Identifying Risk for Massive Transfusion in the Relatively Normotensive Patient: Utility of the Prehospital Shock Index

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Background: In the prehospital environment, the failure of medical providers to recognize latent physiologic derangement in patients with compensated shock may risk undertriage. We hypothesized that the shock index (SI; heart rate divided by systolic blood pressure [SBP]), when used in the prehospital setting, could facilitate the identification of such patients. The objective of this study was to assess the association between the prehospital SI and the risk of massive transfusion (MT) in relatively normotensive blunt trauma patients.

Methods: Admissions to a Level I trauma center between January 2000 and October 2008 with blunt mechanism of injury and prehospital SBP >90 mm Hg were identified. Patients were categorized by SI, calculated for each patient from prehospital vital signs. Risk ratios (RRs) and 95% confidence intervals (CI) for requiring MT (>10 red blood cell units within 24 hours of admission) were calculated using SI >0.5 to 0.7 (normal range) as the referent for all comparisons.

Results: A total of 8,111 patients were identified, of whom 276 (3.4%) received MT. Compared with patients with normal SI, there was no significant increased risk for MT for patients with a SI of ≤0.5 (RR, 1.41; 95% CI, 0.90–2.21) or >0.7 to 0.9 (RR, 1.06; 95% CI, 0.77–1.45). However, a significantly increased risk for MT was observed for patients with SI >0.9. Specifically, patients with SI >0.9 to 1.1 were observed to have a 1.5-fold increased risk for MT (RR, 1.61; 95% CI, 1.13–2.31). Further increases in SI were associated with incrementally higher risks for MT, with an more than fivefold increase in patients with SI >1.1 to 1.3 (RR, 5.57; 95% CI, 3.74–8.30) and an eightfold risk in patients with SI >1.3 (RR, 8.13; 95% CI, 4.60–14.36).

Conclusion: Prehospital SI > 0.9 identifies patients at risk for MT who would otherwise be considered relatively normotensive under current prehospital triage protocols. The risk for MT rises substantially with elevation of SI above this level. Further evaluation of SI in the context of trauma system triage protocols is warranted to analyze whether it triage precision might be augmented among blunt trauma patients with SBP >90 mm Hg.

Key Words: Trauma, Vital signs, Shock index, Heart rate, Blood pressure, Massive transfusion, Prehospital.

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In the prehospital setting, the prompt recognition of patients at risk for hemorrhagic shock is essential for optimizing patient outcomes. A patient requiring massive transfusion (MT) requires resources that typically only regional trauma centers can provide, and transport to a hospital with lesser capabilities is not in the best interest of such a patient. Hypotension, the most conspicuous indicator of shock, has somewhat arbitrarily been defined as systolic blood pressure (SBP) ≤90 mm Hg in conventional prehospital triage protocols. It is well appreciated, however, that in the face of hemorrhage, a compensatory phase ensues to maintain a relatively normal blood pressure, such that SBP >90 mm Hg can be sustained for some time despite significant blood loss. Recognition of this compensatory phase of shock by prehospital personnel may enhance the early recognition of significant blood loss. This is of particular importance in patients injured by blunt mechanism. In such patients, the presence of significant internal injuries is not apparent by physical examination (in contrast, the presence of a penetrating wound heralds the risk for significant hemorrhage and is often a criteria for transport to a regional trauma center in and of itself).

Shock index (SI) is defined as the ratio of heart rate (HR) to SBP and normally ranges from 0.5 to 0.7 in healthy adults. Compared with HR or SBP alone, SI has been suggested to be a better measure of hemodynamic stability in the emergency department (ED) setting.[1–5] We speculated that calculation of SI may be useful for prehospital personnel toward the identification of blunt trauma patients in the compensatory phase of shock. The objective of this study was to assess the association between SI, as calculated in the prehospital setting, and the risk of MT in bluntly injured patients that would be considered relatively normotensive (i.e., SBP ≥90 mm Hg) by standard triage protocols.

