Original Investigation | September 30, 2015

The Effect of a Golden Hour Policy on the Morbidity and Mortality of Combat Casualties FREE ONLINE FIRST

Russ S. Kotwal, MD, MPH[1,2,3]; Jeffrey T. Howard, PhD[1]; Jean A. Orman, ScD, MPH[1]; Bruce W. Tarpey, BS[1]; Jeffrey A. Bailey, MD[1,2]; Howard R. Champion, FRCS[2]; Robert L. Mabry, MD[1]; John B. Holcomb, MD[4]; Kirby R. Gross, MD[1,2]

[1]Joint Trauma System, United States Army Institute of Surgical Research, Joint Base San Antonio–Ft Sam Houston, Texas

[2]Uniformed Services University of the Health Sciences, Bethesda, Maryland

[3]Texas A&M Health Science Center College of Medicine, College Station

[4]Center for Translational Injury Research, The University of Texas Medical School at Houston

JAMA Surg. Published online September 30, 2015. doi:10.1001/jamasurg.2015.3104

ABSTRACT

Importance The term *golden hour* was coined to encourage urgency of trauma care. In 2009, Secretary of Defense Robert M. Gates mandated prehospital helicopter transport of critically injured combat casualties in 60 minutes or less.

Objectives To compare morbidity and mortality outcomes for casualties before vs after the mandate and for those who underwent prehospital helicopter transport in 60 minutes or less vs more than 60 minutes.

Design, Setting, and Participants A retrospective descriptive analysis of battlefield data examined 21 089 US military casualties that occurred during the Afghanistan conflict from September 11, 2001, to March 31, 2014. Analysis was conducted from September 1, 2014, to January 21, 2015.

Main Outcomes and Measures Data for all casualties were analyzed according to whether they occurred before or after the mandate. Detailed data for those who underwent prehospital helicopter transport were analyzed according to whether they occurred before or after the mandate and whether they occurred in 60 minutes or less vs more than 60 minutes. Casualties with minor wounds were excluded. Mortality and morbidity outcomes and treatment capability–related variables were compared.

Results For the total casualty population, the percentage killed in action (16.0% [386 of 2411] vs 9.9% [964 of 9755]; $P < .001$) and the case fatality rate ([CFR] 13.7 [469 of 3429] vs 7.6 [1344 of 17 660]; $P < .001$) were higher before vs after the mandate, while the percentage died of wounds (4.1% [83 of 2025] vs 4.3% [380 of 8791]; $P = .71$) remained unchanged. Decline in CFR after the mandate was associated with an increasing percentage of casualties transported in 60 minutes or less (regression coefficient, –0.141; $P < .001$), with projected vs actual CFR equating to 359 lives saved. Among 4542 casualties (mean injury severity score, 17.3; mortality, 10.1% [457 of 4542]) with detailed data, there was a decrease in median transport time after the mandate (90 min vs 43 min; $P < .001$) and an increase in missions achieving prehospital helicopter transport in 60 minutes or less (24.8% [181 of 731] vs 75.2% [2867 of 3811]; $P < .001$). When adjusted for injury severity score and time period, the percentage killed in action was lower for those critically injured who received a blood transfusion (6.8% [40 of 589] vs 51.0% [249 of 488]; $P < .001$) and were transported in 60 minutes or less (25.7% [205 of 799] vs 30.2% [84 of 278]; $P < .01$), while the percentage died of wounds was lower among those critically injured initially treated by combat support hospitals (9.1% [48 of 530] vs 15.7% [86 of 547]; $P < .01$). Acute morbidity was higher among those critically injured who were transported in 60 minutes or less (36.9% [295 of 799] vs 27.3% [76 of 278]; $P < .01$), those severely and critically injured initially treated at combat support hospitals (severely injured, 51.1% [161 of 315] vs 33.1% [104 of 314]; $P < .001$; and critically injured, 39.8% [211 of 530] vs 29.3% [160 of 547]; $P < .001$), and casualties who received a blood transfusion (50.2% [618 of 1231] vs 3.7% [121 of 3311]; $P < .001$), emphasizing the need for timely advanced treatment.

Conclusions and Relevance A mandate made in 2009 by Secretary of Defense Gates reduced the time between combat injury and receiving definitive care. Prehospital transport time and treatment capability are important factors for casualty survival on the battlefield.

INTRODUCTION

Minimizing time between critical injury and definitive care has long been a hallmark and metric of trauma systems, particularly in war, where devastating injuries result in death occurring predominantly before hospital arrival.[1-3] Despite advances in battlefield trauma systems, especially in prehospital care,[4-6] there are still potentially preventable deaths associated largely with torsal exsanguination.[3,7] Thus, efficient and effective use of prehospital helicopter transport, and associated en route care, are of paramount importance.

Prehospital transport time was reduced from 10 hours in World War II to 5 hours in the Korean conflict to 1 hour in the Vietnam conflict,[8] primarily owing to helicopters, which were first used in the Korean conflict.[9-12] Although helicopters are vulnerable to hostile fire and risk of crashing during unfavorable environmental conditions, their advantages of range and speed across difficult terrain and ability to land in small areas permitted more rapid prehospital transport and potential reduction of morbidity and mortality in critically wounded casualties.[11]

Rapid helicopter evacuation continued to influence survival from combat trauma during the Vietnam conflict,[13,14] which solidified the role of helicopters for prehospital battlefield transport and convinced surgeons returning from the conflict to use helicopters in civilian practice along with trauma centers and regional trauma systems. There are now more than 250 civilian helicopter programs in the United States and as many as 1000 worldwide.

