

Prediction of Mortality and of the Need for Massive Transfusion in Casualties Arriving at Combat Support Hospitals in Iraq

Leopoldo C. Cancio, MD, Charles E. Wade, PhD, Susan A. West, BSN, CNOR, and COL John B. Holcomb, MC

Background: Our purpose was to compare the Revised Trauma Score (RTS) with the new Field Triage Score (FTS) for prediction of mortality (MORT) and of need for massive transfusion (MASS, ≥ 10 units of packed cells or whole blood) in casualties arriving at combat support hospitals in Iraq.

Methods: Six hundred ninety-two cases were reviewed; 536 had complete data and were included. Total Glasgow Coma Scale score (GCS_{total}) not GCS_{motor} was used. Thus, a modification (FTS₀₇) of the FTS was calculated, using GCS < 8 and systolic arterial pressure (SAP) < 100 as cut-points, with range 0 to 2. Variables different by univariate analysis under-

went logistic regression analysis (LRA) and areas under the curve for receiver operating characteristic curves (AUC) were calculated. By LRA, probability of an outcome is given by $p = e^k / (1 + e^k)$.

Results: By LRA for MORT, $k = 0.616 - 0.438 \times \text{RTS}$; AUC = 0.708. When used instead of RTS, FTS₀₇ provided $k = -0.716 - 1.009 \times \text{FTS}_{07}$; AUC = 0.687 (NS). For MASS, $k = 0.638 - 0.115 \times \text{RTS} - 0.011 \times \text{DAP} + 0.358 \times \text{SI}$, where DAP is diastolic arterial pressure and SI is shock index, i.e., heart rate or SAP; AUC = 0.638. When used instead of RTS, FTS₀₇ provided $k = -0.740 - 0.376 \times \text{FTS}_{07} - 0.011 \times \text{DAP}$; AUC = 0.618 (NS).

Conclusions: RTS emerged as the best predictor of MORT, with FTS₀₇ a close surrogate. This indicates the effect of impaired mentation on MORT in these data. For prediction of MASS, RTS as well as the heart rate and blood pressure predominated. The advantage of FTS₀₇ (or original FTS) over RTS is the former's ease of computation.

Key Words: Triage, Wounds and injuries, War, Military personnel, Blood pressure, Glasgow Coma Scale Score, Outcome and process assessment, Death, Blood transfusion.

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Civilian trauma scores have been developed, primarily in the post-Vietnam War era, to help decide where trauma patients should be sent within a regional Emergency Medical Services system. Such scores also support research, evaluation of patient outcome, quality improvement, and prevention programs. In brief, they are intended to facilitate real-world decision making in the field, as well as retrospective data analysis.^{1,2}

One such score is the Revised Trauma Score (RTS), introduced by Champion et al. in 1989.³ The RTS (Table 1) is based on physiology rather than on knowledge of the anatomic location and severity of injury. That is, it is based

on measurable vital signs to include the Glasgow Coma Scale score (GCS), the systolic arterial blood pressure (SBP), and the respiratory rate (RR). These three variables are recoded into integers between 0 and 4. The recoded data are then inserted into an equation, in which the GCS is given the greatest weight, followed by the SBP and then the RR. RTS correlates with mortality in a typically sigmoidal, dose-responsive manner (Fig. 1).

With the advent of a US military Joint Theater Trauma System on the current battlefield in Iraq and Afghanistan,⁴ and recognizing the significant differences between warfighters and civilians with respect to both injury mechanism and tactical scenario,⁵ the need arose to validate the existing scores for use in combat. Furthermore, it was evident that the RTS could not be calculated by combat medics in the field, unless one presupposes their carrying and using Personal Digital Assistants (PDAs) or a similar computers—an impractical requirement.

