RESEARCH ARTICLE

Intervention- versus physiology-based risk assessment scores for predicting cardiac arrest: a pilot study [version 1; peer review: 2 approved with reservations, 1 not approved]

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Abstract

There is increasing interest in predicting and avoiding cardiac arrest in hospitalized patients. Multiple studies have used vital signs or scores based upon them, such as the Modified Early Warning Score (MEWS). Scoring systems that measure supportive care, such as the Sequential Organ Failure Assessment (SOFA) and the 28-item Therapeutic Interventions Scoring System (TISS-28) might be superior to systems used in previous studies. This study was performed to determine if a system using SOFA and/or TISS would be superior in detecting clinical deterioration prior to cardiac arrest.

Using a retrospective chart review, MEWS, SOFA and TISS-28 scores were calculated for twenty patients at baseline and then in the 24 hours prior to their cardiac arrest. Supportive interventions and nursing care (SOFA and TISS-28) changed more than measures of physiology (MEWS) in the period prior to cardiac arrest, likely due to the fact that vital sign deterioration can be delayed by supportive measures. These results support the idea that a SOFA and/or TISS-28 scoring system might be superior to the MEWS, which could be used to make hospital rapid response teams more effective.

Keywords

TISS-28, SOFA, MEWS, cardiac arrest, risk assessment

Open Peer Review

Approval Status **X ? ?**

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Any reports and responses or comments on the article can be found at the end of the article.

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Introduction

Cardiac arrest in hospitalized patients outside the intensive care unit (ICU) carries a high mortality. Many studies have shown that these cardiac arrests are rarely sudden, as demonstrated by abnormal vital signs in the hours leading up to these events¹⁻⁷. The challenge lies in developing robust algorithms to predict cardiac arrests in order to better target interventions. In fact, one potential explanation for the failure of rapid response systems (RRS) to better impact patient outcomes is an inability to identify which patients actually require RRS intervention⁸.

The **Modified Early Warning Score** (MEWS) is one attempt at a risk prediction algorithm. This scale, which assigns point values for abnormal vital signs or mental status assessments, has been used to predict requirement for hospital admission in emergency department patients⁹ and to predict hospital mortality¹⁰. However, although a vital sign-based tool is appealing for general ward patients, it is limited by the quality of the data, specifically with respect to respiratory rate and mental status, which are poorly assessed and documented outside the intensive care unit. In addition, physiology-based tools do not take into account what has been done to the patient to maintain that physiology, such as the use of supplemental oxygen to maintain oxygen saturation or vasopressor agents to maintain blood pressure.

In the ICU setting, scales such as the **Sequential Organ Failure Assessment** (SOFA)¹¹ have been developed to account for both physiology and supportive measures, but have not been validated for use outside the ICU. Yet another ICU scale with the potential to fill this critical role for floor patients is the 28-item **Therapeutic Interventions Scoring System** (TISS-28)¹². This system was designed to quantify nursing workload in the intensive care setting, and as such does not include any physiology-based scales. Rather, the scale assesses the intensity of caregiver interventions such as the frequency of vital signs, use of invasive catheters and drains, and the frequency and intensity of certain treatments.

We hypothesized that a scoring system that includes supportive measures and interventions (such as the SOFA and/or TISS-28) would be superior to a system relying only on physiology (such as the MEWS) in detecting clinical deterioration preceding cardiac arrest on the floors.

Method

We conducted a retrospective chart review of patients between 2006 and 2008 at the University of Chicago Medicine, which is a tertiary-care, university teaching hospital with approximately 600 beds, without a RRS at the time of the study. The study protocol was approved by the University of Chicago Institutional Review Board.

A convenience sample of patients suffering cardiac arrest in the hospital were included in the analysis. Paper charts were

reviewed and data sufficient to calculate the SOFA, TISS-28, and MEWS for each patient was extracted. This included vital signs, laboratory results for creatinine, bilirubin, arterial blood gases, vasoactive drug doses, and nursing notes related to mental status and care duties. When arterial gas data were not available, we estimated the PaO₂ necessary for the SOFA using a validated conversion algorithm¹³.