Recognizing that trauma patients reaching definitive care sooner had a better chance for survival, one prior military surgeon, R Adams Cowley, established Baltimore's Shock Trauma Center and a statewide system of care served by Maryland police helicopters piloted by Vietnam veterans. He also coined the well-known term *golden hour* to promote this urgency between injury and care.[15] Despite general agreement that prompt access to appropriate care is essential for the critically injured, evidence-based validation of the golden hour has remained elusive.[15-21]

In addition to speed, helicopters provided opportunity for earlier advanced care. Although small helicopters used during the Korean conflict could carry only patients, larger helicopters used in the Vietnam conflict also carried flight medics with basic training. While these medics provided favorable care within their scope of practice, recent US military use of critical care–trained flight paramedics and UK military use of medical teams (physician, nurse, and paramedics) on helicopters in Afghanistan demonstrated casualty survival benefit from advanced expertise and capability delivered earlier through en route care.[22-25] Nearly all civilian medical helicopter programs have already integrated advanced health care professionals and capability.

With the premise that battlefield casualties would gain additional benefit from further reduced time between injury and care and a firm belief that 1 hour was a matter of morale and moral obligation to the troops, on June 15, 2009, Secretary of Defense Robert M. Gates mandated a standard of 60 minutes or less, from call to arrival at the treatment facility, for prehospital helicopter transport of US military casualties with critical injuries,[26] cutting in half the previous goal of 2 hours,[27] and aligning with the concept of the golden hour. To provide novel insights for military and civilian trauma systems, this study evaluated compliance with this new mandate for prehospital helicopter transport in 60 minutes or less and described patient injury, treatment, and transport time relative to morbidity and mortality outcomes.

METHODS

A retrospective descriptive analysis of US military combat casualties in Afghanistan from September 11, 2001, to March 31, 2014, was performed as a quality improvement project. Non–US military personnel were excluded because data, especially for follow-up, were not available or reliable. Analysis was conducted from September 1, 2014, to January 21, 2015. This study met US Army Institute of Surgical Research regulatory requirements.

To compare combat casualties, both wounded in action and killed in action (KIA), according to whether they occurred before or after the mandate and with other conflicts, aggregate data for the total population were obtained from the Department of Defense Manpower Data Center and analyzed using 4 combat casualty care statistical definitions: (1) percentage returned to duty in 72 hours or less (RTD), (2) percentage KIA, (3) percentage died of wounds (DOW), and (4) case fatality rate (CFR).[28,29] Casualties who underwent prehospital helicopter transport were further evaluated. However, casualties with minor wounds (categorized as RTD) were excluded because they appropriately lacked urgency for transport. Prehospital flight data, including time stamps (injury, aircraft call, launch, scene arrival, and arrival at treatment facility), were matched with Department of Defense Trauma Registry casualty data and Armed Forces Medical Examiner autopsy data and categorized (≤60 minutes vs >60 minutes) based on overall helicopter mission time from call to arrival at the treatment facility.

Three primary outcomes of mortality were measured: overall mortality and its 2 components, KIA mortality and DOW mortality. Four secondary outcomes of acute morbidity as identified by treatment facility–documented complications or *International Classification of Diseases, Ninth Revision* codes were also measured: amputation, cardiac arrest, coagulopathy, and shock. Demographic and injury-related variables included age, sex, military injury severity score (ISS), mechanism of injury (explosion, gunshot, blunt trauma, or other), and primary body region injured (head, neck, chest, abdomen, extremity, or external). Treatment-related variables included blood transfusion (massive transfusion [MT], nonmassive transfusion [NMT], prehospital transfusion [PHT]) and type of initial receiving treatment facility (forward surgical team or combat support hospital [CSH] or their equivalents). *Massive transfusion* is defined as 10 U or more of packed red blood cells administered within the first 24 hours following injury. Injury severity score groupings are per American College of Surgeons guidelines.[30]

Outcome differences were assessed using χ^2 significance testing. Trends for CFR vs percentage of casualties transported in 60 minutes or less were analyzed by applying regression models to premandate data and to estimate the expected CFR in the postmandate period. The difference between the observed and expected CFR at the end of the observation period was used to estimate the number of lives saved in the postmandate period. Unadjusted individual-level differences in demographic, injury, treatment, and outcome variables were evaluated using the χ^2, the *t* test, and the Wilcoxon rank sum test. The Cochrane-Mantel-Haenszel test was used to evaluate ISS and time period–adjusted differences in individual-level KIA mortality, DOW mortality, and acute morbidity. The number needed to treat was calculated as 1/absolute difference. Analyses were performed using SAS, version 9.2 (SAS Institute, Inc).

