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# A simple morbidity prediction tool for the critically ill patients: Experience in a single unit

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## ABSTRACT

**Introduction:** Monitoring intensive care performance is an essential component in improving the outcome of critically ill patients. Introduction of scoring systems such as Acute Physiology and Chronic Health Evaluation (APACHE), Sequential Organ Failure Assessment (SOFA) scores etc had played a pivotal role in managing critically ill patients. The objective of our study was to evaluate the application of a simple prognostication tool - the Tropical Intensive Care Score (TICS) in the Sri Lankan ICU setting and compare the outcome with APACHE score.

**Methods:** One thousand patients admitted to Surgical Intensive Care Unit at Colombo South Teaching Hospital during the period from 2019 to 2023 were analysed using TICS. In patients who had TICS greater than 70%, the APACHE score was calculated in retrospect. Considering APACHE score as the gold standard, sensitivity, specificity, positive and negative predictive values were calculated for TICS.

**Results:** The sensitivity, specificity, positive and negative predictive values of TICS were 99.3%, 100%, 100% and 98.1% respectively when calculated against APACHE score.

**Conclusions:** TICS was found to be a simple, easily applicable prognosticating tool and closely corelates with that of APACHE making it suitable for low-income setting like in Sri Lanka

**Keywords:** *Critical care, Prognostication, Scoring systems.*

## Introduction

The first intensive care units (ICUs) were set up in the 1940s in Copenhagen to manage the polio epidemic that swept through Europe. Having made tremendous advancements since then, scoring systems for ICU outcomes were introduced only in the 1980s. Outcome measures of a scoring system reflect on a group or a cohort of patients rather than an individual one. It allows one to estimate a statistical probability of prognosis between similar cohorts or to compare outcomes between different units or how good or bad a particular unit is compared to the average. Monitoring ICU performance and improving healthcare training are part of diverse attempts to improve the outcomes of ICU patients (1).

The first endeavour in this regard was the introduction of the Acute Physiology and Chronic Health Evaluation (APACHE) score in the early 1980s (Table1) (2).

This translated domains of premorbid conditions, diagnosis and early physiologic derangements into a numeric expression of illness severity. In addition, the absolute score provided an estimate

of the risk of death. The variables used were the worst in the first 24 hours, giving more time for data collection and less missing data (2). Current critical care prognostic models are predominantly developed in high income countries that require multiple parameters which are not always available in the ICUs of low-income countries like Sri Lanka. The need for a simple but reliable scoring system was a long-felt need. However, valuing the parameters in such a scoring system should be done with good clinical reasoning to prevent wrong predictions. Outcome analysis of interventions and provision for reporting unusual cases will add great value to such a system in the future.

APACHE score was soon followed by Mortality Prediction Model (MPM) (3) in the USA and Simplified Acute Physiology Score (SAPS) (4) in Europe (Table 2).

Both used more or less the same variables at admission to ICU. Less commonly used scores are Multiple Organ Dysfunction Score (MODS) (Table 3) and Logistic Organ Dysfunction Score (LODS).

Dynamic scores may be applied in the ICU such as Sequential Organ Failure Assessment (SOFA) (5) to define the degree of organ failure in sepsis, Model for End Stage Liver Disease (MELD) or Therapeutic Intervention Scoring System (TISS) to estimate the severity of illness and quantity of burden of work for ICU staff.

Ideal scoring system should have the following features (6, 7).

1. Calculated on the basis of easily and routinely recordable variables
2. Well established and validated
3. A high level of discrimination
4. Applicable to all patient populations in the ICU
5. Consider co-morbidities
6. Consider organizational aspects
7. Can be used in different countries
8. The ability to predict mortality

Scoring systems may have several drawbacks as well (6, 7).

1. Application of score prediction to an individual may perpetuate biases inherited in the score and can potentially influence perverse behaviour.
2. Geo-economic aspects play a substantial role in case mix, resource availability, organisational structure and finally outcome. Therefore, each country may need to develop, update and re-calibrate their own mortality prediction model.
3. Scores developed in general populations may be inaccurate when applied to specific groups such as transplant patients for example.

**Future of scoring systems**

Sophisticated data science techniques, machine learning and artificial intelligence bring more predictive capacity and algorithms into healthcare. Linking Global Intensive Care Consortium of national ICU registers and the Global Open Score Severity Illness Score (GOSSIS) are currently working on effective ways to provide international comparison.

