RADIAL PULSE CHARACTER RELATIONSHIPS TO SYSTOLIC BLOOD PRESSURE AND TRAUMA OUTCOMES

John McManus, MD, MCR, Andrey L. Yershov, MD, PhD, David Ludwig, PhD, John B. Holcomb, MD, Jose Salinas, PhD, Michael A. Dubick, PhD, Victor A. Convertino, PhD, Denise Hinds, RN, BSN, Will David, RN, BSN, NREMT-P, Tom Flanagan, RN, BSN, MA, LP, CMTE, James H. Duke, MD

ABSTRACT

Background. Patient measurements that do not require monitoring equipment may be the only way to evaluate casualties in austere conditions to determine treatment and transport priority. **Objective**. To test the hypothesis that palpable pulse characteristics in the radial artery would estimate systolic blood pressure (SBP) and predict outcome in trauma patients. **Methods**. Data were analyzed from the medical records of 342 trauma patients ranging from 18 to 50 years of age. Prehospital data were collected by helicopter emergency medical personnel at the scene of the injury. Based on radial pulse character, patients were divided into normal ($n = 313$) and weak ($n = 29$) groups. Those whose medical records did not describe pulse characters were not considered. Differences in SBP, mortality, and medical interventions between the radial-pulse-character groups were evaluated. **Results**. The SBP taken at the scene was a mean of 26 mm Hg lower in those patients with weak radial pulse characters (102 mm Hg versus 128 mm Hg). Similarly, the lowest mean SBPs recorded in the field between the normal- and weak-pulse-character groups were 112 mm Hg and 99 mm Hg, respectively. Patient mortality increased with weak pulse character such that the mortality rats were 3% for the normal-pulse-character group and 29% for the weak-pulse-character-group (odds ratio = 15.2). **Conclusions**. These preliminary data suggest that a weak radial pulse may be an acceptable method for initial rapid evaluation of trauma patients. This simple and rapid method of pulse evaluation should be considered for the triage of trauma patients in field conditions with limited instrumentation.

Key words: pulse character; radial artery; systolic blood pressure; trauma; mortality.

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The tactical and multiple-casualty incident (MCI) environments provide many challenges for prehospital medical personnel. These environments are often chaotic, with limited equipment and resources available to assist medical providers in triage decision making and prioritization with regard to evacuation of patients. Triage decision making on scene in the prehospital setting relies on easy-to-use triage tools. The primary purpose of a triage tool is to ensure delivery of the right patient to the right medical asset at the right time. Most multicasualty triage tools currently use the patient's physiologic data to help determine priority. Physiologic data are used for combat triage and mass-casualty events because they are assumed to be readily obtainable at the site of injury and provide a snapshot of a patient's stability. The U.S. Army's Combat Casualty Care Research Program and the U.S. Army Institute of Surgical Research are currently developing a prototype system that will alert combat medics of wounding events in combat and that will allow the medic to remotely assess patient physiologic signs and status in order to make triage decisions from a distance (i.e., remote triage). However, no such system is currently available, and prehospital personnel must rely on direct, hands-on assessment to make triage decisions.

Previous studies have found that the ability of the patient to follow commands (the motor component of the Glasgow Coma Scale) and the patient's SBP had the strongest association with critical injury when using physiologic variables for trauma triage in an MCI.[1,2] However, the use of the SBP for triage decision making in a combat or MCI setting is problematic. The ability to obtain a blood pressure (BP) measurement in an austere environment is often limited by time constraints, equipment availability, and noisy conditions. Past literature has advocated the use of a palpable radial pulse as a possible tool to estimate SBP.[3] Interpretations of the ideal sequence of procedures and the value of such pulse palpability in patients for predicting BP and clinical outcome are contradictory, with some physicians continuing to support the use of pulse character in triage decision making[4–7] and others reporting that its

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Address correspondence and reprint requests to: LTC John McManus, MD, U.S. Army Institute of Surgical Research, 3400 Rawley East Chambers Avenue, Fort Sam Houston, TX 78234-6315. e-mail: <john.mcmanus@amedd.army.mil>.

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value is limited.[8,9] Thus, the diagnostic value of palpable pulse characteristics in trauma patients remains controversial.