RESULTS

Table 1 depicts complete aggregate data for the total US military casualty population (N = 21 089) for the Afghanistan conflict study period. Compared with the period before the mandate, the period after the mandate saw an increase in percentage RTD (33.5% [1018 of 3043] to 47.3% [7905 of 16 696]; $P < .001$), a decrease in percentage KIA (16.0% [386 of 2411] to 9.9% [964 of 9755]; $P < .001$) and CFR (13.7 [469 of 3429] to 7.6 [1344 of 17 660]; $P < .001$), and no significant difference in percentage DOW (4.1% [83 of 2025] vs 4.3% [380 of 8791]; $P = .71$). The Afghanistan conflict had a lower percentage KIA and CFR compared with other military conflicts but a higher percentage DOW compared with World War II and the Vietnam conflict, consistent with findings reported earlier in the Afghanistan conflict.[29]

Table 1. US Military Combat Casualty Care Statistics in the Afghanistan Conflict and Historical Conflicts[a]

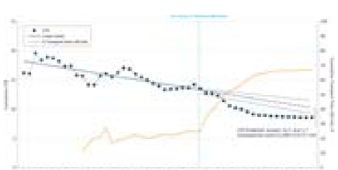
View Large | Save Table | Download Slide (.ppt) | View in Article Context

Figure 1 depicts trends for cumulative CFR and percentage of transport times 60 minutes or less, with significant association in the postmandate period (regression coefficient = −0.141; $P < .001$). The CFR declined throughout the premandate period, followed by a more rapid decline after the mandate. Simultaneously, the percentage of casualties transported in 60 minutes or less increased gradually during the premandate period, then rapidly increased after the mandate. If no mandate had been issued, linear model projections predict a CFR of 10.3 at the end of the study period vs 8.6 actually observed, a difference of 1.7 that equates to 359 lives saved.

Figure 1.

Case Fatality Rate and Transport Time

Trend in case fatality rate (CFR) based on linear model where CFR = 0.183 + (−0.002 × quarterly time period). Model $R^2 = 0.625$. Linear model projections (dashed line) surrounded by 95% CIs (dotted lines) predict a CFR of 10.3 (95% CI, 8.7-11.9) at the end of the study period compared with the CFR of 8.6 actually observed, for a difference of 1.7, which equates to potentially 359 lives saved. Logarithmic and higher-order polynomial models had inferior model fit characteristics compared with the linear model. Stratified regression analysis of transport time and CFR trends conducted separately for the periods before and after the mandate showed no association between transport time and CFR in the period before the mandate (regression coefficient, 0.058; $P = .48$), but they showed a highly significant association in the period after the mandate (regression coefficient, −0.141; $P < .001$) and an overall correlation coefficient of −0.96 ($P < .001$) for the association between transport time in 60 minutes or less and CFR.

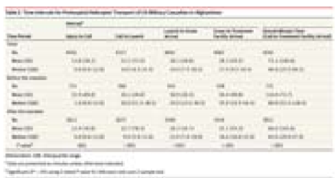


View Large | Save Figure | Download Slide (.ppt) | View in Article Context

Of 21 089 casualties, 12 166 (total – RTD) met criteria for potential further exploratory study of individual-level data. Of 19 148 helicopter transport cases available for review, 5985 (31.3%) lacked patient identification, flight data, or both and 8621 did not meet inclusion criteria. Excluded were non–US military (n = 3124) and US military categorized as RTD (n = 4780), interfacility transfer (n = 448), nontrauma or disease (n = 215), and cancelled flights (n = 54), which left 4542 cases for study of individual-level data (eFigure in the Supplement).

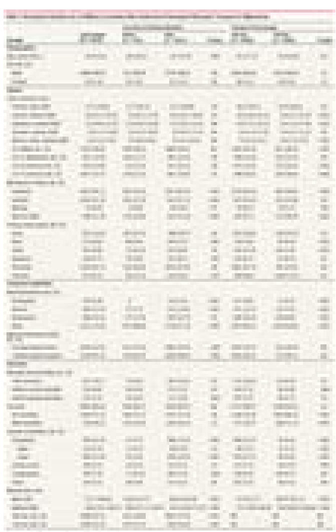
Table 2 and Table 3 show results for casualties with sufficient data for additional individual-level analysis. As data were available for only 37.3% (4542 of 12 166) of the population, the study was limited to descriptive analyses using cross-tabulations. Among these 4542 casualties (4480 male [98.6%]; mean [SD] age, 25.4 [5.5] years; and 4085 survivors [89.9%]), 3048 [67.1%] experienced helicopter evacuation in 60 minutes or less.

Table 2. Time Intervals for Prehospital Helicopter Transport of US Military Casualties in Afghanistan



View Large | Save Table | Download Slide (.ppt) | View in Article Context

Table 3. Descriptive Statistics for US Military Casualties Who Underwent Prehospital Helicopter Transport in Afghanistan



View Large | Save Table | Download Slide (.ppt) | View in Article Context

Compared with transport time before the mandate, reductions in prehospital transport time were seen across all time intervals after the mandate ($P \leq .002$), with a 52% median overall transport time reduction from 90 minutes to 43 minutes ($P < .001$) and an increase in prehospital transport missions that achieved transport times of 60 minutes or less (before the mandate, 24.8% [181 of 731]; after the mandate, 75.2% [2867 of 3811]; $P < .001$). Patients with transport times of 60 minutes or less had higher mortality (10.9% [331 of 3048] vs 8.4% [126 of 1494]; $P = .01$) and acute morbidity (18.7% [571 of 3048] vs 11.2% [168 of 1494]; $P < .001$) compared with those whose transport times were longer than 60 minutes. However, these patients also tended to have injuries with higher ISS (mean, 18.5 vs 14.9; $P = .01$) as well as a higher prevalence of chest injuries (11.0% [335 of 3048] vs 7.8% [116 of 1494]; $P < .001$), abdominal injuries (8.3% [253 of 3048] vs 6.5% [97 of 1494]; $P = .03$), and explosive blast injuries (69.2% [2110 of 3048] vs 56.6% [845 of 1494]; $P < .001$).