METHODS

Data Source and Study Population

The study population consisted of trauma patients admitted to the University of Alabama at Birmingham (UAB) University Hospital between January 1, 2000, and October 12, 2008. UAB University Hospital is the only Level I trauma center within a 7-county 1.5 million population geographic region with ~3,500 annual admissions. Patients were excluded from the study cohort if they were transferred from another facility, were injured by penetrating mechanism, had

prehospital SBP ≤90 mm Hg, or had no record of prehospital vital signs in the UAB trauma registry. Study approval was obtained from the UAB Institutional Review Board.

Variable Definitions

For each patient, the UAB trauma registry was used to collect information regarding demographics (i.e., age and gender), injury characteristics (i.e., Injury Severity Score [ISS] and mortality), and both prehospital (i.e., HR and SBP) and postadmission (i.e., packed red blood cell [PRBC] units transfused within 24 hours of hospital arrival, length of hospital stay, and in-hospital mortality) clinical characteristics. MT was defined as the transfusion of 10 or more PRBC units within 24 hours of hospital arrival. SI was calculated as the ratio of prehospital HR to prehospital SBP. If multiple sets of prehospital vital signs were recorded in the trauma registry, the initial set of prehospital vital signs was used in this analysis. In addition, SI was calculated based on ED vital signs. For purposes of this analysis, SI was categorized as ≤0.5, >0.5 to 0.7, >0.7 to 0.9, >0.9 to 1.1, >1.1 to 1.3, and >1.3.

Analysis

Demographic, injury, and clinical characteristics were compared among SI categories using χ^2 and analysis of variance tests for categorical and continuous variables, respectively. Proportional hazards regression assuming an equal time at risk for each patient was used to estimate risk ratios (RRs) and 95% confidence intervals (95% CIs) for the association between SI and MT. The category comprised of normal values of SI (i.e., >0.5–0.7) was used as the referent category for the analysis.

RESULTS

In total, 20,095 patients with blunt injuries were admitted to the trauma service at UAB University Hospital between January 1, 2000, and October 12, 2008. Three thousand three hundred eighty-two patients were transfers, 774 had prehospital SBP ≤90, and 7,828 had no record of prehospital vital signs, leaving 8,111 patients for analysis.

Two hundred seventy-six (3.4%) patients required MT. Total transfusions of PRBC units during the hospital course ranged from 0 to 103 per patient, with a mean transfusion requirement of 1.1 units. The mean age was 38.4 years and 66.8% were men. The mean ISS was 12.7. Overall mortality was 2.3% among the cohort.

When comparing the prehospital SI, a majority of the patients had SI between >0.5 and 0.7 (38.0%) or >0.7 and 0.9 (35.0%), followed by patients having SI of >0.9 and 1.1 (14.5%), ≤0.5 (8.7%), >1.1 to 1.3 (3.1%) and >1.3 (0.8%). Both male gender and age were inversely associated with SI, with the lowest SI categories having the oldest mean age and highest percentage of men ($p < 0.0001$; Table 1). The groups with the highest SI (>1.1 to 1.3 and >1.3) also had the highest mean ISS (18.5 and 20.3, respectively), mean PRBC units transfused (3.6 and 5.3, respectively), mean hospital length of stay (9.4 days and 10.8 days, respectively), and highest mortality (6.5% and 10.3%, respectively; $p < 0.0001$ for all comparisons). Although mean Glasgow Coma Scale (GCS) was statistically different across SI groups, the significance appears to be the result of a relatively lower mean GCS in the highest SI groups, >1.1 to 1.3 and >1.3 (13.1 and 12.4, respectively), versus a mean GCS of ~14 in the remaining groups. Similarly, the distribution of injury mecha-

TABLE 1. Comparison of Demographic, Prehospital, Injury, and Clinical Characteristics by Prehospital SI