**Our work done at Colombo South Teaching Hospital (CSTH)**

The work that is presented in this paper was carried out in the Surgical Intensive Care Unit (SICU) at CSTH from 2019 to 2023. This is a pioneering study in Sri Lanka to assess the suitability of a simple prognostic scoring system proposed by a group of researchers who had studied the ICU data from resource-poor settings in few low income Southeast Asian countries. I joined CSTH in late 2015 and was impressed by the nursing staff's enthusiasm in collecting ICU data for many years. However, the data were purely demographic such as the types of admission, gender, age, indication for admission, number and the number of deaths. Table 4 shows the mortality statistics for the year 2018.

**Table 1:** Acute Physiology and Chronic Health Evaluation II (APACHE II) score

| | Physiologic variable | Point score | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | **4** | **3** | **2** | **1** | **0** | **1** | **2** | **3** | **4** |
| 1 | Temperature | ≥41 | 39-40.9 | _ | 38.5-38.9 | 36-38.4 | 34-35.9 | 32-33.9 | 30-31.9 | ≤29.9 |
| 2 | Mean areterial pressure (mm Hg) | ≥160 | 130-159 | 110-129 | _ | 70-109 | _ | 50-69 | _ | ≤49 |
| 3 | Heart rate | ≥180 | 14-179 | 110-139 | _ | 70-109 | _ | 55-69 | 40-54 | ≤39 |
| 4 | Respiratory rate (non-ventilated or ventilated) | ≥50 | 35-49 | _ | 25-34 | 24-Dec | 11-Oct | 9-Jun | _ | ≤5 |
| 5 | Oxygenation | | | | | | | | | |
| | a) $FiO_2$ ≥ 0.5: use $AaDO_2$ | ≥500 | 350-499 | 200-349 | _ | <200 | _ | _ | _ | _ |
| | b) $FiO_2$ < 0.5 : use $PaO_2$ (mm HG) | _ | _ | _ | _ | >70 | 61-70 | _ | 55-60 | <55 |
| 6 | Arterial pH | ≥7.7 | 7.6-7.69 | _ | 7.5-7.59 | 7.33-7.49 | _ | 7.25-.7.32 | 7.15-7.24 | <7.15 |
| 7 | Serum Na (mMol/L) | >180 | 160-179 | 155-159 | 150-154 | 130-149 | _ | 120-129 | 111-119 | ≤110 |
| 8 | Serum K (mMol/L) | ≥7 | 6-6.9 | _ | 5.5-5.9 | 3.5-5.4 | 3-3.4 | 2.5-2.9 | _ | <2.5 |
| 9 | Serum creatinine (mg/dL) : double point score for acute renal failure | ≥3.5 | 2-3.4 | 1.5-1.9 | _ | 0.6-1.4 | _ | <0.6 | _ | — |
| 10 | Haematocrit (%) | >60 | _ | 50-59.9 | 46-49.9 | 30-45.9 | _ | 20-29.9 | _ | <20 |
| 11 | WBC (in 1000s) | ≥40 | _ | 25.39.9 | 15-19.9 | 3-14.9 | _ | 1-2.9 | _ | <1 |
| 12 | Glasgow come scale (GCS) | Score = 15 minus actual GCS | | | | | | | | |
| | Acute physiology score is the sum of the 12 individual variable points. | | | | | | | | | |
| | Add 0 points for the age <44.2 years. 45-54 years: three points. 55-64 years: five points.65-74 years: Six points ≥ 75 years | | | | | | | | | |
| | **APACHE II score = acute physiology score + age points + chronic health points**. Minimum score =0; maximum score = 71. Increasing score is associated with increased-g risk of hospital death | | | | | | | | | |
| | Add chronic health status points: two points if elective postoperative patient with immunocompromise or history of severe organ insufficiency: Five points for nonoperative patient or emergency postoperative patient with immunocompromise or severe organ insufficiency. | | | | | | | | | |
| 13 | Serum $HCO_3$ (venous-mMol/L) use only if ABGs | ≥52 | 41 - 51.9 | _ | 32-40.9 | 22-31.9 | _ | 18-21.9 | 15-17.9 | <15 |

Adapted deom Knaus WA, Draper EA, Wagner DP, Zimmermann JB. APACHE II: Severity of disease classification system. *Critical care medicine* 1985;13:818-829

Interpretation of APACHE II score (predicted mortality rate.

