

# Redefining Hypotension in the Elderly

## Normotension Is Not Reassuring

Tolulope A. Oyetunji, MD, MPH; David C. Chang, PhD, MPH, MBA; Joseph G. Crompton, MD; Wendy R. Greene, MD; David T. Efron, MD; Elliott R. Haut, MD; Edward E. Cornwell III, MD; Adil H. Haider, MD, MPH

**Background:** Recent debate concerns the most appropriate definition of hypotension. Some have advocated raising the systolic blood pressure (BP) threshold to 110 mm Hg while others favor 80 mm Hg.

**Hypothesis:** The optimal definition of hypotension differs by age group.

**Design:** An analysis was performed of trauma victims 18 years and older in the National Trauma Data Bank, excluding burn injury patients and those with incomplete data.

**Setting:** Injured patients who were hospitalized in various trauma centers across the continental United States.

**Patients:** Three age groups were identified for analysis as follows: 18 to 35 years, 36 to 64 years, and 65 years and older. One hundred one multiple logistic regression analyses were performed for each population. Hypotension was sequentially defined as an emergency department systolic BP (SBP) of 50 to 150 mm Hg to see which model best predicted mortality, adjusting for demographic and injury covariates. The discriminatory power

of each model was measured using the area under the receiver operating characteristic (AUROC) curve. Optimally defined hypotension was identified as the model with the highest AUROC curve.

**Main Outcomes Measure:** In-hospital mortality.

**Results:** A total of 902 852 patients (median age, 44 years; 66.2% men) were analyzed. Overall mortality was 4.1%. Optimal emergency department SBP cutoff values for hypotension were 85 mm Hg for patients aged 18 to 35 years, 96 mm Hg for patients aged 36 to 64 years, and 117 mm Hg for elderly patients.

**Conclusions:** For patients younger than 65 years, the classic definition of hypotension as an emergency department SBP less than 90 mm Hg remains optimal. With increasing involvement of elderly individuals in trauma and their peculiarity as a comorbid state, there is a need to redefine what is presently defined as a cutoff value for hypotension in elderly patients.

*Arch Surg.* 2011;146(7):865-869

**E**LDERLY TRAUMA PATIENTS have poorer survival rates than do younger trauma patients. This disparity stems from several contributors, including hypotension. Hypotension is an abnormally low blood pressure (BP) in which end-organ perfusion becomes compromised. Although BP is not a direct correlate of tissue perfusion, it remains a non-invasive surrogate with clinical utility. Most evidence supporting the less than 90 mm Hg systolic BP (SBP) threshold definition for hypotension in adults has been extrapolated from animal models.<sup>1-4</sup>

However, clinical evidence is increasingly supporting the hypothesis that BP values associated with hypotension are inconsistent across different patient populations. Moreover, investigators have recently muddied the waters by suggesting a higher SBP threshold of 110 mm Hg, and others are sug-

gesting a lower value of 80 mm Hg as being indicative of hypotension.<sup>5,6</sup> Although age-adjusted BP is an accepted concept in the pediatric trauma population, a blanket definition of SBP less than 90 mm Hg has generally been applied to the adult population. As with many physiologic variables, age modifies what may be termed “normal” in one age group compared with another.

### See Invited Critique at end of article

The danger of applying a single definition of hypotension to trauma patients at the extremes of age has been documented in elderly patients. Age-related changes in the cardiovascular system (inadequate cardiac output, reduced maximum heart rate, and increased peripheral vascular resistance) may inhibit the cardiovascular compensa-

#### Author Affiliations:

Department of Surgery, Howard University College of Medicine, Washington, DC (Drs Oyetunji, Greene, and Cornwell); and Department of Surgery, The Johns Hopkins University School of Medicine, Baltimore, Maryland (Drs Chang, Crompton, Efron, Haut, and Haider).