	SI*						
	≤0.5	**>0.5 – 0.7**	**>0.7 – 0.9**	**>0.9 – 1.1**	**>1.1 – 1.3**	**>1.3**	***p*†**
N	702	3,080	2,838	1,175	248	68	
Mean age	48.3	41.3	35.5	33.7	33.0	32.8	<0.0001
Male (%)	71.8	72.4	64.6	58.0	52.0	63.2	<0.0001
Prehospital							
Mean HR	70.5	86.7	100.5	113.8	127.3	147.3	<0.0001
Mean SBP	162.7	141.7	127.6	116.1	107.4	102.6	<0.0001
Mean ISS	13.3	11.9	12.4	13.7	18.5	20.3	<0.0001
Mean GCS	13.9	14.4	14.3	14.0	13.1	12.4	<0.0001
Mechanism (%)							<0.0001
MVC	60.1	63.9	68.7	73.7	78.6	67.6	
MCC	7.7	8.0	9.0	5.6	8.5	13.2	
Pedestrian vs. auto	3.7	3.9	3.4	4.0	3.2	5.9	
Fall	15.7	12.6	7.8	7.2	4.4	2.9	
Other	12.8	11.6	11.0	9.5	5.2	10.3	
Mean PRBC units	1.1	0.8	1.0	1.3	3.6	5.3	<0.0001
Mean LOS (days)	7.3	5.7	5.9	6.4	9.4	10.8	<0.0001
Mortality (%)	4.0	1.9	1.9	2.0	6.5	10.3	<0.0001

MVC, motor vehicle collision; MCC, motorcycle collision; LOS, length of hospital stay.
* Defined as HR/SBP as recorded in prehospital records.
† Based on χ^2 and analysis of variance for categorical and continuous variables, respectively.

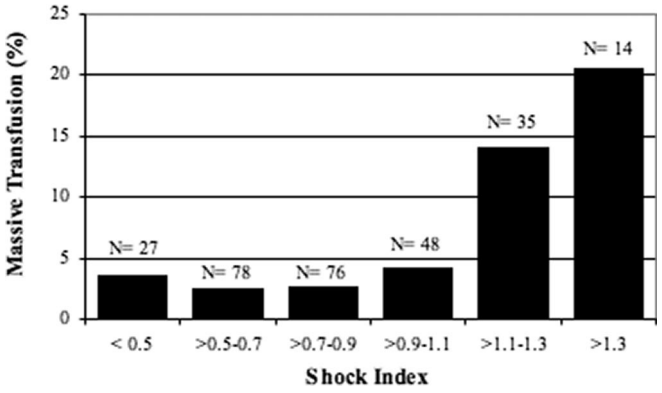

Figure 1. Incidence of MT as categorized by SI.

TABLE 2. RR and 95% CI for the Association Between Prehospital SI and MT

SI*	RR (95% CI)
≤0.5	1.41 (0.90–2.21)
>0.5–0.7	Ref
>0.7–0.9	1.06 (0.77–1.45)
>0.9–1.1	1.61 (1.13–2.31)
>1.1–1.3	5.57 (3.74–8.30)
>1.3	8.13 (4.60–14.36)

* Defined as HR/SBP as recorded in prehospital records.

nism was statistically different across SI groups, and this appears to be related to a progressively lower proportion of fall injuries as SI increases, as well as a relatively larger proportion of motorcycle injuries in the highest SI category.

In the normal prehospital SI group (>0.5–0.7), the incidence of MT was 2.5% and was similar in the SI >0.7–0.9 group (2.7%) and only slightly higher in the SI <0.5 group (3.6%; Fig. 1). As SI increased above >0.9, increased incidence of MT was observed; at the highest SI (>1.3), >20% required MT. Compared with patients with normal prehospital SI, there was no statistical difference concerning MT in patients with SI of ≤0.5 (RR, 1.41; 95% CI, 0.90–2.21) or >0.7 to 0.9 (RR, 1.06; 95% CI, 0.77–1.45; Table 2). However, a significantly increased risk for MT was observed for patients with SI above 0.9. Patients in the SI >0.9 to 1.1 group had a ~1.5-fold increased risk for MT and further increases in SI were associated with incrementally higher risks for MT, with up to an eightfold risk in the SI >1.3 group.

When comparing ED SI for the same group of patients, a similar but more exaggerated trend was observed. Compared with patients with normal ED SI (>0.5–0.7), there was no statistically significant difference concerning MT in patients with SI <0.5 (RR, 1.54; 95% CI, 1.00–2.36). However, a significantly increased risk for MT was observed for all patients with ED SI >0.7 (Table 3). Although patients with ED SI >0.7 to 0.9 had a twofold increased risk for MT, those with ED SI 0.1.3 had a near 20-fold risk.