The concept of estimating SBP in trauma patients based on palpable pulses was introduced in the Advanced Trauma Life Support (ATLS) course manual printed in 1985.[3] The manual presented the relationships that the SBP was 60–70 mm Hg if the patient's carotid pulse was the only palpable pulse, the SBP was 70–80 mm Hg if both the carotid and femoral pulses were palpable, and the SBP was more than 80 mm Hg if the radial pulse was palpable in addition to the carotid and femoral pulses. Teaching the association between palpable pulses and SBP was subsequently discontinued after the printing of the 1985 course manual because of the absence of data to support such a relationship. In addition, it has also been demonstrated that assessment of the carotid pulse is time-consuming and leads to an incorrect conclusion (present or absent) in up to 45% of cases.[10] Consequently, training in the detection of the carotid pulse during ATLS is no longer recommended in trauma patient care. Furthermore, a multinational panel in 2001 recommended that the guidelines for the assessment of circulation prior to initiation of cardiopulmonary resuscitation no longer include pulse checks for the layperson and de-emphasized pulse checks for the professional rescuer.[11]

Despite the controversy, the concept of using pulse character as a reliable diagnostic tool of circulatory stability is very attractive to far-forward military medical personnel operating in austere environments and in civilian situations dealing with mass casualties. In fact, this approach is currently being taught to combat and emergency ambulance medics, albeit without supporting data.[12–14] Because little is known about the sequence of pulse weakening and disappearance, this study hypothesized that such information might be useful for the medics and physicians participating in the triage of injured soldiers on the battlefield or during other mass-casualty situations.

Based on a prehospital trauma database, the Trauma Vitals System (TVS),[15,16] the present study was designed to evaluate the relationship of palpable characteristics of the radial artery at the scene to BP and patient outcomes. This study hypothesized that pulse character in the radial artery could estimate SBP and predict outcome in acute trauma patients.

METHODS

This study was approved by the Institutional Review Board of the University of Texas Health Science Center, Houston, and the U.S. Army Human Subject Research Review Board. This was a retrospective study of prospectively collected data.

Data-Collection System Overview

Data for the present study were obtained using the TVS developed by the U.S. Army Institute of Surgical Research, Fort Sam Houston, Texas, in collaboration with the University of Texas Health Science Center in Houston. This system, which began operating in January 2002, is composed of a data-collection unit that automatically records and stores all vital signs (numeric and waveform) during helicopter transport on the Houston Life Flight service from the incident site into the Level 1 trauma center, Memorial Hermann Hospital in Houston. The trauma patients enrolled in the study included only trauma patients transported from the scene of a trauma event to the trauma center, and not interfacility transports. The Life Flight service has three helicopter transport vehicles for the Houston metropolitan and surrounding areas and averages more than 2,000 trauma scene calls per year. All helicopters in the service have been deployed with a data-collection unit for complete coverage of all trauma patients transported by air. A full-time research nurse manages the data collection and correlates electronic physiologic patient data with helicopter run sheets, critical hospital outcomes, and trauma scoring using an online Web-enabled database system. Captured data from the helicopters were transferred to a removable storage card for subsequent upload to the database server. Written run sheet information recorded by the emergency medical services (EMS) flight personnel was matched to the captured physiologic data and added to the database. Additional data such as lifesaving interventions, procedures done in the hospital, and mortality were recorded by the study nurse and also added to the database. The current system contains more than 1,100 fully correlated incident records with prehospital, hospital, and outcome data.

Subjects and Measurements

In spring 2002, paramedics assigned to the Houston Life Flight service helicopter team were trained to distinguish three pulse characteristics: "normal" (N, a strong pulse that was easy to palpate), "weak" (W, a palpable pulse but difficult to find), and "absent" (A, no pulse found) in the radial artery. The paramedics were instructed to take and quantify the character of the radial pulse prior to obtaining a BP measurement at the scene. Once the pulse character was obtained and recorded on a standardized run sheet, a BP measurement was then obtained using an automated vital sign monitor (Propaq 206 EL, Welch Allyn, Skaneateles Falls, NY).