To develop a more user-friendly score, Eastridge et al. recently developed a simplified Field Triage Score (FTS) using over 800,000 records from the National Trauma Data Bank (Eastridge B, Salinas J, McManus J, et al. Field Triage Score (FTS): development and validation of a simple and practical pre-hospital triage instrument. *J Trauma*. In press.). SBP was categorized as ≤ 100 mm Hg or > 100 mm Hg; that cut-off was chosen based on the SBP at which the radial pulse typically changes from strong to weak. The motor component of the GCS (GCS_{motor}) was used instead of the total score

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(GCS_{total}), and was categorized as either abnormal (<6) or normal (=6). The FTS was derived by assigning a value of 0 for low SBP or an abnormal GCS_{motor} and 1 for a normal SBP or GCS_{motor}. Adding the scores results in an FTS value of 0, 1, or 2. Areas under the receiver operating characteristic curves (AUC ROC) for RTS and FTS were each about 0.80.

Both the RTS and the FTS, however, were developed using data from civilian trauma patients. In this study, we sought to apply these scores in the combat environment. We reviewed data for combat casualties arriving at the Emergency Department of US Combat Support Hospitals (CSH) in Iraq to predict mortality (MORT) and the need for massive transfusion (MASS), defined as ≥ 10 units of packed cells (RBC) or whole blood (WB). Our goal was to compare the predictive accuracy of the RTS and the FTS with respect to these important endpoints. We hypothesized that these two scores would be equally accurate (measured by AUC ROC) in prediction of MORT and MASS.

METHODS

This retrospective study was conducted using data on US combat casualties from an existing performance-improvement database. The majority of cases were contributed by the US Army CSH at Ibn Sina Hospital, Baghdad, Iraq, with a lesser

number from other US Level III hospitals in Iraq. The database included the vital signs upon arrival in the CSH Emergency Department, specifically the systolic (SBP) and diastolic (DBP) arterial blood pressures; heart rate (HR); RR; and GCS_{total}. Derived variables, to include the pulse pressure (PP = SBP – DBP) and shock index (SI = HR/SBP), were calculated. It also included the RTS; whether the patient was artificially ventilated upon arrival; number of units of packed red blood cells received during the first 24 hours (RBC); number of units of whole blood received during the first 24 hours (WB); and mortality during hospitalization, to include hospitalization in the United States. Data to include ultimate hospital mortality were verified by review of the Joint Theater Trauma Registry. Data from 692 casualties were reviewed, of which 536 had complete data and were included in the study. The GCS_{total} rather than GCS_{motor} was available. Thus, a modification (FTS₀₇) of the FTS described by Eastridge et al. was calculated, using GCS_{total} < 8 and systolic arterial pressure (SAP) < 100 mm Hg as cut-points, with range 0 to 2. In the calculation of GCS_{total}, no distinction was made between patients who were intubated and those who were not intubated. Likewise, the RR was recorded without distinguishing between artificially ventilated or spontaneously breathing patients.

Statistical analysis was performed using SPSS v. 11 (SPSS Inc., Chicago, IL). Variables different by univariate analysis (T, Mann-Whitney U, or χ^2 tests) by $p < 0.10$ were subjected to logistic regression analysis (LRA), backwards likelihood ratio method. For LRA, Hosmer and Lemeshow goodness-of-fit tests (HL); Nagelkerke pseudo r^2 ; odds ratios (OR) and their 95% confidence intervals (CI); and AUC ROC were calculated. Also, LRA accuracies were calculated, at a cutpoint of $p = 0.5$. Data are presented as means $\pm$ SD or frequencies.

RESULTS

Univariate results are listed in Table 2. By LRA, probability of an outcome is given by $p = e^k / (1 + e^k)$. For MORT,

Table 1 Revised Trauma Score (RTS)

Glasgow Coma Scale (GCS)	Systolic Blood Pressure (SBP)	Respiratory Rate (RR)	Coded Value (GCS _{code} , SBP _{code} , or RR _{code})
13–15	>89	10–29	4
9–12	76–89	>29	3
6–8	50–75	6–9	2
4–5	1–49	1–5	1
3	0	0	0

$$\text{RTS} = 0.9368 \cdot \text{GCS}_{\text{code}} + 0.7326 \cdot \text{SBP}_{\text{code}} + 0.2908 \cdot \text{RR}_{\text{code}}$$

Adapted from Champion HR, et al. A revision of the Trauma Score. *J Trauma*. 1989;29:623–629.