Differences were observed in capability-related variables of blood transfusion and initial treatment facility. The percentage of patients who received MT (7.3% [53 of 731] vs 14.0% [532 of 3811]; $P < .001$), NMT (11.9% [87 of 731] vs 14.7% [559 of 3811]; $P = .05$), and PHT (0% [0 of 731] vs 3.5% [132 of 3811]; $P < .001$) was greater after the mandate. Similarly, patients who received MT (15.5% [471 of 3048] vs 7.6% [114 of 1494]; $P < .001$), NMT (16.4% [500 of 3048] vs 9.8% [146 of 1494]; $P < .001$), and PHT (4.0% [121 of 3048] vs 0.7%

[11 of 1494]; $P < .001$) were more likely to have had transport times of 60 minutes or less. In addition, the percentage of patients who were delivered initially to a CSH (42.4% [310 of 731] vs 48.0% [1828 of 3811]; $P = .006$) was greater after the mandate.

Unadjusted data showed no difference before vs after the mandate in overall mortality (9.8% [72 of 731] vs 10.1% [385 of 3811], respectively; $P = .83$), an increase in KIA mortality (4.9% [36 of 731] vs 7.2% [274 of 3811]; $P = .03$), and a decrease in DOW mortality (4.9% [36 of 731] vs 2.9% [111 of 3811]; $P = .005$). Morbidity also differed because the total percentage of amputations (7.3% [53 of 731] vs 13.3% [506 of 3811]; $P < .001$) and amputations of the lower extremity (5.6% [41 of 731] vs 12.0% [458 of 3811]; $P < .001$) were more common after the mandate, and coagulopathy (10.5% [77 of 731] vs 7.4% [281 of 3811]; $P = .004$) was more common before the mandate. Since mortality outcomes among this detailed sample were either unchanged or opposite those observed in Table 1 for the total population, these unadjusted numbers do not account for ISS and are likely conservative and biased toward the null from underrepresentation of KIA deaths in the detailed sample, particularly in the period before the mandate.

Figure 2 shows KIA mortality, DOW mortality, and acute morbidity by type of treatment facility, type of blood transfusion, and transport time, adjusted for ISS and whether the injury time period was before or after the mandate. The rate of KIA mortality was lower for critically injured who received a blood transfusion (6.8% [40 of 589] vs 51.0% [249 of 488]; $P < .001$), lower for severely and critically injured casualties who received MT (0% [0 of 169] vs 4.7% [12 of 253]; $P < .001$; and 3.2% [12 of 372] vs 51.0% [249 of 488], respectively; $P < .001$), critically injured casualties who received NMT (12.9% [28 of 217] vs 51.0% [249 of 488]; $P < .001$), and critically injured casualties who were transported in 60 minutes or less (25.7% [205 of 799] vs 30.2% [84 of 278]; $P < .01$). The rate of DOW mortality was lower for critically injured casualties initially treated at a CSH (9.1% [48 of 530] vs 15.7% [86 of 547]; $P < .01$). Those receiving PHT had a lower rate of KIA mortality (2.3% [3 of 132] vs 7.0% [308 of 4410]; $P = .04$) and no difference in rate of DOW mortality. Acute morbidity was higher for critically injured casualties who were transported in 60 minutes or less (36.9% [295 of 799] vs 27.3% [76 of 278]; $P < .01$), for severely injured and critically injured casualties initially treated at a CSH (51.1% [161 of 315] vs 33.1% [104 of 314]; $P < .001$; and 39.8% [211 of 530] vs 29.3% [160 of 547], respectively; $P < .001$), and for all ISS casualty groups who received blood transfusions (50.2% [618 of 1231] vs 3.7% [121 of 3311]; $P < .001$), which emphasizes the need for rapid transport and advanced treatment capabilities. For critically injured casualties, the estimated number needed to treat to prevent KIA mortality for those receiving MT, NMT, or PHT compared with similar casualties who received no blood transfusion was 2 (1/[249 of 488] – [12 of 372]), 3 (1/[249 of 488] – [28 of 217]), and 4 (1/[286 of 994] – [3 of 83]), respectively. For the entire population regardless of ISS, the estimated number needed to treat to prevent KIA mortality for those receiving MT, NMT, and PHT was 17 (1/[264 of 3311] – [12 of 585]), 39 (1/[264 of 331] – [35 of 646]), and 21 (1/[308 of 4410] – [3 of 132]), respectively.

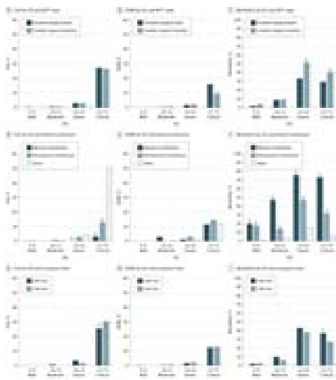
Figure 2.