The TISS-28 is comprised of 28 items with point values from one to eight, with higher scores equating to a higher nursing workload. The items are subdivided into component physiologic systems (Basic Monitoring, Cardiovascular, Respiratory, Interventions, Renal, Neurologic and Metabolic subscales) to isolate the dynamic aspects of the scale in the time preceding arrest; each subscale consists of one to several items. For example, the Neurologic subscale consists solely of the presence or absence of intracranial pressure monitoring (worth four points), whereas the Cardiovascular subscale consists of the presence of single or multiple vasoactive medications, the presence of a central line, and the presence of an arterial line (worth three, four, two, and five points, respectively). The Basic Monitoring scale consists of items related to the care of drains and wounds, and the frequency of vital sign checks and lab draws. The Intervention subscale encompasses recent procedures and studies the patient might undergo, such as endotracheal intubation, echocardiography, and trips to radiology or the operating room. The Respiratory and Renal subscales consist of items pertaining to the support of those particular organ systems (ventilatory management, diuresis and hemodialysis, respectively). Finally, the Metabolic subscale consists of items related to treatment of acid-base abnormalities and malnutrition.

MEWS, SOFA and TISS-28 scores were calculated for the calendar day of the arrest (pre-arrest) and the day prior to the arrest (baseline). MEWS scores were based on vital signs such as heart rate, respiratory rate, temperature, systolic blood pressure and patient responsiveness. Data obtained during or after the arrest was excluded. In accordance with studies using the SOFA score^{14,15}, we used the highest score for each organ system to calculate the total score, and then used the highest score from each time point. For the sake of consistency, we used this approach to calculate the TISS-28 and MEWS scores as well. Data were stored in a spreadsheet (Microsoft Excel, Redmond, WA) and analyzed using SPSS (Chicago, IL). Baseline and pre-arrest scores were compared using two-sided paired sample t-tests. Percentages of change in the various scales from baseline to pre-arrest were compared using chi-squared statistics. An alpha of 0.05 was used for all analyses.

Results

A total of twenty patients were included in the study. Demographic data are presented in **Table 1**. The mean age of subjects was 68±15 years. Eighty five percent of patients were black and sixty percent were female. Admission diagnoses for the 20 patients were highly variable and included dyspnea, subdural

Table 1 Demographics of patients.

Characteristic	Value
Subjects, n	20
Age, mean (SE),	68 (15)
Height, mean (SE), cm	153 (12.2)
Weight, mean (SE), kg	87.9 (8.7)
Body mass index, mean (SE), kg/m ²	30.8 (3.13)
Male sex, n (%)	8 (40)
Race	
Black, n (%)	17 (85)
White, n (%)	1 (5)
Other, n (%)	2 (10)
Comorbidities	
Hypertension, n (%)	14 (70)
Chronic renal insufficiency, n (%)	8 (40)
Diabetes (type 2), n (%)	8 (40)
History of CVA, n (%)	7 (35)
History of myocardial infarction, n (%)	5 (25)
COPD, n (%)	5 (25)
Tobacco use, n (%)	4 (20)
Alcohol use, n (%)	4 (20)
Atrial fibrillation, n (%)	4 (20)
Asthma, n (%)	2 (10)
Liver disease, n (%)	1 (5)
Discharge status	
Transferred home, n (%)	2 (10)
Transferred to another in-patient facility, n (%)	5 (25)
Died, n (%)	13 (65)
Length of stay, mean (SE), d	17 (3.4)

SE denotes standard error. CVA; cardiovascular accident

hematoma, and congestive heart failure, amongst others. For three subjects, cardiac arrest took place on the day of admission, and hence no baseline data were available. In the remaining 17 patients, the SOFA score increased from 1.29 ± 0.40 at baseline to 1.76 ± 0.45 ($p=0.03$) on the calendar day before the event, representing an increase of 36%, while the TISS-28 increased from 9.9 to 15.0 ($p=0.04$), representing a 52% increase. There was no significant change in the MEWS (see Table 2).

Analysis of the TISS-28 subscales revealed that the primary driver of the increase in TISS-28 was due to an increase in the Interventions score, which more than tripled (0.59 ± 0.40 at baseline vs. 2.00 ± 0.73 the day before arrest; $p=0.03$). There was no significant difference in the Basic Monitoring, Cardiovascular, and Respiratory subscales, despite a trend in the same direction (see Table 3).

Table 2 Mean SOFA, TISS-28, and MEWS, from baseline to pre-arrest.

Scale	Baseline mean (SE)	Pre-arrest mean (SE)	P*	# Worse* (%)
SOFA	1.29 (0.40)	1.76 (0.45)	0.03	7 (41)
TISS	9.9 (0.84)	15.0 (2.26)	0.04	11 (65)
MEWS	6.18 (0.37)	6.06 (0.49)	0.8	6 (35)

*Paired samples t-test

*Out of the 17 subject with baseline data

Table 3 TISS-28 subscales from baseline to pre-arrest.