Survival Probability by Revised Trauma Score

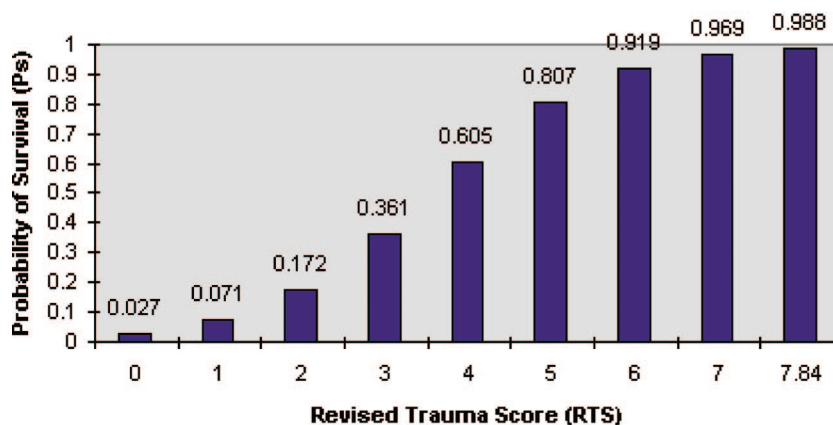


Fig. 1. Data from Champion HR, et al. A revision of the Trauma Score. *J Trauma*. 1989;29:623–629. Available at <http://www.trauma.org/archive/scores/rts.html>. Accessed July 2007.

Table 2 Univariate Results

Variable	Live	Die	No MASS	MASS
SBP	116 ± 28	109 ± 31*	119 ± 27	110 ± 29**
DBP	64 ± 18	60 ± 23	65 ± 18	60 ± 19**
PP	53 ± 21	50 ± 22	53 ± 20	50 ± 21
HR	104 ± 26	107 ± 32	101 ± 25	111 ± 28***
SI	1.0 ± 0.5	1.1 ± 0.5	0.9 ± 0.5	1.1 ± 0.4**
RR	21 ± 7	20 ± 7	20 ± 7	21 ± 8
GCS _{total}	11 ± 5	7 ± 5***	11 ± 5	10 ± 6*
FTS ₀₇	1.4 ± 0.7	0.9 ± 0.7***	1.4 ± 0.7	1.2 ± 0.7***
RTS	6.4 ± 1.7	4.9 ± 1.8***	6.4 ± 1.8	6.0 ± 1.8**
Artif vent	107/142 (75%)	35/142 (25%)***	78/142 (55%)	64/142 (45%)
RBC	9.6 ± 10.1	13.6 ± 15.3*	3.9 ± 2.4	19.5 ± 12.3***
WB	1.3 ± 4.6	1.7 ± 4.3	0.1 ± 0.4	3.4 ± 6.8***
Sum	11.1 ± 13.0	15.5 ± 17.6*	4.0 ± 2.4	22.9 ± 15.8***
MASS	179/212 (85%)	33/212 (15%)	—	—

MASS indicates massive transfusion; Artif vent, artificially ventilated and/or intubated; Sum, RBC+WB.

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$ (Live vs. Die, or Massive Tx vs. No Massive Tx).

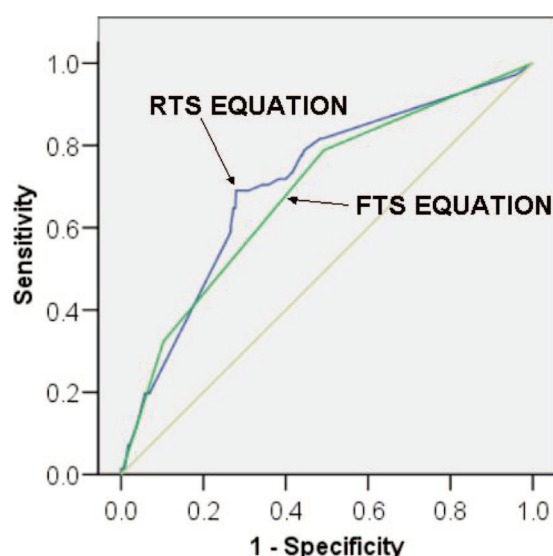


Fig. 2. Comparison of ROC curves for prediction of mortality based on RTS and FTS₀₇.