0-4 = ~ 4% death rate 10-14 = ~ 15% death rate 20-24 = ~ 40% death rate 30-34 = ~75% death rate

5-9 = ~ 8% death rate 15-19 = ~ 25% death rate 25-29 = ~ 55% death rate > 34 = ~85%death rate

**Table 2:** Simplified Acute Physiology Score (SAPS) II

| Variables | Score | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | **26** | **13** | **12** | **11** | **9** | **7** | **6** | **5** | **4** | **3** | **2** | **2** | **0** | **1** | **2** | **3** | **4** | **6** | **7** | **9** | **10** |
| HR (beats/min) | | | | <40 | | | | | | | 40-69 | 70-119 | | | | | 120-159 | | ≥160 | | |
| SBP (mmHg) | | <70 | | | | | | 70-99 | | | | 100-199 | | | ≥200 | | | | | | |
| Temperature (°C) | | | | | | | | | | | | | <39 | | | ≥39 | | | | | |
| $PaO_2/FiO_2$ only if | | | | <100 | 100-199 | ≥200 | | | | | | | | | | | | | | | |
| VENT or CPAP | | | | | | | | | | | | | | | | | | | | | |
| Urine output (L/day) | | | | <0.5 | | | | | 0.5-0.999 | | | | ≥1 | | | | | | | | |
| Urea (g/L) | | | | | | | | | | | | | <0.6 | | | | | 0.6-1.7 | | | >1.8 |
| TLC | | | <1 | | | | | | | | | | 1-19.9 | | ≥20 | | | | | | |
| Potassium | | | | | | | | | | <3 | | | 3-4.9 | | ≥5 | | | | | | |
| Sodium | | | | | | | | <125 | | | | | 125-144 | ≥145 | | | | | | | |
| Bicarbonate | | | | | | | <15 | | | 15-19 | | | >20 | | | | | | | | |
| Bilirubin (mg/dL) | | | | | | | | | | | | | <40 | | | | 40-59.9 | | | ≥60 | |
| GCS | <6 | 6-8 | | | | 9-10 | | 11-13 | | | | | 14-15 | | | | | | | | |

| **Age** | **Score** | **Chronic disease** | **Score** | **Type of Admission** | **Score** |
|---|---|---|---|---|---|
| <40 | 0 | Metastatic cancer | 9 | Scheduled surgical | 0 |
| 40-59 | 7 | Haematological malignancy | 10 | Medical | 6 |
| 60-69 | 12 | AIDS | 17 | Emergency surgical | 8 |
| 70-74 | 15 | | | | |
| 75-79 | 16 | | | | |
| >80 | 18 | | | | |
| SAPS II score | 29 | 40 | 52 | 64 | 77 |
| Mortality risk % | 10 | 25 | 50 | 75 | 90 |

GCS: Glasgow coma score; HR: Heart rate; SBP: Systolic blood pressure, $PaO_2$ (mmHg) arterial oxygen tension; $FiO_2$; Fractional concentration of inspired oxygen; VENT: Ventilator; CPAP: Continuous positive airway pressure; TLC: Total leucocyte count; AIDS: Acquired immunodeficiency syndrome. Probability of death, $P$ may be calculated using the following equation: $P = (e^{Logit}) / (I+e^{Logit})$ ; $Logit = -7.7631 + 0.0737\ (score) + 0.9971\ log([score+I])$

**Table 3:** Multiple Organ Dysfunction Score (MODS)

| Organ system and their variables | Score | | | | |
|---|---|---|---|---|---|
| | **0** | **1** | **2** | **3** | **4** |
| Hematologic ; Platelet count ( x $10^3/mm^3$ or $10^9/L$) | >120 | 81-120 | 51-80 | 21-50 | ≤20 |
| Hepatic: Serum bilirubin (µmol/L) | ≤ 20 | 21-60 | 61-120 | 121-240 | >240 |
| Renal: Serum creatinine (µmol/L) | ≤100 | 101-200 | 201-350 | 351-500 | >500 |
| Cardiovascular : PAR | ≤10 | 10.1-15 | 15.1-20 | 21-30 | >30 |
| Glasgow coma score | 15 | 13-14 | 10-12 | 7-9 | ≤6 |
| Respiratory: $PO_2/FIO_2$ | >300 | 226-300 | 151-225 | 76-150 | ≤75 |
| Score | 0 | 1-4 | 5-8 9-12 | 13-16 17-20 | 21-24 |
| ICU mortality % | 0 | 1-2 | 3-5 25 | 50 75 | 100 |

ICU. Intensive care unit, CVP. Central venous pressure (mmHg), GCS. Glasgow coma score. HR. Heart rate (beats/min), MAP; Mean arterial pressure (mmHg), PAR: Pressure adjusted heart rate (which is calculated as the product of the HR and the ratio of CVP to MAP); $PaO_2$ (Torr) arterial oxygen tension; $FiO_2$: Fractional concentration of inspired oxygen. If the result result for a sporadic test is not available, then a score of 0 is used for that test. The serum creatinine conc. is measured without the use of dialysis and the $PO_2/FiO_2$ ratio ($PO_2$ in mmHg and $FiO_2$ in %) is calculated without the use of mechanical ventilation or positive end-expiratory pressure.

