studies, a more diverse set of parameters as well as information about their dynamics in time should be considered for constructing a more precise model.

Furthermore, more research needs to be performed where trauma patients arrive at a wider range of healthcare facilities. Both in terms of urbanization as well as not only including specialized tertiary care trauma hospitals. This in order to better be able to follow the patients care, not only from the time they are transferred to a specialized trauma hospital, and also to be able to draw conclusions that apply in a wider range of circumstances. A study like this will be difficult to design but would yield the most information regarding the care of trauma patients in low resource settings.

Conclusion

An updated qSOFA score can be used to estimate the overall risk for ICU admission in trauma patients in urban Indian hospitals but more research is needed before it can be implemented and used in clinical decision making.

# Contributions

Aside from the collecting of data done before the start of this project, most of this project has been made by me, with supervision and help from my supervisor Martin Gerdin Wärnberg. My work has apart from this paper also included writing and performing all the statistical analyses for this project.

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