**Table. Comparison of Demographic and Injury Characteristics Among the Different Age Groups**

Characteristic	Age Group, y		
	18-35 (n = 364 400)	36-64 (n = 367 024)	≥65 (n = 171 428)
Race/ethnicity, %			
White	54.7	68.2	85.7
Black	20.6	16.5	6.1
Hispanic	17.6	9.0	3.2
Asian	1.7	1.6	1.4
Age, median, y	25	47	77
Sex, %			
Female	25.1	30.2	57.2
Male	74.9	69.8	42.8
Insurance status, %			
Commercial	33.2	41.0	15.8
Government	11.4	14.7	68.8
Uninsured	33.2	22.8	3.2
Other	22.2	21.5	12.2
Mortality, %	3.3	3.6	6.7
ISS category, %			
<9	50.0	45.9	35.2
9-15	27.0	30.1	40.4
16-25	12.1	13.9	14.4
>25	10.9	10.1	10.0
Injury type, %			
Blunt	80.5	90.4	98.3
Penetrating	19.5	9.6	1.7

Abbreviation: ISS, Injury Severity Score.

tory response in elderly individuals and potentially mask hypotension. These cardiovascular concerns, coupled with preexisting comorbidities, preclude a similar cutoff value for hypotension in elderly patients.

The objective of this study was to determine the BP best associated with worse outcomes in adult trauma patients, especially geriatric patients. It is hypothesized that the BP associated with hypotension and greater mortality varies across different age groups.

## METHODS

The National Trauma Data Bank, version 7.1, 2002-20006 (NTDB), was used in this retrospective analysis to define hypotension in elderly trauma patients and to determine its effect on mortality. The NTDB is maintained by the American College of Surgeons and is the largest known collection of trauma index cases in the world. Data from more than 1.8 million patients are captured in this most recent version. Data are voluntarily submitted by more than 700 trauma centers across the United States and in Puerto Rico.<sup>7</sup>

## STUDY SAMPLE

We included in the analysis patients 18 years and older with an SBP of 50 to 150 mm Hg. A broad SBP range was chosen to provide a graphical visualization of the most appropriate threshold value to define hypotension. We excluded the following from the analysis: burn injury patients because their care may differ from that for other mechanisms of injury, patients younger than 18 years, and patient records with missing data.

Patients who met the inclusion criteria were then categorized into 1 of the following 3 age groups: 18 to 35 years, 36 to

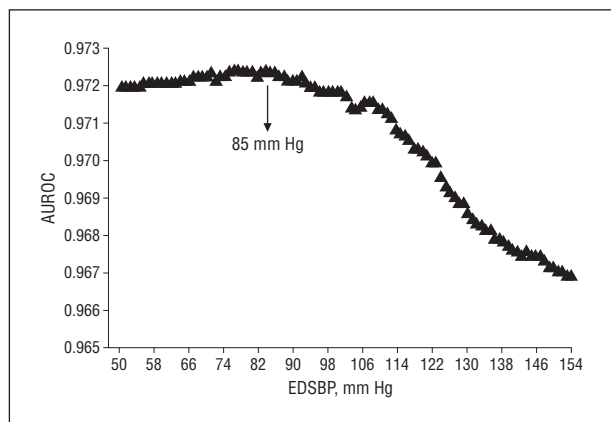
64 years, and 65 years and older. The 18- to 35-year-old age range was defined because this population has the highest incidence of trauma. Those 65 years and older are defined as elderly. In this population, age-related changes affect the cardiovascular system and impact the ideal BP at which tissue perfusion becomes compromised. Thus, it was imperative to analyze this group as a defined subset. The 36- to 64-year-old age group was clustered together and represented the transition group.