Medical records of all the patients in the TVS database that contained radial pulse character were reviewed for this study. Patients with head injuries (Abbreviated Injury Scale [AIS] head > 2) were excluded. Subjects without radial pulse characters were not enrolled in this study because the status of these subjects was primarily dead on arrival (DOA). The patients were further refined by including only those ranging in age from 18 to 50 years, in order to represent a population of trauma patients with minimal underlying medical conditions. This also provided a sample of subjects with ages similar to those casualties seen in a combat environment. Other data analyzed for the study included age, capillary refill time, respiratory rate, Glasgow Coma Score (GCS), application of prehospital and in-hospital lifesaving interventions (LSIs), disposition of patients within the hospital once they left the emergency department (ED), and mortality.

Statistical Analysis

The data used in the current investigation represent the entire population of trauma cases between March 2002 and October 2004. In light of the descriptive population-based nature of this investigation, 95% confidence intervals (CIs) were used to reflect variation in the means for the two radial-pulse-character groups across the dependent measures (as opposed to Neyman-Pearson hypothesis testing). When the dependent measures were continuous, measures of association (i.e., R^2) and associated group variance were determined by constructing a two-group (normal, weak) one-way analysis of variance. Categorical outcomes such as mortality were statistically modeled using 2 × 2 contingency tables and subsequent calculation of odds ratios. Measures of association reflecting the percentage of variance explained by pulse characteristic were used to quantify relationships obtained from both continuous and categorical outcomes. A classification and regression tree (CART) analysis was performed to determine the best decision path for predicting a patient's SBP.[17] The tree was constructed from a model that attempted to predict the SBP (averaged from the field) from radial pulse character, age, respiratory rate, capillary refill time, GCS, and gender, These six predictors were selected because of their ability to be rapidly assessed in a field environment without instrumentation.

Results

A maximum of 342 patients were eligible for analysis. Patients' ages ranged from 18 to 50 years, with a mean of 32 years. The study population was predominantly male (75%), with a racial mix of 50% white, 35% Hispanic, 10% African American, 3% Asian, and 2% other. Although blunt trauma represented the majority (89%) of the patients, penetrating trauma was also represented.

Differences between the normal- and weak-pulse-character groups are summarized in Table 1. With the exception of pulse taken in the field, respiratory rate, and lowest SBP in the ED, none of the radial-pulse-character groups' 95% CIs were overlapping and all of the odds ratios and R^2 values were statistically discernible from zero ($p < 0.05$). On average, radial pulse character explained approximately 10% of the variance in SBP (90% unexplained). The odds of mortality for patients with weak radial pulse characters was 15.2 (95% CI = 5.1 to 44.4) times greater than for subjects with normal pulse characters.

The results of the CART analysis (Figure 1) indicated that radial pulse character was the best "overall" predictor of SBP among the six predictor variables. Weak pulse was associated with a mean SBP of 99.8 mm Hg, and normal pulse was associated with a mean SBP of 128.7 mm Hg. The R^2 (i.e., variance explained in SBP by this first split) was 12%. This technique then split the normal pulse character group by age. Subjects in the normal pulse character group who were 39 years old or older had a mean SBP of 134.2 mm Hg compared with those less than 39 years old, who had a mean SBP of 126.3 mm Hg. The model R^2 at this split increased to 15%. This is a modest gain and it probably reflects the general increase in BP with increasing age. The final split was in the group of patients aged 39 years or older. They were split based on initial respiratory rate. A respiratory rate >31.5 breaths/min yielded 13 individuals

Table 1. Percentages, Means, Confidence Intervals, and Measures of Association by Radial-pulse-character Group

Variable (Dichotomous)	Normal*	Weak*	OR
Mortality	8/312 = 3% (1%–5%)	8/28 = 29 % (15%–47%)	15.2
Blunt trauma	289/313 = 93% (90%–96%)	21/29 = 72% (54%–84%)	5.2
Intubated	44/312 = 14% (11%–18%)	16/29 = 72% (38%–72%)	7.5
ICU admission	98/292 = 34% (28%–39%)	16/22 = 73% (53%–87%)	5.3
Delayed capillary refill time	6/310 = 2% (1%–4%)	16/28 = 57% (39%–74%)	67.6
Variable (Continuous)	**Normal**	**Weak**	**R^2**
First field SBP (mm Hg)	128 (125–130) $n = 307$	102 (90–114) $n = 26$	0.08
Lowest field SBP	117 (115–120) $n = 308$	84 (74–94) $n = 23$	0.14
First SBP in ED	130 (127–132) $n = 307$	99 (89–110) $n = 20$	0.10
Lowest SBP in ED	112 (108–115) $n = 181$	99 (87–110) $n = 13$	0.02
Field pulse (beats/min)	98 (95–101) $n = 247$	109 (96–121) $n = 22$	0.02
Respiratory rate (breaths/min)	20 (19–21) $n = 282$	19 (15–23) $n = 20$	0.00
Prehospital fluids (mL)	305 (274–339) $n = 298$	757 (533–1075) $n = 27$	0.07