TISS-28 Subscale	Baseline mean (SE)	Pre-arrest mean (SE)	P*	# Worse* (%)
Basic Monitoring	4.06 (0.41)	5.41 (0.77)	0.11	9 (53)
Cardiovascular	0.94 (0.39)	2.77 (1.10)	0.14	8 (47)
Interventions	0.59 (0.40)	2.0 (0.73)	0.03	5 (29)
Respiratory	1.65 (0.30)	2.12 (0.29)	0.23	5 (29)
Renal	1.94 (0.36)	1.88 (0.32)	0.85	3 (18)
Metabolic	0.77 (0.42)	0.82 (0.36)	0.79	0 (0)

*Paired samples t-test

*Out of the 17 subject with baseline data

Supportive interventions and physiological changes in patients at baseline, pre- and post-cardiac arrest

1 Data File

<http://dx.doi.org/10.6084/m9.figshare.646166>

Discussion

In this study of patients suffering cardiac arrest, we found that the measure of nursing care (TISS-28) changed to a greater degree than the physiology-based measures (MEWS) in the period preceding the arrest. While some patients experience sudden arrest, many are believed to decompensate over a period of hours or even days prior to their ultimate cardiac or respiratory arrest⁵. Schein and colleagues identified respiratory disorders as the most common antecedent to arrest, and noted that most patients experiencing arrest had “documented observations of clinical deterioration or new complaints within eight hours of arrest”⁷. In a retrospective, case-controlled study Hodgetts *et al*¹⁶ observed that abnormal breathing, heart rate, or systolic blood pressure were powerful predictors of arrest. In contrast, Kause *et al*⁴ identified hypotension and altered mental status as the primary predictors of arrest in their study examining patients from the United Kingdom and New Zealand.

The detection of patient deterioration by vital signs-based systems can be delayed by supportive measures, suggestive of low

sensitivity. In many decompensating patients, vital signs may be altered by a variety of supportive measures instituted by caregivers. These supportive measures will delay the detection of deterioration by physiologic based scoring systems such as the MEWS, but would be detected by a scoring system of supportive measures such as the TISS. Intervention and laboratory based scoring systems may be more sensitive or earlier predictors of patient deterioration than any scoring system limited to only one of these dimensions.

Studies of RRS have varied in their ability to demonstrate an effect on cardiac arrest and mortality^{17–19}. The systems in most of these studies rely on nursing or medical staff to notice the sometimes subtle changes in patients' well-being in order to activate the RRS. The attraction of simple severity of illness scales like those studied here is that, in conjunction with an electronic medical record, they can be calculated automatically. Such a system could prompt caregivers to consider RRS consultation when scale scores (i.e., caregiver duties) increase or pass some threshold, and this might better direct RRS resources to the sickest patients.

Our study demonstrates that the intensity of caregiver intervention, particularly those interventions related to procedures and cardiovascular and respiratory systems, is superior to MEWS in detecting patient decompensation. In our patients, the liver and coagulation components of the SOFA score changed less than the other parts of the SOFA score, though it is possible that the indicators of liver and coagulation function (i.e. bilirubin and platelet count) would be more useful in a larger sample of patients in which these parameters changed significantly. Similarly, the CNS component of the TISS-28, the measurement of intracranial pressure, was not performed on any patient in our study at any time point. Using only the presence or absence of intracranial pressure monitoring as a metric for CNS deterioration would likely miss a patient's deteriorating mental status as a sign of clinical worsening.

Our study has several limitations. First, our sample size is small. It is possible that the MEWS would prove to be a significant predictor in a larger study. However, as an exploratory study of the utility for intervention-based assessment, either in addition to or in place of physiology-based predictors, these data show promise for the TISS-28 as a measure of clinical deterioration. Second, our study is a retrospective case series. These findings will need to be validated in a larger prospective, controlled trial. Third, although the TISS-28 describes caregiver interventions across subscales and organ systems, some subscales are

more comprehensive than others (e.g., as mentioned above, the Neurologic subscale consists of one item, whereas other subscales cover a broader range of potential interventions). While changes in mental status are widely believed to foreshadow decompensation, variable and generally incomplete documentation of mental status frustrates abstracting SOFA and MEWS from charts.

Assessment of the central nervous system is probably sub-par in all three clinical scales. Whereas the TISS-28 focuses exclusively on ICP monitoring, the SOFA CNS subscale consists solely of the Glasgow Coma Scale (GCS) and the MEWS CNS variable captures patients' responsiveness to stimulation. Each of these measures probably misses the subtle mental status alterations that precede clinical decompensation. Furthermore, the various CNS measures in this study were the most likely variables to have missing data. For the GCS, when data were lacking, we inferred a value of 15 (normal), and did the same for the CNS measure of the MEWS. This approach may lower the total scale scores, but we believe this is the most conservative approach to handling these missing data.