Rates Adjusted for Injury Time Period (Before vs After Mandate) of Killed in Action (KIA) Mortality, Died of Wounds (DOW) Mortality, and Acute Morbidity, by Injury Severity Score (ISS) and Type of Medical Treatment Facility (MTF), Blood Transfusion, and Transport Time

The data provide 12 cases labeled as KIA who also received a massive transfusion; although these cases were dead on arrival to an MTF, heroic measures were undertaken. For blood transfusion, sample sizes were too small to evaluate prehospital transfusion (PHT) using the Cochrane-Mantel-Haenszel test. However, KIA mortality, DOW mortality, and acute morbidity (defined by presence of amputation, cardiac arrest, coagulopathy, and/or shock) were compared between patients who received PHT (n = 132) and patients who did not (n = 4410). Of patients who received PHT, 2.3% (3 of 132) were KIA, while 7.0% (308 of 4410) of patients who did not receive PHT were KIA ($\chi^2_1 = 4.460$; $P = .04$). Of patients who received PHT, 5.3% (7 of 132) were DOW, while 3.2% (141 of 4410) of patients who did not receive PHT were DOW ($\chi^2_1 = 1.803$; $P = .18$). Of patients who received PHT, 80.3% (106 of 132) experienced acute morbidity, while 14.4% (633 of 4410) of patients who did not receive PHT experienced acute morbidity ($\chi^2_1 = 409.175$; $P < .001$). Statistical comparisons are based on the Cochrane-Mantel-Haenszel test with adjustment for ISS and injury time period (before vs after the mandate).

[a]$P < .01$.

[b]$P < .001$.



View Large | Save Figure | Download Slide (.ppt) | View in Article Context

DISCUSSION

Time and treatment capability are important factors for the survival of critically injured casualties. In the civilian sector, increased prehospital capability and expertise, as well as rapid transport to surgical and hospital care, have been shown to improve trauma outcomes.[31-37] Within the Department of Defense, advances in prehospital initiatives are subject to fragmented ownership and decision making. Decisions are made or deferred by any number of leaders at any level within the chain of command.[38] The 2009 Secretary of Defense mandate of a prehospital medical practice is unique. It sent a clear message affirming ownership, priority, and intent that translated into practice and compliance, as evidenced by the shift from 24.8% to 75.2% of missions achieving transport in 60 minutes or less.

Although challenging to measure and subject to confounding, secondary effects resulting from the mandate that contributed to achieving the mandated time included streamlined authority and helicopter launch procedures, increased number and dispersion of Army helicopters, and the addition of Air Force helicopters to assist with the Army prehospital transport mission. As decreased time from critical injury to treatment capability was the underlying goal, personnel with increased expertise (blood transfusion protocol–trained basic medics, critical care paramedics, and critical care nurses) were trained and assigned to prehospital flights more routinely, resulting in earlier availability of blood products and other advanced care.

In addition, an increase in the number and dispersion of small but mobile forward surgical teams across the battlefield brought major surgical capability even closer to the point of injury and provided an alternative to transporting patients longer distances to large, but less mobile, civilian trauma center–equivalent CSHs. However, as we found DOW mortality to be lower for critically injured casualties initially treated at CSHs, future detailed study is needed for comprehensive comparison of the capabilities and outcome differences between facility types.

In our study, prehospital helicopter transport time shortened, affording critical casualties who would have previously died in the field the opportunity to receive en route and facility-based care. Other critical casualties who previously would have died in treatment facilities were also afforded care earlier. Moreover, the observed reduction in KIA mortality was not accompanied by a proportional change in DOW mortality, suggesting that rapid evacuation combined with earlier en route and facility-based care resulted in survival but with risk for attendant morbidity or DOW mortality status. In summary, as transport time decreased and capabilities increased, casualties who would previously have been in the KIA mortality group survived outright or survived long enough that they shifted to the DOW mortality group, and casualties who would previously have been in the DOW mortality group were also surviving. Decreasing the time from injury to arrival at the treatment facility challenged the full measure of the trauma system with more critically injured casualties who then benefited from the care they received.

From the total casualty population, our study showed a significant survival benefit after the mandate, specifically as a result of a reduction in KIA mortality. An increase in injuries from explosions and amputations of the lower extremity in the period after the mandate also conveyed the changing nature of the etiologic factors of injury and the increased severity and complexity of wounds as the war evolved. As the prevailing mechanism of injury shifted from gunshot to explosion, it was accompanied by an inherent ability to generate multiple complex blast-related casualties with higher ISS.

Our finding that median transport time was reduced by 52% after the mandate is notable, especially given the wartime conditions in which the reduction was achieved. A meta-analysis and 30-year review of civilian trauma prehospital transport showed an overall 73-minute mean helicopter ambulance time for the interval between activation and hospital arrival.[32] Our study, which evaluated a helicopter evacuation system established and maintained by the US military for more than a decade in a hostile region more than 7000 miles away, also showed an overall 73-minute mean.