TABLE 3. RR and 95% CI for the Association Between Emergency Department SI and MT Among Patients With Prehospital Vital Signs Recorded in the Trauma Registry

SI*	RR (95% CI)
≤0.5	1.54 (1.00–2.36)
>0.5–0.7	Ref
>0.7–0.9	1.87 (1.34–2.60)
>0.9–1.1	3.49 (2.34–5.20)
>1.1–1.3	9.67 (6.09–15.36)
>1.3	18.66 (12.49–27.88)

* Defined as HR/SBP as recorded in ED records.

DISCUSSION

The resources necessary to manage patients who require MT are extensive. These include an estimated $10,000 in blood component charges accrued per patient, limitations in blood supply availability, coordination and communication between nursing unit, laboratory services, and blood bank, and the need for specialized services such as interventional radiology and the operating room.[6] Caring for such patients may place undue stress on already resource-constrained hospitals, thus underscoring the importance of facility preparedness and the importance of early recognition of patients at high risk of MT.

Prompt recognition of injury-induced hemorrhage in the prehospital setting is paramount to improved patient outcomes. Assessment of conventional vital signs in this context is a fundamental clinical skill. Although the limitations and pitfalls of using HR or SBP as indicators of shock have been well described,[7–11] the seasoned paramedic, nurse, or physician does not evaluate HR and SBP as separate entities and is attuned to the identification of the shock state in its more subtle forms. Such "gestalt," however, is not inherent in relatively less experienced health care providers nor does it translate well into research or practice protocols.

The appeal of SI is that it quantifies the relationship between HR and SBP to allow for a more objective evaluation of hemodynamic status. A given set of vital signs may on initial interpretation appear unalarming, but calculation of SI adds additional perspective that could influence clinical decisions. For example, from this study, a patient with prehospital HR = 100 bpm and prehospital SBP = 110 mm Hg (and therefore SI of 0.91) has more than 1.5 times the risk of MT compared with normal SI. Furthermore, with prehospital HR = 120 bpm and prehospital SBP = 105 mm Hg (SI, 1.14), the risk of MT is elevated fivefold. SI is easily calculable in the field or at the bedside and is well suited for incorporation into clinical or investigational protocols.

The potential utility of SI has been demonstrated in various clinical scenarios including trauma care. Rady et al.[1] evaluated a SI cut-point of 0.9 in a cohort of 275 adult patients presenting to an ED with stable vital signs. The authors found that SI > 0.9 was associated with an illness that was treated immediately, admission to the hospital, and intensive therapy on admission. Others have described the use of SI to facilitate identification of ruptured ectopic preg-

nancies.[4,12] King et al.[13] compared the predictive ability of SI with both HR and SBP in a cohort of 1,101 patients presenting to a Level I trauma center, and observed that SI, HR, and SBP thresholds, as determined by receiver operating characteristic curves, similarly predicted injury severity and mortality. Recently, however, Zarzaur et al.[5] compared SI against HR and SBP using a cohort of 16,077 patients presenting to a Level I trauma center and found SI to be a significantly better predictor of both 48-hour mortality and transfusion of 4 or more PRBC units within 48 hours.

Other methods to identify those requiring MT are primarily based on experiences in combat trauma, as well as cardiothoracic and liver transplantation operations, and use complex calculations or advanced technology that preclude their utility in the hectic prehospital environment.[14–21] For example, the Assessment of Blood Consumption scoring system uses nonlaboratory, nonweighted measures; but predicts the likelihood for MT on focused assessment sonography for trauma (FAST), along with mechanism of injury, arrival SBP $\leq$ 90 mm Hg, and HR $\geq$ 120 bpm.[19] Although the latter three components are available to emergency medical service providers during transport, FAST requires specialized equipment and training for appropriate interpretation, making it impractical for the prehospital setting. The Trauma-Associated Severe Hemorrhage scoring system uses seven independent weighted variables (SBP, HR, sex, hemoglobin, FAST, base excess, and extremity or pelvic fracture) to calculate 16 individual scores that are used to obtain the final score that ranges from 0 to 28.[21] Similarly, the McLaughlin Scoring system uses four dichotomous variables (HR $>$ 105 bpm, SBP $<$110 mm Hg, pH $<$7.25, and hematocrit $<$32%) to calculate overall risk for MT.[17] The use of laboratory tests, in addition to cumbersome calculations, makes the Trauma-Associated Severe Hemorrhage and McLaughlin scoring systems similarly unsuitable.[17,21]