## OUTCOME MEASURE AND COVARIATES

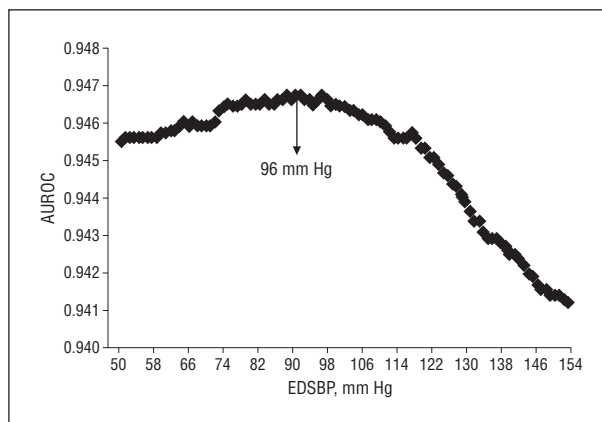
The primary comparison was the different SBP measure, and the primary outcome measure was in-hospital mortality. The age groups were then compared for multiple covariates known to independently predict mortality. Patient demographics were sex, self-reported race/ethnicity (white, black, Hispanic, and other), and insurance status classified as commercially insured (Blue Cross/Blue Shield, managed care organization, other commercial indemnity plan, workers' compensation, or liability insurance), government insured (Medicare and Medicaid), or uninsured. The Injury Severity Score was used to quantify anatomical injury.<sup>8</sup> The Emergency Department Glasgow Coma Scale motor component combined with shock was used to measure severity of physiologic injury; use of the Emergency Department Glasgow Coma Scale motor component with shock as an adequate surrogate for physiologic injury after trauma has been previously demonstrated.<sup>9</sup> The mechanisms of injury included motor vehicle collisions, bicycle crashes, motorcycle crashes, and falls, as determined by *International Classification of Diseases, Ninth Revision*, external injury codes.

## STATISTICAL ANALYSIS

Because the purpose of this research was to determine the optimal SBP cutoff value that accurately predicts mortality, only adjusted regressions were performed for each age group analysis. However, the **Table** highlights a comparison of the different age groups by injury and demographic factors. For each analysis, hypotension was sequentially defined as an emergency department SBP of 50 to 150 mm Hg to determine which model best predicted mortality, adjusting for the independent variables. Each regression analysis was performed with in-hospital mortality as the primary outcome and adjusted for the independent variables described previously herein. A total of 101 multiple logistic regressions were performed for each defined age group. With each regression, the threshold value and definition for hypotension were changed sequentially (starting with 50 mm Hg and finishing with 150 mm Hg). Patients with an emergency department SBP less than 50 mm Hg were defined as hypotensive, and those with an SBP of 50 mm Hg or greater were defined as normotensive. The area under the receiver operating characteristic (AUROC) curve was measured for each regression. The AUROC curve or C statistic measures the ability of each variable (in this case, combination of variables) to accurately predict the outcome of interest, in-hospital mortality.<sup>9</sup> The AUROC curve calculates the area under the curve and plots the true-positive rate against the false-positive rate; 1.00 is a 100% true-positive rate. Therefore, 2 cutoff values with the same true-positive rate and different false-positive rates will have different AUROC curves. The cutoff value with the lower false-positive rate will have a better AUROC curve. The conventional classifications of AUROC curve were used in this analysis, and an AUROC curve of less than 0.60 was considered poor, 0.70 to 0.79 fair, 0.80 to 0.89 good, and 0.90 or greater excellent.<sup>10</sup> Hypotension was identified as the emergency department SBP used in the model with the highest value of AUROC curve for each population. All the analyses were performed using a commercially available statistical software program.<sup>11</sup>



**Figure 1.** Area under the receiver operating characteristic (AUROC) curve by emergency department systolic blood pressure (EDSBP) for patients aged 18 to 35 years (n=364 400) showing the optimal cutoff value for hypotension (85 mm Hg).



**Figure 2.** Area under the receiver operating characteristic (AUROC) curve by emergency department systolic blood pressure (EDSBP) for patients aged 36 to 64 years (n=367 024) showing the optimal cutoff value for hypotension (96 mm Hg).