Evidence from the published literature shows that civilian patients with severe injury, particularly penetrating, thoracic, and brain trauma, benefit from more rapid evacuation.[34-36] McCoy et al[35] noted that patients with penetrating trauma and ISS greater than 15 had increased mortality with longer total prehospital transport times. Kidher and colleagues[34] found that patients with thoracic trauma and high ISS had reduced mortality associated with total prehospital transport times of less than 65 minutes. Dinh et al[36] noted that patients with severe head injuries had improved functional outcomes with a total prehospital transport time of 60 minutes or less and survival benefit when arriving within 90 minutes and within 120 minutes. A recent comprehensive and systematic review of the medical literature on the effect of prehospital time on the outcome of trauma patients also found a benefit of rapid transport for patients with traumatic brain injury and penetrating trauma, particularly those who are hypotensive.[37]

Comprehensive mortality studies of the Afghanistan and Iraq conflicts by Eastridge et al[3,7] reported that 91% of all potentially survivable deaths are related to hemorrhage and 77% are categorized as KIA, with the death occurring in the prehospital period before reaching a location capable of performing surgery. The KIA rate is a potential measure of weapon lethality, effectiveness of prehospital care, and availability of prehospital transport.[29] In our study, as availability of prehospital transport increased after the mandate, a decrease in KIA mortality was seen in spite of a simultaneous increase in ISS. The relatively large beneficial influence of blood transfusions on KIA mortality seen in our study may be explained by the fact that hemorrhage is the leading cause of potentially survivable combat trauma death. Increased availability of blood transfusions on evacuation platforms and quicker evacuation response allowed transfusions to be performed earlier en route and in the hospital, possibly enabling casualties to survive longer, albeit at a potential cost of DOW mortality or survival with morbidity.

Limitations of our study include the use of historical controls for pre-post comparisons and reliance on post hoc analysis of nonrandomized data, primarily owing to variance in data capture and collection that may have introduced bias; analysis of blood transfusions, particularly MTs, which has been known to contribute to survival bias; and use of ISS, which can confound pre-post comparisons and may underestimate complex battlefield wounds.[39] Battlefield prehospital data have proved challenging to collect, validate, and analyze for many reasons, including lack of a mandate to collect such data and lack of enforcement of prehospital documentation. Details for prehospital field care and ground transport are unknown because these data were not comprehensively documented, collected, or consolidated. Although protocols for prehospital blood transfusion resulted in reliable documentation of this practice, documentation of hemorrhage control (eg, tourniquets, hemostatic agents) and other prehospital interventions was sporadic, and their potential confounding and degree of influence on morbidity and mortality could not be reliably measured.

Since only 37.3% of potential individual-level analysis casualties had both prehospital flight data and treatment facility data that could be matched and since the total casualty population suggests underrepresentation for casualties injured before the mandate, adjustment for ISS and whether the injury time period was before or after the mandate had to be performed to account for these differences. Coupled with the fact that multiple variables contributing to outcomes were changing simultaneously, only descriptive interpretation was viable. A review of the published literature also lacked detailed prehospital flight data and analysis from historical conflicts for guidance or comparison. Although inherently challenging, future efforts must emphasize capture of prehospital data on the battlefield.

Despite limitations of our study, the data show that compliance with the 2009 mandate resulted in shorter transport times and enhancements to treatment capability that improved outcomes and potentially saved 359 lives. Trauma-related performance improvement must be derived from detailed documentation, registry-based data analysis, and quality metrics to establish benchmarks, decrease variance, prevent adverse events, and inform and adapt evidence-based prehospital practices and leadership decisions. To improve data quality and quantity, the Department of Defense Joint Trauma System recently improved and standardized prehospital documentation tools.[40-42] As of May 2015, the Department of Defense still has no mandate for prehospital documentation; however, the US forces commander in Afghanistan mandated prehospital documentation in 2013, and commensurate registries were developed to consolidate data.

Prehospital data are crucial since the greatest opportunity to prevent death from potentially survivable combat injury can be realized through prehospital efforts.[3,38] Future analysis should consider the actual tactical combat conditions of war to account for influences of weather, illumination, altitude, terrain, protective equipment, mass casualty scenarios, and enemy actions on prehospital efforts. As medical, environmental, and tactical considerations dictate prehospital practices and priority and mode of transport, a systems approach is paramount for optimizing casualty outcomes. Integrated trauma system practices and emergency medical services should be tailored to each battlefield to accommodate casualty demands within each unique environment. Future efforts should also include continuous review and translation of best practices between nations and the civilian and military sectors.

Time-related trauma outcome is inextricably linked to injury severity and effective treatment capability. If treatment is unavailable or ineffectively performed, then time, particularly in the setting of critical injury, is independently less relevant for optimizing outcomes. Casualty risk mitigation must consider the balance between speed and availability of treatment capability—rapid casualty transport to treatment, delivering treatment to the casualty, or both, as permitted by the environment and enemy threat.

CONCLUSIONS

A 2009 mandate by Secretary of Defense Gates reduced the time between critical injury and definitive care for combat casualties in Afghanistan. Despite evidence of increased severity and complexity of wounds from explosive devices, the combination of reduced prehospital transport time and increased treatment capability are likely contributors of casualty survival.

ARTICLE INFORMATION

Accepted for Publication: June 13, 2015.

Corresponding Author: Russ S. Kotwal, MD, MPH, Joint Trauma System, United States Army Institute of Surgical Research, 3698 Chambers Pass, Joint Base San Antonio-Ft Sam Houston, TX 78234 (russ.kotwal@us.army.mil).

Published Online: September 30, 2015. doi:*10.1001/jamasurg.2015.3104*.