Note: Parenthetical values are upper and lower limits of within-group 95% confidence intervals for the mean (continuous data) or percentage (dichotomous data). OR = odds ratio; R^2 = variance accounted for by radial pulse character. Due to high skewness, prehospital fluid values were log-transformed and then inverse log-retransformed back to the original scale. ICU = intensive care unit; SBP = systolic blood pressure; ED = emergency department.
*The n varies due to missing values.

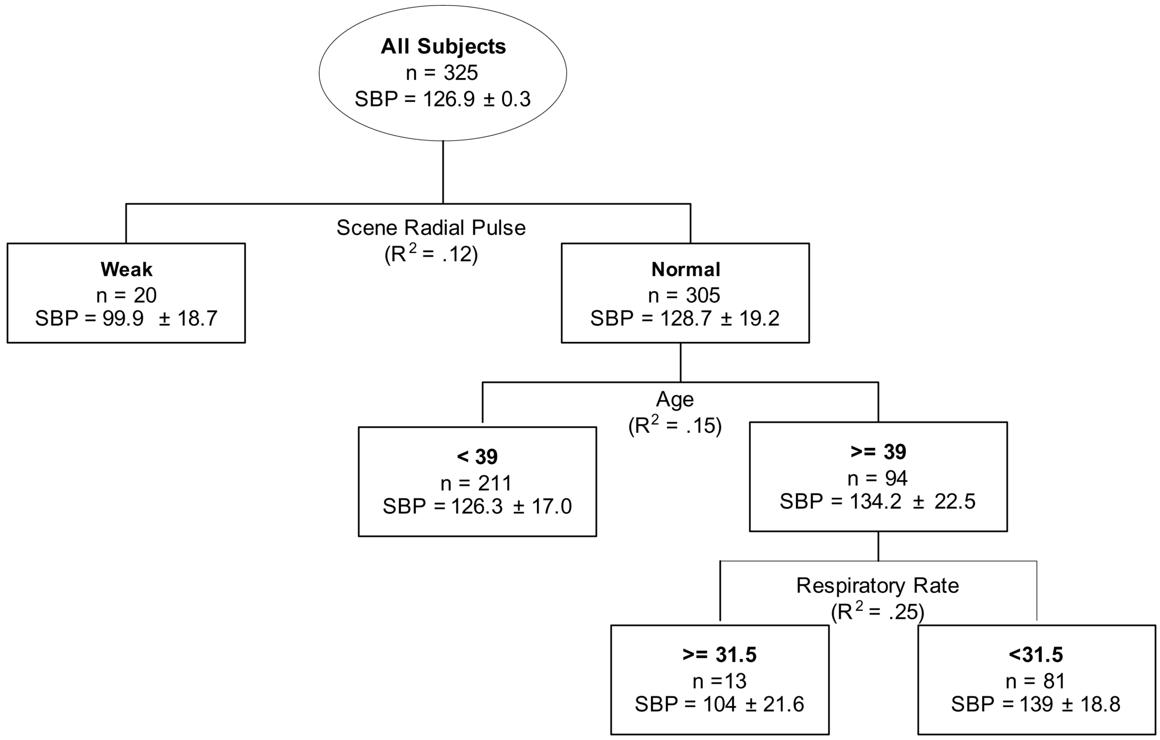

FIGURE 1. Classification-tree diagram for the dependent variable of systolic blood pressure (SBP = mean ± standard deviation). SBP is expressed in mm Hg; pulse is expressed in beats/min; age is expressed in years; and respiratory rate is expressed in breaths/min.

with a mean SBP of 104 mm Hg. Those with a respiratory rate <31.5 breaths/min had an average SBP of 139 mm Hg. The R^2 jumped to 25%. The results indicated that as a predictor of SBP, radial pulse character is highly sensitive but lacks specificity. Almost all subjects who were classified as having a weak radial pulse had low SBPs. The reverse, however, was not true, as subgroups of subjects with normal radial pulse characters (i.e., older subjects with higher respiratory rates) also had low SBPs.