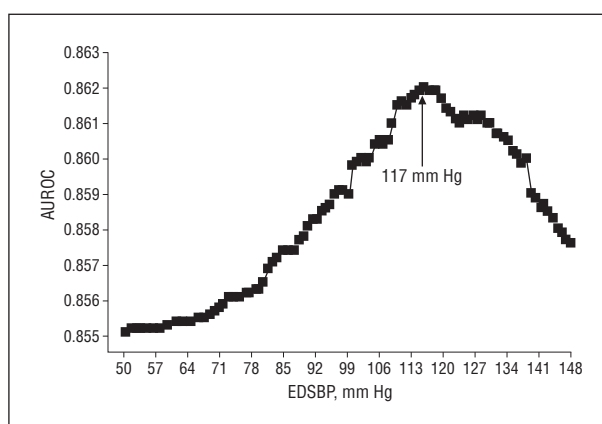
## RESULTS

Of approximately 1.8 million records in the NTDB, 902 852 met the inclusion criteria. The median patient age was 44 years, and men accounted for two-thirds of the population (66.2%). Most patients were white (66.1%), and black (16.2%), Hispanic (11.3%), and other (6.4%) racial/ethnic groups accounted for the remaining sample population. Approximately 25% of the patients had an Injury Severity Score greater than 15. Overall mortality in this population was 4.1%. Patients in the 18- to 35-year-old group accounted for 40.4% (n=364 400) of the sample, the 36- to 64-year-old group made up 40.7% (n=367 024), and those 65 years and older represented 19.0% (n=171 428). A comparison of demographic and injury characteristics among the 3 age groups is given in the Table.

An AUROC curve distribution with different cutoff values was completed for each age group to identify the optimal threshold in which to define hypotension. In **Figure 1**, the highest AUROC curve value for the 18- to 35-year-old group intersected at an SBP of 85 mm Hg, after which the values began to trend downward. In **Figure 2**, the highest AUROC curve value for the 36- to 64-year-old group intersected at an SBP of 96 mm Hg. In **Figure 3**, the highest AUROC curve value for the group 65 years and older intersected at an SBP of 117 mm Hg. A subset analysis of the group aged 65 years and older was conducted by race/ethnicity, with no change demonstrated (**Figure 4**).

## COMMENT

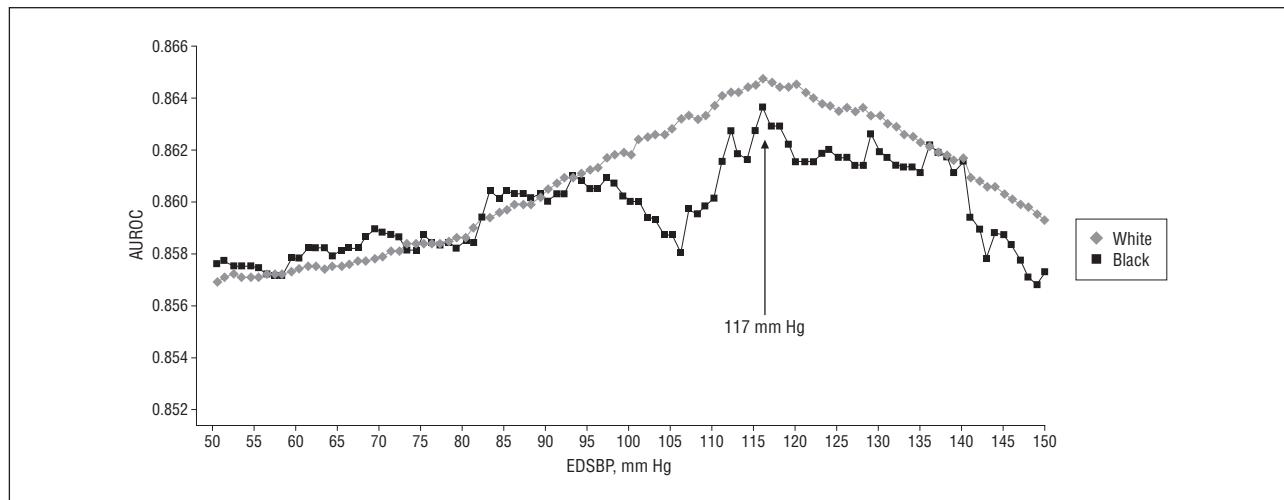
In this study, an SBP of 117 mm Hg was identified as the threshold value defining hypotension in trauma patients 65 years and older. Moreover, the threshold SBP associated with hypotension varied by age group. These findings have important clinical implications given that 90 mm Hg is the classic SBP definition for hypotension in adults and is linked to significantly greater mortality in the geriatric population. Recent debate on the most accurate definition of hypotension in adults has varied