**Table 4:** Mortality statistics of the year 2018.

| | **Mortality Statistics 2018** | | |
|---|---|---|---|
| **Specialty** | **Total admission** | **Death** | **%** |
| Surgical | 456 | 60 | 13.1 |
| Medical | 72 | 27 | 37.5 |
| Obs/Gynae | 52 | 1 | 1.9 |
| Paediatric | 3 | 0 | 0 |
| Others | 47 | 1 | 2.7 |

However, the mere demographic data or a mortality figure alone completely lacked analytical and projective capability. The answer to this problem was clear. That is to use a score as APACHE. Calculation of APACHE using 12 parameters including a blood gas analysis for all admissions is practically difficult in a resource-poor setting (8). The use of an online APACHE calculator needed a data connection which was not provided by the hospital or Ministry of Health. This added to problems. To circumvent this problem, categorisation of patients was changed to septic, trauma, post-surgical etc. We attempted to use a separate simple score for each category such as SOFA (Sequential Organ Failure Assessment) in sepsis, ISS (Injury Severity Score) in trauma and the POSSUM (Physiologic and Operative Severity Score for the Study of Mortality and

Morbidity) in post-surgical patients. The following problems were identified in the evaluation process:

1. When the patient had more than one clinical condition, selection of a score type to be used for an issue.
2. Clinical condition of some patients changed after admission to ICU. *e.g.* A trauma patient becoming septic after admission.
3. Uncertainty about deciding on the type of score to be applied in certain patients by nursing staff.
4. Difficulty in comparing patients categorised under different scoring systems.
5. Morbidity prediction was difficult as a common ICU admission.

The unsuccessful attempt was tried for about one and half years. In the year 2018, Haniffa *et al.,* published on a simple prognostic tool to be used in ICUs of resource-poor settings (9). The morbidity score was called the Tropical Intensive Care Score (TICS) was the first international prognostic model developed for the use in a low-income setting like in Sri Lanka. The score was based on the 5 simple parameters of haemoglobin (Hb), blood urea nitrogen (BUN), the Glasgow coma scale (GCS), systolic blood pressure (SBP), respiratory rate (RR) and admission mode (elective or emergency). Depending on the value for each variable, a risk could be read on a scale and the mortality risk could be read from another scale against the summed cumulative risk (Figure 1).

Haniffa *et al.,* have validated the score against APACHE and SAPS using data from 3400 patients in different ICUs in South East Asia.

The objective of our study was to see the application of this model in the Sri Lankan ICU setting.