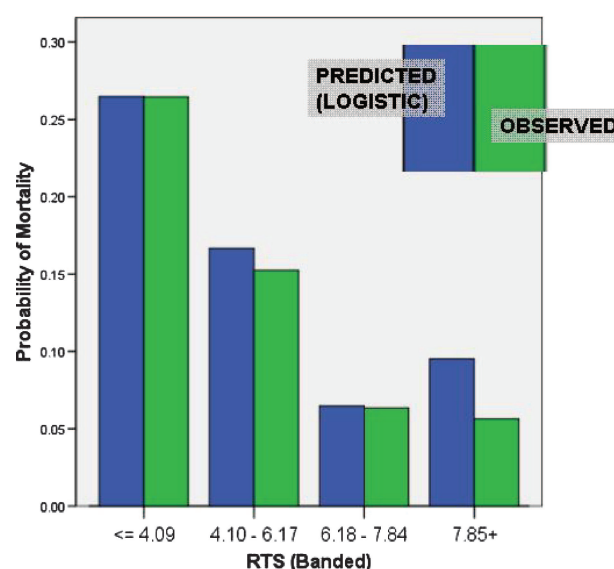


Fig. 3. Prediction of mortality. Comparison of observed versus predicted mortality for RTS-based equation.

$k = 0.616 - 0.438 \times \text{RTS}$. OR (RTS) = 0.645 (CI, 0.560, 0.744); HL $p = 0.4$; $r^2 = 0.133$; accuracy = 86.9%; AUC = 0.708 (CI, 0.643, 0.774).

When used instead of RTS for MORT prediction, the FTS₀₇ provided the following: $k = -0.716 - 1.009 \times \text{FTS}_{07}$. OR (FTS₀₇) = 0.365 (CI, 0.255, 0.521); HL $p = 0.9$; $r^2 = 0.107$; accuracy = 86.8%; AUC = 0.687 (CI, 0.620, 0.754).

The ROCs for the two equations for prediction of MORT are given in Figure 2. In addition, we grouped RTS and FTS₀₇ into “bands” or categories to evaluate the performance of the LRA predictive equations across a range of values for the independent variables. A comparison of observed versus predicted MORT is given in Figures 3 and 4. Of note, the FTS₀₇-based equation is overly sensitive when FTS₀₇ is low (tends to overpredict mortality in comparison with actual mortality when patients are sick), likely a desirable characteristic.

For MASS, $k = 0.638 - 0.115 \times \text{RTS} - 0.011 \times \text{DAP} + 0.358 \times \text{SI}$. OR(RTS) = 0.891 (0.808, 0.983); OR (DAP) = 0.989 (0.978, 0.999); OR (SI) = 1.431 (0.962, 2.128). HL $p = 0.3$; $r^2 = 0.052$; accuracy = 61.7%; AUC = 0.638 (0.590, 0.686).

Again, when FTS₀₇ was submitted to LRA for prediction of MASS with RTS withheld, $k = -0.740 - 0.376 \times \text{FTS}_{07} - 0.011 \times \text{DAP}$. OR (FTS₀₇) = 0.687 (0.524, 0.900); OR (DAP) = 0.989 (0.979, 1.000); HL $p = 0.1$; $r^2 = 0.046$; accuracy = 61.1%; AUC = 0.618 (0.569, 0.666).

The ROCs for the two equations for prediction of MASS are given in Figure 5. Comparison of observed versus predicted rates of MASS for various bands of RTS (using the RTS-based equation) and for FTS₀₇ (using the FTS₀₇-based equation), while holding the other independent variables constant, are given in Figures 6 and 7.

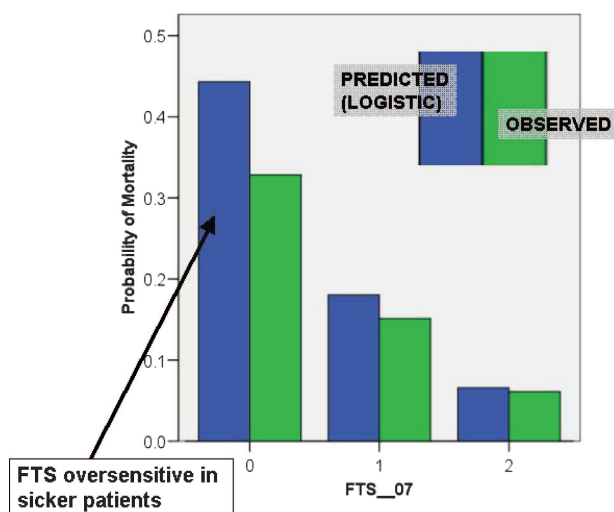


Fig. 4. Prediction of mortality. Comparison of observed versus predicted mortality for FTS₀₇-based equation.