In conclusion, our data show that an intervention-based scoring system changes more than physiology-based scoring systems in the period prior to cardiac arrest. This may be due to support used to maintain normal vital signs in the early period of decompensation, which is not captured by vital sign-based scoring systems. This finding needs to be validated prospectively.

Author contributions

Christopher G Choukalas, conceived study and analyzed data. Suzanne Kellman, analyzed data and prepared manuscript. Michelle L Keese, collected/extracted and analyzed data. Michelle Loor, collected/extracted data. Marzanna Vasington, collected/extracted data, developed data collection tool. Michael F O'Connor, conceived study and analyzed data. Dana P Edelson, analyzed data. All authors reviewed and approved the manuscript for publication.

Competing interests

No competing interests were disclosed.

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This article presents a study that compares three forecasting models used in healthcare. The models are based on scores for predicting cardiac arrests. The idea is useful and the theme is very important due to the huge number of people that are affected by cardiac arrests worldwide. However, there are some gaps that are crucial to validate the success of the study. The small sample is indeed the main flaw of this study and consequently, it compromises the results interpretation. It is very dangerous to take solid conclusions with just a few examples. In other words, the reliability of this study is not enough to evaluate and to compare these three forecasting models. A larger sample, as well as a more heterogeneity is demanded. The description of the models could be more detailed, in order to a better comprehension. The bibliography is adequate.

Competing Interests: No competing interests were disclosed.

I confirm that I have read this submission and believe that I have an appropriate level of expertise to confirm that it is of an acceptable scientific standard, however I have significant reservations, as outlined above.

Reviewer Report 13 August 2013

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Una Kyriacos

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Studies on patient monitoring systems such as this are important. The study has limitations and the authors acknowledge this: it is an exploratory study of limited scope. This limits the conclusions to tentative assumptions at best.

The study could be strengthened by acknowledging that the two scoring systems (TISS-28 and SOFA) are not intended for general ward use, whereas this is the overt intention with the MEWS, with which the former systems are compared. [Morrice and Simpson \(2006\)](#) did this successfully in a cross-sectional survey using the EWS, TISS-28 and APACHE II. Neither the abstract, nor the main paper, forefront the difference in purpose of the MEWS, TISS-28 AND SOFA. The results are therefore not surprising: both the TISS-28 and SOFA systems, used within high dependency areas, require staff-intensive input and supportive interventions. The TISS-28 point equals 10.6 minutes of a nurses' shift (a total of 46.55 points per shift delivered by one nurse) ([Miranda, de Rijk & Schaufeli, 1996](#)). The MEWS, on the other hand, although also designed for early recognition of physiological deterioration in ward patients, but by non-specialist nurses, is used in a context characterised by sicker, more dependent patients than previously described in the literature.

Inclusion and exclusion criteria for patient records have been omitted making replication difficult. The results do not indicate if the MEWS was used as a single parameter or aggregate weighted track-and-trigger system for the record review.

Competing Interests: No competing interests were disclosed.

I confirm that I have read this submission and believe that I have an appropriate level of expertise to confirm that it is of an acceptable scientific standard, however I have significant reservations, as outlined above.

Reviewer Report 14 June 2013

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Anders Aneman

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The conclusion is not justified based on the presented data because of the following concerns:

Small convenience sample (n=17) studied retrospectively. Article does not specify DNR status or comment on limitations of care preceding cardiac arrest. Only 48 hrs of hospitalization studied. No detail provided on level of care, level of monitoring, or level of nursing.

TISS-28 and SOFA has not been validated outside ICU and present sample size precludes any meaningful correlations between scoring systems.

TISS-28 and SOFA excludes the intuitive criterion (concern for patient) that is included in RRS trigger track systems and found to be both common and predictive of outcome. For example, normal physiology maintained with significant support would not meet numerical triggers but

definitely be very concerning for clinical staff (cf. discussion MEWS vs. TISS-28/SOFA). This limits both the novelty and the validity of the study.

Insufficient detail for SOFA provided in article to delineate cardiorespiratory pathology (only aggregate SOFA) and notably TISS-28 did not change significantly in any domain apart for "Interventions" (again, concern for patient).

Competing Interests: No competing interests were disclosed.

I confirm that I have read this submission and believe that I have an appropriate level of expertise to state that I do not consider it to be of an acceptable scientific standard, for reasons outlined above.

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