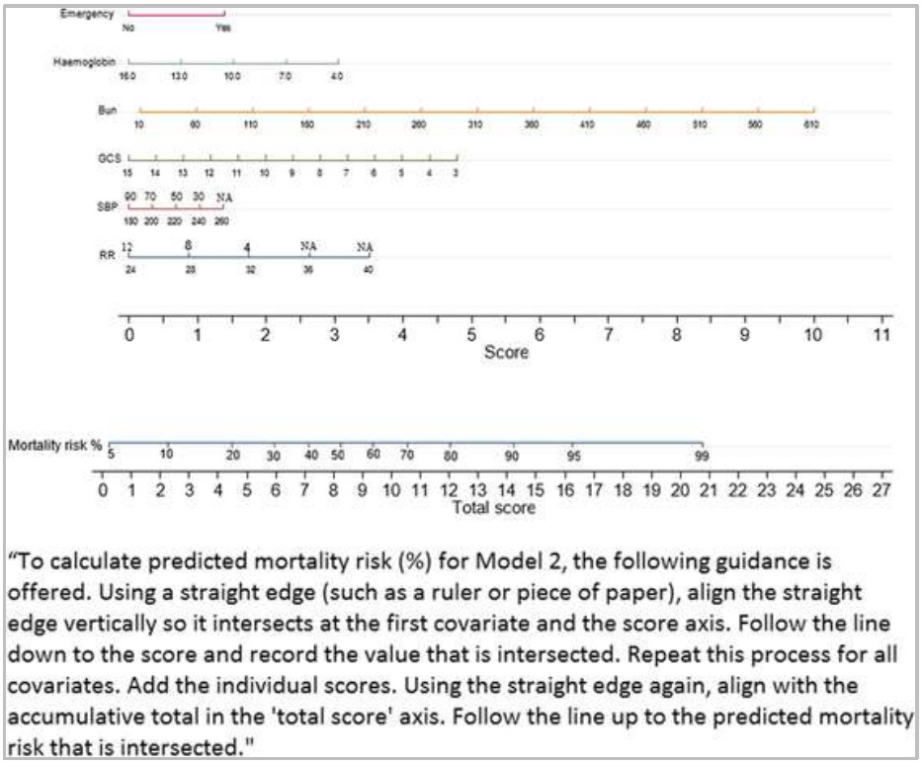


**Figure 1:** A critical care prognostic model for critical care in South Asia (9).

## Methods

The data collection for the study commenced in 2019. On admission to the SICU, every patient's Hb level, blood urea, level of consciousness, systolic blood pressure and the respiratory rate were documented along with whether the admission was routine or emergency. A score according to the above scale was assigned to each parameter. The sum score was then calculated and the mortality risk was predicted against this score from another scale in the same chart. We encountered difficulties in finding out scores for certain parameters such as the respiratory rate before intubation when the patient came intubated to the ICU. In such instances we have used a clinically acceptable value for the figure. Some examples are given below.

1. A patient who is ventilated for any kind of lung pathology the RR was taken as "0" whereas a patient who was ventilated for some other reason like a paralysis for a tracheal repair the rate was taken as normal.
2. A patient on inotropes on admission to ICU the SBP was taken as what it was before starting them.
3. A patient who has a low GCS due to sedation the GCS value prior to sedation was taken.

Over the last 4 years, nearly 2400 patients were analysed using the TICS.

In 2019, we started to project the mortality of our SICU patients on admission to the unit using the TICS for the first time. For the analysis, we considered the data of last 1000 patients we included in TICS in our unit.

As the study proceeded, it was realized that the TICS had a good clinical prediction. Then, we started calculating the APACHE score in retrospect in the patients who had a TICS score greater than 70%. Using the available data of APACHE, sensitivity, specificity, the predictive power of a positive and a negative test were calculated for TICS against APACHE.

## Results

The monthly admission rate was around 50 to 60 patients. In the sample 59.2% (n=592/1000) were males. When considering the distribution according to the speciality; surgical 81.5% n=815), medical 12.6% (n=126), gynaecology and obstetrics 5.7% (n=57) and paediatrics 0.2% (n=2). Figure 2, outlines the age distribution of the sample.