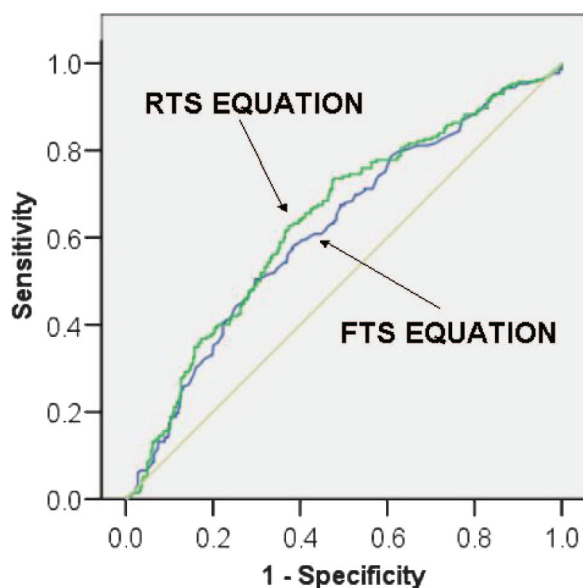


Fig. 5. Comparison of ROC curves for prediction of massive transfusion based on RTS and FTS₀₇.

DISCUSSION

The principal finding in this study of 536 combat casualties admitted to Level III US military hospitals in Iraq is that a newly derived Field Triage Score (FTS₀₇) performed almost as well as the RTS in predicting outcome (mortality) and the need for MASS. The FTS₀₇, or the FTS described by Eastridge et al., offer the advantage of being readily calculated by medics in the field. This contrasts with the RTS, which would require a PDA or similar computer for calculation.

Another important observation is the fact that standard vital signs (SBP, DBP, HR) and calculated vital signs (PP, SI) all trended in the expected direction in distinguishing mortally injured patients, but the differences were slight and in many cases statistically insignificant. This indicates the im-

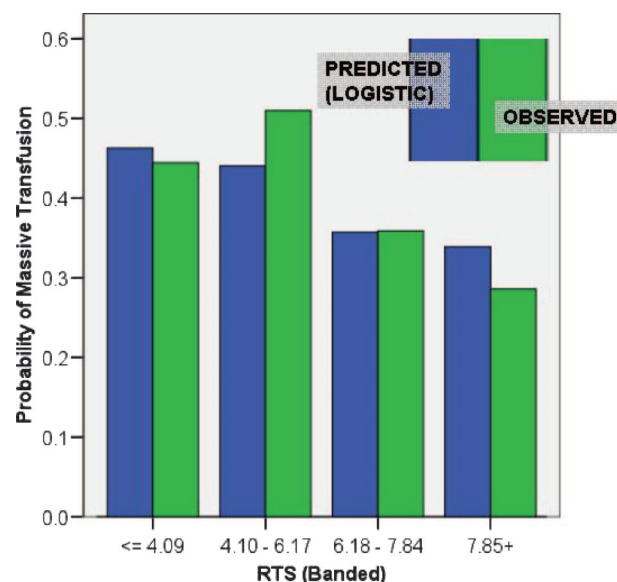


Fig. 6. Prediction of massive transfusion; RTS-based equation. Comparison of observed versus predicted rates of massive transfusion across various bands of RTS, holding the other independent variables constant.