Author Contributions: Dr Kotwal had full access to all the data in the study and takes responsibility for the integrity of the data and the accuracy of the data analysis.

Study concept and design: Kotwal, Orman, Bailey, Mabry, Holcomb.

Acquisition, analysis, or interpretation of data: Kotwal, Howard, Tarpey, Bailey, Champion, Mabry, Gross.

Drafting of the manuscript: Kotwal, Howard, Bailey, Champion, Mabry.

Critical revision of the manuscript for important intellectual content: Kotwal, Howard, Orman, Tarpey, Champion, Mabry, Holcomb, Gross.

Statistical analysis: Kotwal, Howard.

Administrative, technical, or material support: Kotwal, Howard, Tarpey, Bailey, Champion, Mabry.

Study supervision: Kotwal, Orman, Holcomb, Gross.

Conflict of Interest Disclosures: None reported.

Disclaimer: The views, opinions, and findings contained in this article are those of the authors and should not be construed as official or reflecting the views of the Department of Defense unless otherwise stated. This article was approved for public release by the US Army Institute of Surgical Research Operational Security Office and Public Affairs Office on January 21, 2015.

Previous Presentation: The Abstract of this article was presented at the Military Health System Research Symposium; August 17, 2015; Fort Lauderdale, Florida.

Additional Contributions: Susan West, BSN, and John Lira, MS, Department of Defense Joint Trauma System, consolidated casualty outcome data and Tamara Zubko, Office of the Armed Forces Medical Examiner, consolidated mortality data. They were not compensated for their contribution. Most important, we recognize the sacrifices of the combat casualties depicted in this article as well as their fellow servicemen who transported and provided care to them.

REFERENCES

1 Bellamy RF. The causes of death in conventional land warfare: implications for combat casualty care research. *Mil Med*. 1984;149(2):55-62.
PubMed

2 Champion HR, Bellamy RF, Roberts CP, Leppaniemi A. A profile of combat injury. *J Trauma*. 2003;54(5)(suppl):S13-S19.
PubMed

3 Eastridge BJ, Mabry RL, Seguin P, et al. Death on the battlefield (2001-2011): implications for the future of combat casualty care [published correction appears in *J Trauma Acute Care Surg*. 2013;74(2):706]. *J Trauma Acute Care Surg*. 2012;73(6)(suppl 5):S431-S437.
PubMed | Link to Article

4 Kotwal RS, Montgomery HR, Kotwal BM, et al. Eliminating preventable death on the battlefield. *Arch Surg*. 2011;146(12):1350-1358.
PubMed | Link to Article

5 Butler FK, Giebner SD, McSwain N, Salomone JP, Pons PT, eds. *PHTLS: Prehospital Trauma Life Support: Military Edition.*7th ed. St Louis, MO: Elsevier Mosby; 2011.

6 Butler FK Jr, Blackbourne LH. Battlefield trauma care then and now: a decade of tactical combat casualty care. *J Trauma Acute Care Surg*. 2012;73(6)(suppl 5):S395-S402.
PubMed | Link to Article

7 Eastridge BJ, Hardin M, Cantrell J, et al. Died of wounds on the battlefield: causation and implications for improving combat casualty care. *J Trauma*. 2011;71(1)(suppl):S4-S8.
PubMed | Link to Article

8 McNabney WK. Vietnam in context. *Ann Emerg Med*. 1981;10(12):659-661.
PubMed | Link to Article

9 Kater NM. Helicopter evacuation in Korea. *Med J Aust*. 1952;2(11):373-374.
PubMed

10 Pulaski EJ. War wounds. *N Engl J Med*. 1953;249(22):890-896.
PubMed | Link to Article

11 Neel SH Jr. Medical considerations in helicopter evacuation. *U S Armed Forces Med J*. 1954;5 (2):220-227.
PubMed

12 Neel SH Jr. Helicopter evacuation in Korea. *U S Armed Forces Med J*. 1955;6(5):691-702.
PubMed

13 Neel SH. Army aeromedical evacuation procedures in Vietnam: implications for rural America. *JAMA*. 1968;204(4):309-313.
PubMed | Link to Article

14 Haacker LP. Time and its effects on casualties in World War II and Vietnam. *Arch Surg*. 1969;98 (1):39-40.
PubMed | Link to Article

15 Lerner EB, Moscati RM. The golden hour: scientific fact or medical “urban legend”? *Acad Emerg Med*. 2001;8(7):758-760.
PubMed | Link to Article

16 Tallon JM. The “golden hour” paradigm. *Acad Emerg Med*. 2002;9(7):760.
PubMed | Link to Article

17 Lerner EB, Moscati RM. In reply to: the “golden hour” paradigm. *Acad Emerg Med*. 2002;9 (7):760.
PubMed

18 Newgard CD, Schmicker RH, Hedges JR, et al; Resuscitation Outcomes Consortium Investigators. Emergency medical services intervals and survival in trauma: assessment of the “golden hour” in a North American prospective cohort. *Ann Emerg Med*. 2010;55(3):235-246.e4.
PubMed | Link to Article

19 Berger E. Nothing gold can stay: EMS crashes, lack of evidence bring the golden hour concept under new scrutiny. *Ann Emerg Med*. 2010;56(5):A17-A19.
PubMed | Link to Article