In addition to the aforementioned predictive formulas, other physiologic and metabolic markers are under investigation to serve as adjuncts in the identification of shock. Sagraves et al.[22] evaluated the Inspectra oxygen saturation monitor, a tissue hemoglobin oxygen saturation (STO_2) monitor (Hutchinson Technology, Hutchinson, MN), as an adjunct in the prehospital environment. From the 55 patients enrolled, they concluded STO_2 monitoring is feasible in the prehospital setting and only minimal structural changes to the monitoring device were needed to allow for configuration into the transport vehicle. In their small study, they observed that nonsurvivors had significantly lower STO_2 recordings than survivors and estimated that a 10% decrease in STO_2 recording corresponded to a threefold increase in in-hospital mortality.[22] HR variability, another noninvasive tool, has been investigated by Cooke et al.[23] In their study, electrocardiogram tracings from the on-board monitors obtained during transport were analyzed using commercially available software. Differences in R-R intervals were noted in the patients who died from hemorrhagic shock when compared with those who survived. Although this study was not designed to analyze whether HR variability was superior to conventional vital signs in the identification of shock, HR variability was found to be a useful adjunct.[23] In addition to noninvasive monitoring, point-of-care measurement of lactic acid and base deficit, both markers of anaerobic metabolism, are also under investigation to serve as adjuncts in identifying hypoperfusion and occult shock in the prehospital setting.[24–27]

In this study, we sought not to compare SI to conventional vital signs; instead, our objective was to evaluate whether SI could augment the interpretation of prehospital clinical data, particularly in the absence of unambiguous hypotension, the presence of which would generally make SI evaluation noncontributory. Although the results show potential utility for incorporation into prehospital protocols, limitations of the study design must be considered. Almost 50% of patients did not have prehospital vitals recorded in the registry and were therefore excluded from analysis. Given our understanding of how the prehospital data are entered into our trauma registry, it is our perception that there was no systematic reason for one patient having recorded vitals and the other not. We have observed that whether or not prehospital personnel leave a copy of the "run sheet," or our ED personnel appropriately input this data in the ED chart is seemingly haphazard. We compared the admission characteristics for those patients with prehospital vital signs recorded to those patients without prehospital vital signs recorded and found these groups to be clinically similar. Nonetheless, we acknowledge that our results are subject to exclusion bias and may have differed were we able to include all patients.

In addition, the study was designed to specifically evaluate the association between prehospital SI and MT in a cohort of patients admitted to a Level I trauma center. Although our results suggest the applicability of SI to triage, further evaluation of prehospital SI will be necessary to analyze whether SI has true utility for field triage. Specifically, we did not evaluate how other triage criteria such as GCS, anatomic location of injury, and mechanism of injury might interact with SI, and it is possible that calculation of the SI may add little to identifying patients at high risk for MT. In addition, although MT can be considered a surrogate for significant traumatic injury, it is by no means an inclusive measure that will identify all patients who have suffered significant traumatic injury requiring the resources of a regional trauma center, and it would be useful to examine alternative outcomes such as need for immediate operative or arteriographic intervention after arrival to hospital. Most importantly, we did not evaluate prehospital SI in a broader cohort that included patients triaged to centers other than the regional trauma center, which would be necessary before making any conclusions about the efficacy of prehospital SI concerning field triage.

In conclusion, SI as calculated in the prehospital setting may facilitate the early identification of a relatively high risk for MT in bluntly injured patients being routed to a regional trauma center. In particular, SI may be most useful for the identification of patients in the compensatory phase of shock, with a corresponding normal to low-normal blood pressure. Further prospective evaluation of the utility of SI in the prehospital setting is warranted before incorporating the SI into clinical or investigational protocols.

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DISCUSSION

Dr. Christopher Dente (Atlanta, Georgia): I would like to thank the Association for the privilege of the podium and I congratulate the authors on a fine presentation and on delivering the manuscript in a timely manner. This is a relatively straightforward retrospective study using trauma registry data and looking at the potential utility of the "shock index" as a prehospital triage tool to identify patients requiring massive transfusion.