**Figure 3.** Area under the receiver operating characteristic (AUROC) curve by emergency department systolic blood pressure (EDSBP) for patients 65 years and older (n=171 428) showing the optimal cutoff value for hypotension (117 mm Hg).

from 80 mm Hg for severe hypotension<sup>6</sup> to a cutoff value of 110 mm Hg.<sup>3</sup> In the latter study,<sup>5</sup> Eastridge et al point out a lack of evidence supporting the 90-mm Hg threshold. After further analysis, they conclude that an SBP of 110 mm Hg is a more accurate definition for hypotension. Although this study had strengths, a major limitation was the use of SBP as a continuous variable in their analyses. In the clinical setting, hypotension is essentially a dichotomous variable; a patient either is or is not hypotensive. For example, patients with an SBP less than 90 mm Hg and those with an SBP less than 80 mm Hg are both defined as hypotensive. Thus, the results of the study by Eastridge et al<sup>5</sup> may be affected by analytic bias.

Our study attempted to correct for this analytic bias by defining each potential threshold as a dichotomous variable and by calculating the AUROC curve after adjusting for other confounders of mortality. Because we systemically used this analytic method for every threshold considered, we believe that these results are more accurate SBP thresholds for defining hypotension and predicting mortality in the elderly age group. We therefore submit that the classic definition of hypotension at 90 mm Hg may be valid for adult trauma patients younger than 65 years.



**Figure 4.** Area under the receiver operating characteristic (AUROC) curve showing the optimal emergency department systolic blood pressure (EDSBP) cutoff value for hypotension in the elderly patients by race/ethnicity.

The elderly trauma patient differs significantly from the younger trauma patient in many ways besides age that increase their risk of mortality. Mortality is 2 times higher in the elderly population compared with the younger population.<sup>12,13</sup> A potential contributor to this disparity is the prevalence of preexisting comorbidities in the elderly, which have been demonstrated to be independent predictors of poor outcomes in the geriatric trauma patient.<sup>14-17</sup> Another important contributor of mortality in geriatric patients is a decreased physiologic response after traumatic injury. In 1 study, one-third of stable geriatric patients with normal BPs died within 24 hours of a cardiac arrest from age-related cardiac insufficiency, which caused hypoperfusion with higher peripheral vascular resistance. This poor response from the cardiovascular reserve makes shock even more difficult to detect and diagnose.<sup>14,18,19</sup> Moreover, the elderly experience diminished cardiac output and poor functional capacity during periods of stress that impair their ability to tolerate injury.<sup>15</sup> Thus, early predictors of shock, such as peripheral perfusion and presence of a pulse, may be missed in the elderly trauma patient because of these age-related changes. In addition, approximately two-thirds of patients older than 60 years have systolic hypertension.<sup>20</sup> Consequently, elderly trauma patients with normal BP measurements may actually be in a significant state of shock.

Although many researchers have recognized physiologic differences in the elderly compared with younger adults, to our knowledge, this study is the first large database analysis to recommend an optimal threshold for defining hypotension in trauma patients 65 years and older. Although Eastridge et al<sup>5</sup> found a similar threshold at 110 mm Hg for older patients in their study, their cutoff age started at 43 years. In addition, their study explored various subsets of patients to account for differences without a defined multivariate analysis; this study went a step further by adjusting for most known independent predictors of poor outcome after trauma, as noted in the "Methods" section. We therefore surmise that the finding from this study supports the utility of this noninvasive assessment in critical decision making and can serve to redirect and provide early goal-directed therapy. The utility of nonin-

vasive assessment in critical decision making may allow for earlier intervention and avoidance of precipitous decompensation in the geriatric trauma patient.