20 Fleet R, Poitras J. Have we killed the golden hour of trauma? *Ann Emerg Med*. 2011;57(1):73-74.
PubMed | Link to Article

21 Newgard CD. In reply to: have we killed the golden hour of trauma? *Ann Emerg Med*. 2011;57(1):74-75.
PubMed | Link to Article

22 Mabry RL, Apodaca A, Penrod J, Orman JA, Gerhardt RT, Dorlac WC. Impact of critical care-trained flight paramedics on casualty survival during helicopter evacuation in the current war in Afghanistan. *J Trauma Acute Care Surg*. 2012;73(2)(suppl 1):S32-S37.
PubMed | Link to Article

23 Clarke JE, Davis PR. Medical evacuation and triage of combat casualties in Helmand Province, Afghanistan: October 2010-April 2011. *Mil Med*. 2012;177(11):1261-1266.
PubMed | Link to Article

24 Morrison JJ, Oh J, DuBose JJ, et al. En-route care capability from point of injury impacts mortality after severe wartime injury. *Ann Surg*. 2013;257(2):330-334.
PubMed | Link to Article

25 Apodaca A, Olson CM Jr, Bailey J, Butler F, Eastridge BJ, Kuncir E. Performance improvement evaluation of forward aeromedical evacuation platforms in Operation Enduring Freedom. *J Trauma Acute Care Surg*. 2013;75(2)(suppl 2):S157-S163.
PubMed | Link to Article

26 Gates RM. *Duty: Memoirs of a Secretary at War.* New York, NY: Random House; 2014:304-305.

27 Aeromedical evacuation. In: Lounsbury DE, Brengham M, Bellamy RF, eds. *Emergency War Surgery.* 3rd US revision. Washington, DC: Borden Institute; 2004.

28 Defense Casualty Analysis System. *Conflict casualties*. https://www.dmdc.osd.mil/dcas/pages/casualties.xhtml. Accessed December 1, 2014.

29 Holcomb JB, Stansbury LG, Champion HR, Wade C, Bellamy RF. Understanding combat casualty care statistics. *J Trauma*. 2006;60(2):397-401.
PubMed | Link to Article

30 American College of Surgeons. *Resources for optimal care of the injured patient 2014/resources repository.*https://www.facs.org/quality-programs/trauma/vrc/%20resources. Accessed May 8, 2015.

31 Baxt WG, Moody P. The impact of a rotorcraft aeromedical emergency care service on trauma mortality. *JAMA*. 1983;249(22):3047-3051.
PubMed | Link to Article

32 Carr BG, Caplan JM, Pryor JP, Branas CC. A meta-analysis of prehospital care times for trauma. *Prehosp Emerg Care*. 2006;10(2):198-206.
PubMed | Link to Article

33 Butler DP, Anwar I, Willett K. Is it the H or the EMS in HEMS that has an impact on trauma patient mortality? a systematic review of the evidence. *Emerg Med J*. 2010;27(9):692-701.
PubMed | Link to Article

34 Kidher E, Krasopoulos G, Coats T, et al. The effect of prehospital time related variables on mortality following severe thoracic trauma. *Injury*. 2012;43(9):1386-1392.
PubMed | Link to Article

35 McCoy CE, Menchine M, Sampson S, Anderson C, Kahn C. Emergency medical services out-of-hospital scene and transport times and their association with mortality in trauma patients presenting to an urban level I trauma center. *Ann Emerg Med*. 2013;61(2):167-174.
PubMed | Link to Article

36 Dinh MM, Bein K, Roncal S, Byrne CM, Petchell J, Brennan J. Redefining the golden hour for severe head injury in an urban setting: the effect of prehospital arrival times on patient outcomes. *Injury*. 2013;44(5):606-610.
PubMed | Link to Article

37 Harmsen AMK, Giannakopoulos GF, Moerbeek PR, Jansma EP, Bonjer HJ, Bloemers FW. The influence of prehospital time on trauma patients outcome: a systematic review. *Injury*. 2015;46 (4):602-609.
PubMed | Link to Article

38 Kotwal RS, Butler FK, Edgar EP, Shackelford SA, Bennett DR, Bailey JA. Saving lives on the battlefield: a Joint Trauma System review of pre-hospital trauma care in Combined Joint Operating Area—Afghanistan (CJOA-A) executive summary. *J Spec Oper Med*. 2013;13(1):77-85.
PubMed

39 Lawnick MM, Champion HR, Gennarelli T, et al. Combat injury coding: a review and reconfiguration. *J Trauma Acute Care Surg*. 2013;75(4):573-581.
PubMed | Link to Article

40 Kotwal RS, Butler FK, Montgomery HR, et al. The Tactical Combat Casualty Care casualty card TCCC guidelines—proposed change 1301. *J Spec Oper Med*. 2013;13(2):82-87.
PubMed

41 Nohrenberg JL, Tarpey BW, Kotwal RS. *Data informs operational decisions: the tactical evacuation project.US Army Aviat Dig.* October-December 2014:17-20.
http://www.rucker.army.mil/aviationdigest/images/Oct-Dec_100114.pdf. Accessed May 8, 2015.

42 US Army Institute of Surgical Research. *Joint Trauma System*.
http://www.usaisr.amedd.army.mil/10_jts.html. Updated March 16, 2015. Accessed May 8, 2015.