Because the shock index has been validated as a useful tool to predict a variety of things, including both the need for transfusion and mortality after trauma, it would seem to be an ideal field triage tool.

In this study, the authors identified that an abnormal shock index increased a blunt trauma patient's risk for requiring greater than ten units in twenty-four hours in a somewhat linear fashion, such that those patients with the highest shock indices, greater than 1.3, had an eightfold higher risk of massive transfusion.

While this hints that the shock index may be a potential useful early marker, I do have some questions for the authors and topics upon which they can hopefully expand.

One, information regarding your transfusion practices is missing from your methods section. What are your indications for transfusion and who makes these decisions? Do you use a massive transfusion protocol? What component ratios does it use? Given the wealth of recent data on aggressive component therapy, I expect your practice patterns have changed over the nearly nine years of the study. Do you think this clouds your conclusions?

Two, much of the literature using the shock index uses a single cut point of 0.9 as a triage decision maker, with greater than 0.9 being considered abnormal. Why did you decide to create so many subgroups and what was the rationale for the groups you did create?

Three, I think more information is needed on the actual timing of transfusion and many authors feel a more appropriate definition for massive transfusion is greater than ten units in six hours, to capture the patients that are truly exsanguinating on arrival. Would changing your definition of massive transfusion have changed the results? A non-trauma center may be able to stabilize a patient who needs ten units over twenty-four hours, but is less likely able to handle a patient requiring massive transfusion in the first several hours after injury. Please comment.

Four, do you have any information regarding the patient's initial coagulation status? As you're likely aware, much of the recent interest in aggressive component therapy is based on several retrospective studies which show a subset of trauma patients arrived at trauma centers already coagulopathic. The risk factors for the s-called "ETIC" are, as yet, ill-defined and I wonder if there's any correlation between the shock index and the presence of ETIC.

Five, why did you decide to use only blunt trauma patients? It makes your data somewhat cleaner, but the rationale was not clear to me in the manuscript.

Six, and finally, the use of registry data is never perfect and I wonder if you are tracking this information prospectively. The shock index may actually be a potentially useful marker and I would like to see if your findings are validated prospectively. Again, I congratulate the authors for their hard work and for adding to this growing body of literature and I would like to thank the Association again for the privilege of the floor.

Dr. Marianne Vandromme (Birmingham, Alabama): I would like to thank Dr. Dente for his kind remarks and provocative questions. To start, there is a massive transfusion protocol at UAB that is blood-bank oriented and when initiated blood components are prepared, usually six red blood cells, six FFP, and two units of platelets. These products are made available in the blood bank and released when transfusion orders are entered by the treating physician.

Although many trauma centers may have changed their blood transfusion practices over the last several years with adoption of massive transfusion protocols focusing on achieving the so-called "hemostatic" ratios, our practice at UAB has not specifically changed during the study period, as we have not adopted a target component therapy ratio or goal. In addition, our group has been hesitant to adopt these target ratios because most of the current available data is relatively weak, limited by retrospective design and inaccuracy in accounting for survival bias.

Even though all prior emergency department based studies identified a shock index of 0.9 as a cut point for increased morbidity and mortality, we did not want to assume that the same cut point would translate to the prehospital setting. With over 8,000 patients identified with complete prehospital vital signs, we were not concerned with having too few numbers in any one category, so we created several categories both above and below the known cut point determined by previous studies. Ultimately once the data was analyzed, we identified, similar to previously reported studies, that a prehospital shock index of greater than 0.9 was associated with increased risk of massive transfusion.

Although massive transfusion is commonly defined as requiring greater than ten units in twenty-four hours, those patients that require ten units in six hours have without a doubt suffered exsanguinating injuries. Unfortunately given how the blood transfusion data is recorded in the trauma registry it would be very difficult to identify those who received ten units within 6 hours of admission. Further from our experience and probably not too unlike many of yours, an ACS level I trauma center is likely the best place to treat any patient that will require ten units of blood within twenty-four hours and smaller non-trauma facilities may have limited resources to provide the necessary care for such patients.

While initial presenting coagulation factors are available on all patients presenting to the emergency department, we did not consider them in this analysis since we were focused on data that is readily available in the prehospital setting. Consideration of initial coagulation factors to predict the need for massive transfusion is very insightful and poses an opportunity for a future study.