DISCUSSION

Medical practitioners have long used arterial pulse character as a guide to diagnose and treat various injuries. Studies of pulse character require the classification of pulses according to their features and then the correlation of those features to various outcomes. For example, the Chinese art of "pulse feeling," which is still practiced, identifies more than 30 different patterns.[18–20] The features used in the present study (normal and weak) were deliberately simplified for potential practical use in unfavorable conditions, such as triage on the battlefield or in mass-casualty incidents. During the first hours in such conditions, medical equipment may not be available, and simple non–technology-based diagnostic approaches become the bases of triage.

Contradictory opinions appear in the literature about the ability to obtain a pulse and the value of pulse weakening in the arteries for predicting SBP during circulatory collapse.[5,21–25] Mather and O'Kelly found that 98% of physicians were able to identify the radial pulse within 5 seconds in 554 anesthetized patients, and more than 99% completed identification within 10 seconds.[21] In contrast, the carotid pulse was harder to identify, requiring 10 seconds for 95% accuracy. Eberle et al.[23] also reported that successful identification of a carotid pulse was low for laypersons with basic life support training, emergency medical technicians in training, and paramedics in training as well as certified paramedics. For example, a carotid pulse was not identified in 45% of patients despite an SBP ≥80 mm Hg. Other studies also found that palpation of pulse alone is an unreliable physical sign and generally should be used only as a last resort.[24–26]

Our data suggest that prehospital providers are capable of characterizing and documenting arterial pulses by palpation in the field. The purpose of this investigation was to assess the value of the radial pulse character as a candidate for an acceptable way to predict outcome in trauma patients. The analysis showed that mortality was 29% in patients with a weak radial pulse when compared with a mortality of only 3% in patients with a normal radial pulse character. Thus, a weak character in the radial pulse may be an important predictor of mortality in trauma patients without head injury. Admission to the intensive care unit (ICU) was also five times more likely in the weak-pulse-character cohort. More importantly, we found that a relationship between the pulse character and SBP could be approximated. However, pulse character lacked specificity when predicting SBP. These results partially support the notion that palpable pulse characteristics may be useful in the triage of trauma patients and for prognosis of trauma outcome.

Despite recommendations that clinical decisions should rely on standard sphygmomanometer measurements of BP rather than the provider's ability to palpate a pulse alone,[9] other critical care physicians have used pulse characteristics in their clinical decision making. In support of the clinical use of pulse palpation in triage decision making, the results of our study endorse the partial prognostic value of palpable pulse characteristics in this small cohort of trauma patients.[6,7,27]

Limitations

This study was retrospective and thus had some limitations. Data were collected and based on written paramedic accounts of field and ED pulse characters that were not validated. Thus, the ability of paramedics to determine a pulse characteristic was subjective. Furthermore, the operational and environmental constraints of the prehospital setting may have led to missing and/or erroneous (miscoded) records that might have affected the interpretation of data. The study design was strengthened by instructions that paramedics obtain pulse character prior to the measurement of BP. Although this approach was designed to eliminate any influence on the interpretation of pulse character by previous knowledge of BP, there was no guarantee that a paramedic could not go back and change his or her pulse opinion about the pulse character without the researcher's knowledge once a BP value was obtained. Finally, the use of oscillometric BP measurements may have underestimated arterial BP and may not have achieved adequate accuracy in some critically ill patients.[28,29]

Conclusion

It should be appreciated that the approach described in this study for assessment of pulse character was not intended to be used as the only triage tool; rather, it may aid in predictive mortality when combined with other clinical assessments as a guide to an effective triage algorithm. Nevertheless, the results from this study suggest that the evaluation of the radial pulse character may be an acceptable method for initial rapid assessment of trauma patients by prehospital providers. The data suggest that a weak radial pulse character has some predictive power for both mortality and SBP. However, although a weak pulse always suggests low SBP, older subjects with rapid respiratory rates may also have low SBPs even when their radial pulse characters are normal.

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