This study has limitations common when using existing data sets and performing retrospective analyses. The NTDB is a convenience sample and does not represent a population-based sample. Thus, these results may not be generalizable. Also, data are reported to this registry from many trauma centers and are subject to underreporting with limited quality control that may reflect in the composite data. Nevertheless, all levels of trauma centers from every region in the United States participate in reporting, which make the data more representative of all trauma patients. Moreover, there is a substantial amount of missing data that may bias these results. Also, the temporal method of data collection of physiologic measures was not standardized among hospitals. Regardless of these limitations, the NTDB provided a large sample size and can serve as a powerful resource to further advance trauma outcomes research.

We demonstrated that an SBP of 117 mm Hg is a better diagnostic definition for hypotension and predictor of mortality in the elderly trauma patient. Unlike the younger population with a highly predictive AUROC curve, other factors yet unaccounted for may still contribute to mortality in the elderly population, most probably comorbidities. However, the current threshold of 90 mm Hg, which may suffice in the younger trauma population, is not a reliable predictor in the geriatric trauma population. As the elderly population rapidly increases, with a projected 20% of the US population in the senior age group by 2030, it is critical to reassess the present definition of hypotension, specifically in the elderly. This reassessment will help mitigate the high morbidity and mortality rates experienced by elderly individuals after traumatic injury.

Accepted for Publication: June 24, 2010.

Correspondence: Tolulope A. Oyetunji, MD, MPH, Howard-Hopkins Surgical Outcomes Research Center, Department of Surgery, Howard University College of Medicine, 2041 Georgia Ave NW, Washington, DC 20060 (toyetunji@howard.edu).

**Author Contributions:** *Study concept and design:* Oyetunji, Chang, Crompton, Greene, Efron, Haut, Cornwell, and Haider. *Acquisition of data:* Oyetunji, Chang, and Haider. *Analysis and interpretation of data:* Oyetunji, Chang, Efron, Cornwell, and Haider. *Drafting of the manuscript:* Oyetunji, Crompton, and Haider. *Critical revision of the manuscript for important intellectual content:* Chang, Greene, Efron, Haut, Cornwell, and Haider. *Statistical analysis:* Oyetunji, Chang, and Haider. *Administrative, technical, and material support:* Crompton, Greene, Cornwell, and Haider. *Study supervision:* Efron, Haut, Cornwell, and Haider.

**Financial Disclosure:** None reported.

**Previous Presentation:** This research was presented as a poster at the Annual Meeting of the American Association for Surgery of Trauma; October 3, 2009; Pittsburgh, Pennsylvania.

