Improving Survival Rates after Civilian Gunshot Wounds to the Brain

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BACKGROUND: Gunshot wounds to the brain are the most lethal of all firearm injuries, with reported survival rates of 10% to 15%. The aim of this study was to determine outcomes in patients with gunshot wounds to the brain, presenting to our institution over time. We hypothesized that aggressive management can increase survival and the rate of organ donation in patients with gunshot wounds to the brain.

STUDY DESIGN: We analyzed all patients with gunshot wounds to the brain presenting to our level 1 trauma center over a 5-year period. Aggressive management was defined as resuscitation with blood products, hyperosmolar therapy, and/or prothrombin complex concentrate (PCC). The primary outcome was survival and the secondary outcome was organ donation.

RESULTS: There were 132 patients with gunshot wounds to the brain, and the survival rates increased incrementally every year, from 10% in 2008 to 46% in 2011, with the adoption of aggressive management. Among survivors, 40% (16 of 40) of the patients had bi-hemispheric injuries. Aggressive management with blood products ($p = 0.02$) and hyperosmolar therapy ($p = 0.01$) was independently associated with survival. Of the survivors, 20% had a Glasgow Coma Scale score ≥ 13 at hospital discharge. In patients who died ($n = 92$), 56% patients were eligible for organ donation, and they donated 60 organs.

CONCLUSIONS: Aggressive management is associated with significant improvement in survival and organ procurement in patients with gunshot wounds to the brain. The bias of resource use can no longer be used to preclude trauma surgeons from abandoning aggressive attempts to save patients with gunshot wound to the brain. (J Am Coll Surg 2014;218:58–65. © 2014 by the American College of Surgeons)

Gunshot wounds to the brain are the most lethal of all firearm injuries, with reported survival rates of only 7% to15%.[1] According to the literature, about 90% of the time, the victims die before arriving at the hospital.[2,3] For victims who survive and make it to the hospital, about 50% die in the emergency room.[2,3] Each year in the United States, there are an estimated 70,000 victims of gunshot wound, resulting in 30,000 deaths.[4] The high morbidity and mortality of gunshot injuries to the brain, impose a staggering burden on hospitals, families, court systems, and society.

Because of the high mortality rate in this group, aggressive management is often withheld in patients who arrive at the trauma center with a low Glasgow Coma Scale (GCS) score (3 to 5) or with bi-hemispheric head injuries in order to preserve precious resources.[5,6] However, over the last 30 years, advances in surgical techniques, resuscitation patterns, and critical care inpatient management have resulted in marked reduction in mortality and morbidity in patients admitted to hospitals with traumatic brain injury.[7,8] Recent reports comparing survival in military vs civilian patients with gunshot wound to the brain, have shown higher survival rates with aggressive operative management and intracranial monitoring.[9] Recently, gunshot wounds to the brain came to national and international attention on January 8, 2011, when US Congresswoman Gabrielle Gifford was shot in the brain. Her successful recovery highlights the need for evidence-based treatment algorithms for management of patients with gunshot wound to the brain.[7]

At our institution, starting in 2008, we implemented the policy of aggressively resuscitating all patients with

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Abbreviations and Acronyms
AIS = Abbreviated Injury Scale
GCS = Glasgow Coma Scale
INR = international normalized ratio
PCC = prothrombin complex concentrate
SBP = systolic blood pressure

gunshot wound to the brain, irrespective of their admission GCS score, because outcomes in these patients are often not predictable, especially in the early stages of care. The aim of this study was to determine outcomes in patients with gunshot wound to the brain presenting to our institution over time. We hypothesized that aggressive management can increase survival and the rate of organ donation in patients with gunshot wound to the brain.

METHODS

After the approval from the Institutional Review Board (IRB) at the University of Arizona, we performed a 5-year (January 2007 through December 2011) retrospective analysis of all the patients with gunshot wound to the head presenting to our level 1 trauma center. Patients with only gunshot wound to the brain were included. We defined gunshot wound to the brain as projectile penetrating the dura with injury to the brain tissue. Patients with gunshot wound to the face and head without brain penetration were excluded from this study.

We reviewed the patients' electronic medical records and collected the following data points: age, sex, mode of injury (suicide, homicide, or accident), pattern of brain injury (uni-hemispheric or bi-hemispheric), time in the emergency department, and vital signs on presentation: systolic blood pressure (SBP); heart rate; temperature; Glasgow Coma Scale (GCS) score; laboratory parameters on presentation, which included international normalized ratio (INR) and platelet count; volume of crystalloid and blood products (packed red blood cells, platelets, fresh frozen plasma, and cryoprecipitate) received in the during the first 24 hours of admission; use, duration, and type of vasopressors; neurosurgical intervention details (craniotomy, craniectomy, intracranial pressure monitor); time to neurosurgical intervention; hospital and ICU length of stay; discharge disposition; GCS on discharge; organ donation details; and in-hospital mortality. The Injury Severity Score (ISS) and the abdominal Abbreviated Injury Scale (AIS) score were obtained from the trauma registry.

At our institution, a change in clinical practice was established in 2008. Although there was no strict protocol for management of patients with gunshot wound to the brain, the trauma surgeons practiced aggressive resuscitation for all patients with gunshot wound to the brain, irrespective of the pattern of head injury and the GCS on presentation. This change was implemented and has become a standard of practice at our institution. Aggressive management was defined as resuscitation with 1 or more of the following: blood products, hyperosmolar therapy, vasopressors, and/ or prothrombin complex concentrate (PCC).

Blood product resuscitation was defined as the units of packed red blood cells, of fresh frozen plasma, and of platelets administered. Hyperosmolar therapy was defined as resuscitation with hypertonic saline. For factor replacement, we used 3-factor PCC (Profilnine SD, Grifols Biologicals) at a dosage of 25 units/kg. Vasopressor support was defined as use of vasopressin, dopamine, epinephrine, or norepinephrine. Aggressive management was based on the principles of damage control resuscitation, which was composed of the following: early use of blood products, 1:1 ratio of pack red blood cells: fresh frozen plasma, early use of hypertonic saline, and factor replacement for treatment of coagulopathy.

Coagulopathy was defined by an INR $\geq$ 1.5. Neurosurgical intervention was defined as craniotomy or craniectomy, and time to neurosurgical intervention was defined as the time from admission to the emergency department to the start of the skin incision.

The primary outcomes measure of our study was survival after gunshot wound to the brain over time. The secondary outcomes measure was organ donation. We defined organ donation as patients who donated only solid organs.

Data are reported as mean $\pm$ standard deviation (SD) for continuous variables, proportions as nominal variables, and as median (range) for ordinal variables. We performed the Student's *t*-test to assess differences between the 2 groups for parametric variables and Mann Whitney U test for nonparametric variables. Chi-square test was performed to compare differences between the 2 groups for ordinal and nominal variables. To compare change in survival rate and rate of organ donation over the years, we used the 1-way analysis of variance (ANOVA) and post hoc analysis. A univariate analysis was performed to assess factors associated with survival. Factors with a p value $\leq$ 0.2 were used in a multivariate logistic regression model to identify independent factors associated with survival after gunshot wound to the brain. A p value $\leq$ 0.05 was considered significant. We used the Statistical Package for Social Sciences (SPSS, version 20; SPSS, Inc) for data analysis.

RESULTS

A total of 132 patients with gunshot wounds to the brain were included; 30.3% (n = 40) of these patients survived.