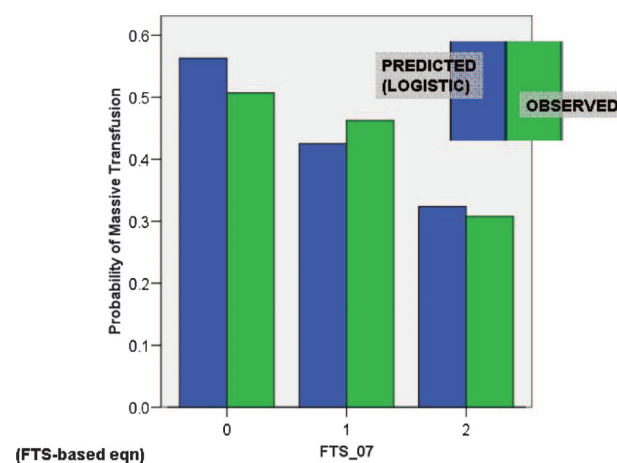


Fig. 7. Prediction of massive transfusion; FTS₀₇-based equation. Comparison of observed versus predicted rates of massive transfusion across various bands of FTS₀₇, holding the other independent variables constant.

portance of continuing to develop “new vital signs,” and new methods of analyzing physiologic data (such as heart-rate variability), to improve our ability to diagnose life-threatening injury.

The predictive accuracy of the equations given here was relatively low, with ROC areas under the curve of about 0.7 for prediction of mortality, and about 0.6 for prediction of MASS. Thus, caution should be used in interpreting these data. Further studies will be needed to place these findings in context, and to refine the predictive equations.

Why was it possible to predict mortality more accurately than MASS? Perhaps the need for transfusion is affected to a

greater extent by anatomic variables; for example, the patient who presents with relative hemodynamic stability but severe intraabdominal injury would be one in whom the prediction of MASS based on hemodynamic data alone would fail.

Both the RTS and the FTS₀₇ are heavily weighted toward the GCS_{total}. Thus, inclusion of these variables in equations predictive of mortality indicates the impact that altered mental status has on outcome in combat casualties. However, it should be borne in mind that endotracheal intubation, head injury, and severe hemorrhagic shock all contribute to a decreased mental status in patients with a low GCS_{total}. Thus, GCS_{total} can be viewed as a surrogate for all of these conditions, rather than solely as a measure of the severity of head injury.

Significant limitations of the data set on which this study was based should be recognized. Patients arriving at Level III hospitals in Iraq may have had interventions such as endotracheal intubation performed by medics or other providers before arrival. To develop predictors of outcome most suitable for use for field medics, data sets should be used which are based on patients arriving directly from the site of injury. Given the importance of GCS_{total} in this data set, it is important that GCS_{total} was essentially a dichotomous variable: most patients had values of either 3 or 15, and few patients had intermediate values. This suggests that accurate determination of the GCS_{total} in the CSH setting may be difficult, and that all we should expect is that the patient's neurologic status be coded as "grossly normal" or "grossly abnormal". In fact, this is the approach followed in the original FTS developed by Eastridge et al.; normal motor function (follows commands) scores a 1, and inability to follow commands scores a 0. We recommend, therefore, that Eastridge's approach be followed in future combat casualty data collection efforts.

Eastridge's work, based on over 800,000 US civilian trauma patients, taken together with the preliminary findings presented here, indicate that the FTS deserves further study in combat casualties. Only a rigorous data collection effort on the battlefield will enable the development and validation of new predictive models suitable for use both by combat medics, and those charged with performance improvement. Such an effort is currently being conducted.

CONCLUSIONS

For mortality prediction, variables such as GCS_{total}, RTS, FTS₀₇, and artificial ventilation were the strongest in this data set. RTS emerged as the best independent predictor of mortality, with FTS₀₇ a close surrogate. These findings indicate the effect of impaired mental status on mortality (presumably caused by head injury, the need for artificial ventilation, and the sequelae of shock and resuscitation) in this data set. For prediction of MASS, RTS as well as hemodynamic data derived from the HR, SBP, and DBP were required. However, the equations predictive of mortality were more accurate than those predictive of the need for MASS. Readily available data can be used to predict outcome in combat

casualties, but more data are needed to refine these findings and to improve predictive accuracy.