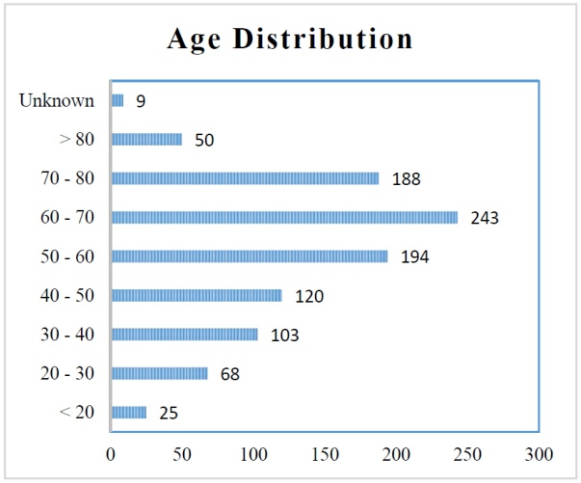


**Figure 2:** Age distribution of the sample of 1000 patients

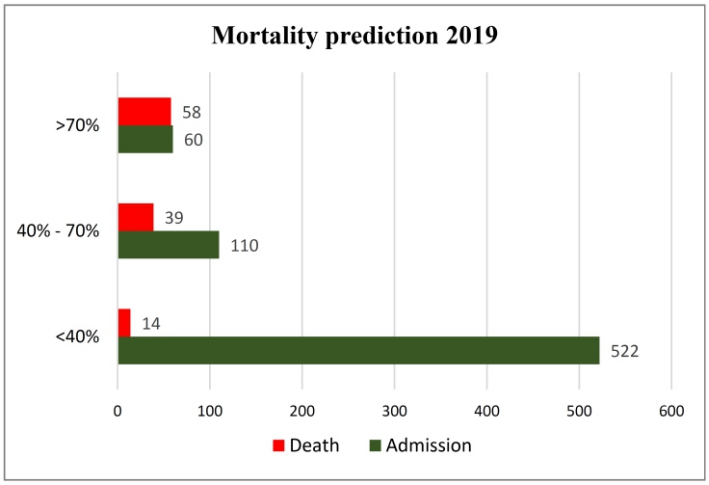


**Figure 3:** Mortality figures for the year 2019

Indications for ICU admission included routine surgery 38.8% (n=388), casualty requests 29.3% (n=293), sepsis 12.5% (n=125), emergency surgery12.4% (n=124), leptospirosis 2.3% (n=23) and others 4.7% (n= 47). From this group of patients, 70.5% (n=705/1000) recovered completely and were discharged.

Figure 3 summerises the number of admissions, deaths and the mortality calculated using TICS for the year 2019.

The difference in the above presented data is due to prediction of likelihood of mortality of patients was predicted on admission to the ICU and later compared the actual mortality against the predicted. This enabled us to see how many of the low-predicted mortality patients actually died and how many of the high predicted mortality patients survived in our unit.

Table 5 shows the comparison between APACHE and TICS. The sensitivity (TP/TP+FN = 149/149 + 1=99.3%), specificity (TN/TN+FP = 53/53 +0=100%), and positive (TP/TP+FP = 149/149+ 0=100%) and negative predictive values (TN/TN + FN = 53/53+1 = 98.1%) of TICS as a score was calculated.

**Table 5:** Comparison between APACHE and TICS

| | APACHE>70% | APACHE<70% |
|---|---|---|
| TICS > 70% | 149 (True +/TP) | 0 (False +/FP) |
| TICS < 70% | 1 (False - /FN) | 53 (True -/TN) |

## Discussion

Ability to predict the outcome of a patient admitted to a unit as compared with the standard is of utmost importance for that unit to assess its own performance. This enables the health care management to identify the causative factors of poor performance and try to introduce remedial measures to correct them. As already has been mentioned, the use of a score like APACHE for this purpose is always not possible in a resource-limited setting like in Sri Lanka. In this regard a simple prognostic model such as the TICS is a very useful tool to be used in our ICUs.

Its close correlation of sensitivity, specificity and the predictive power compared with APACHE was impressive. Over the last 4 years, we have analysed on a monthly basis all patients who died with an admission TICS of less than 40%. TICS had the same drawback as any score calculated on admission as the patient could soon deteriorate. Sometimes even a very serious clinical condition might have a low score if their physiological parameters are stable. *e.g.* a patient with a leaking abdominal aortic aneurysm who is haemodynamically stable. To circumvent this problem, we adopted a policy to repeat the score after 24 hours. The 24-hour demarcation was taken to match that of APACHE which uses the worse score in the first 24 hours. The worse TICS value was taken as the initial score. However, we have analysed only the patients admitted to the surgical intensive care unit. Many of these patients may not have significant other medical conditions as compared to a medical intensive care unit. All the pathological conditions that a patient may have might not be reflected in the parameters that are measured.

### Sub group analysis

The following planned further analyses will help to check on drops of TICS.

1. Analysis of re-admissions within 48 hours after discharging from the ICU.
2. Analysis of the reasons for patients TICS to drop significantly within the first 48 hours.

Drops of TICS may be due to either patient's clinical deterioration or iatrogenic events such as a pneumothorax after a central line placement. We do not have these data with us at the moment.

## Conclusions

TICS is a simple, easily applicable prognosticating tool. Its value closely corelates with that of APACHE when values for parameters are given with clinical reasoning where appropriate. It is highly sensitive, specific and has a high predictive value as with APACHE under the above circumstances. A manual calculation is possible without the need for electronic devices, and it is repeatable.

## Recommendations

This is a single unit study. We need data from across the country from multiple units as monitoring ICU performances by establishing registers. Outcome analysis of interventions such as ventilation of a particular condition can be added as required. Provision for reporting unusual cases will be a very useful addition. Possibility of recruiting data collectors should be a consideration as doctors may be poor performing this task as this not what they are trained for.

There is an ongoing retrospective study by the same authors using data of over a cohort of over 65000 patients from different ICUs in India, Bangladesh, Pakistan, Afghanistan, Vietnam and Malaysia. This is on a more complex data platform incorporating many of the future endeavours that I have spoken earlier.

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