## REFERENCES

- Wiggers CJ. *Experimental Hemorrhagic Shock*. New York, NY: Commonwealth; 1950:121-132.
- Gross D, Landau EH, Assalia A, Krausz MM. Is hypertonic saline resuscitation safe in 'uncontrolled' hemorrhagic shock? *J Trauma*. 1988;28(6):751-756.
- Gross D, Landau EH, Klin B, Krausz MM. Treatment of uncontrolled hemorrhagic shock with hypertonic saline solution. *Surg Gynecol Obstet*. 1990;170(2):106-112.
- Bickell WH, Bruttig SP, Wade CE. Hemodynamic response to abdominal aortotomy in the anesthetized swine. *Circ Shock*. 1989;28(4):321-332.
- Eastridge BJ, Salinas J, McManus JG, et al. Hypotension begins at 110 mm Hg: redefining "hypotension" with data [published correction appears in *J Trauma*. 2008;65(2):501]. *J Trauma*. 2007;63(2):291-299.
- Shapiro MJ, McCormack JE, Jen J. Let the surgeon sleep: trauma team activation for severe hypotension. *J Trauma*. 2008;65(6):1245-1252.
- National Trauma Data Bank (NTDB) research data set v.7.0 user manual. American College of Surgeons Web site. 2007. <http://www.facs.org/trauma/ntdb/pdf/usermanual72.pdf>. Accessed June 28, 2009.
- Baker SP, O'Neill B, Haddon W Jr, Long WB. The Injury Severity Score: a method for describing patients with multiple injuries and evaluating emergency care. *J Trauma*. 1974;14(3):187-196.
- Oyetunji TA, Crompton JG, Efron DT, et al. Simplifying physiologic injury severity measurement for predicting trauma outcomes. *J Surg Res*. 2010;159(2):627-632.
- Tape TG. Interpreting diagnostic tests: the area under an ROC curve. <http://gim.unmc.edu/dxtests/roc3.htm>. Accessed June 28, 2009.
- STATA Statistical Software [computer program]. Release 10. College Station, TX: StataCorp LP; 2007.
- Lonner JH, Koval KJ. Polytrauma in the elderly. *Clin Orthop Relat Res*. 1995;(318):136-143.
- Finelli FC, Jonsson J, Champion HR, Morelli S, Fouty WJ. A case control study for major trauma in geriatric patients. *J Trauma*. 1989;29(5):541-548.
- Horst HM, Obeid FN, Sorensen VJ, Bivins BA. Factors influencing survival of elderly trauma patients. *Crit Care Med*. 1986;14(8):681-684.
- Hossack KF, Bruce RA. Maximal cardiac function in sedentary normal men and women: comparison of age-related changes. *J Appl Physiol*. 1982;53(4):799-804.
- Broos PL, D'Hoore A, Vanderschot P, Rommens PM, Stappaerts KH. Multiple trauma in elderly patients. Factors influencing outcome: importance of aggressive care. *Injury*. 1993;24(6):365-368.
- Broos PL, Stappaerts KH, Rommens PM, Louette LK, Gruwez JA. Polytrauma in patients of 65 and over. Injury patterns and outcome. *Int Surg*. 1988;73(2):119-122.
- Oreskovich MR, Howard JD, Copass MK, Carrico CJ. Geriatric trauma: injury patterns and outcome. *J Trauma*. 1984;24(7):565-572.
- Safih MS, Norton R, Rogers I, Gardener JP, Judson JA. Elderly trauma patients admitted to the intensive care unit are different from the younger population. *NZ Med J*. 1999;112(1098):402-404.
- Stamatos GA. Geriatric trauma patients: initial assessment and management of shock. *J Trauma Nurs*. 1994;1(2):45-56.

## INVITED CRITIQUE

# Great Statistics and the Real World

Oyetunji et al<sup>1</sup> performed a meticulous statistical analysis of a large nationwide database concerning admission BP and subsequent mortality as a consequence of traumatic injury. The statistical methods used are time-consuming and available for use only in very large data sets. Nevertheless, Oyetunji et al<sup>1</sup> showed, with good statistical power, that a "normal" SBP may not predict a good outcome in elderly patients. For this study, elderly was defined as 65 years and older.

Although this study was elegantly performed from a statistical viewpoint, the message to the bedside caregiver is unclear. Should all persons older than 65 years with an admission SBP of 110 mm Hg be given a full trauma alert after falling in the parking lot while on their way into an office building? What if 110 mm Hg is the baseline SBP for that patient?

The point that this large data set analysis makes is not that a BP of 117 mm Hg is a magic number but that mortality in the elderly patient may have more to do with what happens after the initial stages of resuscitation than what can be predicted by a single vital sign measured once at the time of arrival. Younger patients with more compensatory mechanisms may be much more physiologically challenged before any noticeable change in BP. Thus, a

large data set will detect this derangement as determined by a single admission BP and show a corresponding rise in the measured mortality rate. The multiple factors involved in mortality analysis of older patients makes a simple approach, such as measuring SBP only once for risk stratification, less predictive.

Oyetunji et al<sup>1</sup> correctly note that comorbidities affect mortality in the geriatric population. Attention to management of the primary injury and management of the medical comorbidities in the geriatric population is needed to reduce trauma-related mortality in this age group. I congratulate the authors for their contribution to the literature concerning the elderly trauma patient.

Erik S. Barquist, MD

**Author Affiliation:** Department of Surgery, Jackson Health Systems, Miami, Florida.

**Correspondence:** Dr Barquist, Department of Surgery, Jackson Health Systems, 9380 SW 150th St, Suite 100, Miami, FL 33176 (erik.barquist@jhsmiami.org).

**Financial Disclosure:** None reported.

- Oyetunji TA, Chang DC, Crompton JG, et al. Redefining hypotension in the elderly: normotension is not reassuring. *Arch Surg*. 2011;146(7):865-869.