The inclusion of only blunt injured patients was based on the presumption that patients injured by a penetrating mechanism would likely meet triage criteria based on the anatomic criteria of field triage that follows the physiologic criteria. The inclusion of patients with blunt injuries would identify those patients with the greatest risk for undertriage based on current field triage guidelines.

With regard to our trauma registry, although the current study was designed retrospectively, our trauma registry obtains and records all patient data prospectively. Once all data is entered it is regularly validated and monitored for accuracy.

Dr. – (Boston, Massachusetts): Thank you for an interesting study. However, I have a problem with the clinical relevance of your presentation. Do you really think that an artificial number will help us to manage patients who require ten units of blood within twenty-four hours?

We all know the endpoints of resuscitation could be elusive, but I don't think for this patient population. It's more relevant to the patient who may require one or two units, but not massive transfusion. I would appreciate it if you could address this question.

Dr. Marianne Vandromme (Birmingham, Alabama): The purpose of this study was to use available prehospital data in patients who do not meet the physiologic criteria for triage to identify patients at high risk of massive transfusions. Although a veteran prehospital provider who has developed a keen recognition of serious injuries may find no utility in the calculation of the prehospital shock index, the prehospital shock index can provide an additional objective calculation to identify patients at high risk of massive transfusion This could be a useful adjunct to assist the relatively less seasoned prehospital provider in making triage decisions. It also has potential utility concerning the identification of patients of interest for the purpose of clinical studies, which tend to require fairly strict enrollment criteria.

Dr. – (Boston, Massachusetts): I understand that, but my point is that I don't think that patients who require ten units of blood within twenty-four hours fall into this group of patients that you are aiming to better triage.

Dr. Marianne Vandromme (Birmingham, Alabama): Unfortunately, our patient selection was limited to those transported to an ACS level I trauma center. Although we attempted to identify patients in hemorrhagic shock or at risk for hemorrhagic shock, we were not able to identify patients who were undertriaged and at risk of massive transfusion. Hopefully future studies will further identify patients who are undertriaged and investigate the utility of the shock index in

assisting field triage. Nonetheless, I think that we have identified a potentially useful measure for objectively identifying patients at risk for massive transfusion, despite being "normotensive" by current triage guidelines.

Dr. Marianne Vandromme (Birmingham, Alabama): Unfortunately, we did not investigate how our results would be affected if other criteria for triage based on anatomic injury or mechanism of injury were considered. Again, the study population was limited to patients transported to an ACS Level I trauma center and subsequent studies may focus on patients that were not triaged to a Level I trauma center and investigate the utility of the prehospital shock index as an adjunct to current field triage guidelines.

Dr. Marie Crandall (Chicago, Illinois): I wanted to commend you on a nice presentation, as well as very nicely answered questions. I have a quick question again about clinical relevance and informing your practice.

The baseline massive transfusion percentage was about 3.4 percent and for your patients who were between 0.9 and 1.1, that risk ratio was significant, but went up by about one-and-a-half. You've increased your risk of massive transfusion to four-and-a-half or 5 percent, which may raise an eyebrow, but isn't particular relevant for that other 95 percent of patients who are completely stable. What does this add to your practice and has your group discussed how this will inform your clinical practice and would it lead to overutilization of resources for this other 95 percent of patients?

Dr. Marianne Vandromme (Birmingham, Alabama): Although the current study presents an increased risk of requiring a massive transfusion for patients with a prehospital shock index greater than 0.9, these are still early retrospective data that should not change clinical practice, but should be investigated further. Among all patients in the study who were considered to be hemodynamically stable with a "normal" systolic blood pressure, greater than 90 mm Hg, the massive transfusion rate was relatively low, but among those with a high shock index the massive transfusion rate reaches 20 percent.

It is important to consider the potential risk for overtriage in any study that attempts to decrease undertriage, and although we are showing that a shock index greater than 0.9 is associated with a significantly increased risk for massive transfusion, the best cut point for clinical practice with regards to triage efficiency remains to be determined. This issue and others have the potential to be appropriately evaluated in the context of the NIH-funded, Resuscitation Outcomes Consortium, which is currently developing protocols to evaluate prehospital markers and potential adjuncts to further improve field assessment, triage, and care.