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DISCUSSION

CDR James R. Dunne (National Naval Medical Center, Bethesda, MD): Before I begin, I thank the committee for the privilege of the floor and thank the authors for providing a copy of the manuscript well in advance of the meeting. In addition, I congratulate the authors on their continued attempt to assist combat medics in making what can sometimes be very difficult triage decisions. In this study, Dr. Cancio and colleagues retrospectively reviewed 536 patients to compare the predictive accuracy of the RTS and a new version of the Field Triage Score (FTS₀₇) in determining mortality and the need for massive transfusion. The authors concluded that the new version of the field triage score performed almost as well as the RTS in predicting mortality and the need for massive transfusion with the added advantage of being easier to calculate. However, the authors admit that the predictive accuracy of either score was extremely low.

Multiple studies have documented numerous scoring systems to assist in prediction of outcome and resource utilization in trauma. Whether the scores are physiologically based or injury based, each has its own set of advantages and disadvantages. This study and others propose yet another scoring system, the field triage score. The main advantage of this new scoring system seems to be its ease of use compared with other scoring systems, whereas the main disadvantage seems to be its oversensitivity in determining mortality in the sickest patients. Based on these observations, I have several questions for the authors.

1. Given the fact that most if not all the current scoring systems in trauma are used for research purposes, how do you propose the combat medic use the field triage score in relation to triaging patients especially given its low predictive accuracy?
2. Do you have any data on how many patients, received treatment either in the field or at a Level II facility before arrival at the Level III and what did that treatment entail?

3. The Joint Trauma Theater System guidelines for damage control resuscitation at Level II and Level III facilities state that rFVIIa, and plasma:packed red blood cells (1:1 ratio) are recommended for use in several situations including decreased mental status from shock, hypotension (defined as a SBP $\leq$ 90 mm Hg) from blood loss or a weak or absent radial pulse. What impact do you think this clinical practice guideline had on the decision for massive transfusion and do you think it is possible that it was the presence of this guideline and not the actual presence of decreased mental status or hypotension per se that resulted in the decision for massive transfusion?
4. Finally, Eastridge et al. similarly compared RTS with the field triage score and found the predictive accuracy to be better in their study (AUCs of 0.8) compared with this most recent study. Can you comment on why you think the field triage score performed better in that study compared with this current study?

Dr. Leopoldo C. Cancio (US Army Institute of Surgical Research, Fort Sam Houston, TX): Thank you for your comments. Previously, Holcomb and colleagues found in a retrospective study of prehospital trauma patients from Houston, TX that manual vital signs, i.e., the motor component of the GCS score (GCS_{motor}) and a weak or absent radial pulse, could be used to predict the need for a life-saving intervention (LSI). These findings were incorporated into the *Prehospital Trauma Life Support* manual, and other training. McManus et al., also using the Houston prehospital patients, reported a mean systolic arterial pressure (SAP) of 100 mm Hg for patients with a weak radial pulse, versus 129 mm Hg for

those with a normal radial pulse. This suggested the equivalency of a SAP of 100 mm Hg to a weak or absent radial pulse, and motivated the subsequent analysis by Eastridge et al. of data from the National Trauma Data Bank (NTDB) which generated the FTS. Taken together, these studies suggest that medics in the field should use the FTS to identify patients at high risk of death (Eastridge's endpoint) or in need of an LSI (Holcomb's endpoint). Because of the low accuracy, patients with a high FTS cannot be, on that basis alone, triaged to a delayed category. Rather, patients with a low FTS should be prioritized to an immediate category.

We do not have information on care at Level II facilities before arrival at the Level III facility. This is currently being put together by the Joint Theater Trauma Registry (JTTR). Such treatment clearly may have had a major impact on the results of this study.

The Factor VII guidelines, and other guidelines introduced into US military medical care during this war, may also have had an impact on the results of this study. Two hundred ninety patients in this database received this drug. However, these patients were not identified as such in the data.

The FTS performed better than the RTS in Eastridge's article, but not by much; AUC for FTS was 0.805, and for RTS it was 0.798. Although the reasons for the difference are unclear, it should be recalled that FTS is more heavily weighted toward hypotension than is the RTS; and that the RTS was developed using patient data from the mid-1980s, whereas most of the NTDB data are from 2000-present. Thus, changes in patient care may have influenced the survival of patients with head injury (low GCS) and highlighted the relative importance of hypotension.