Advancing Combat Casualty Care Statistics and Other Battlefield Care Metrics

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ABSTRACT

Aggregate statistics can provide intra-conflict and inter-conflict mortality comparisons and trends within and between U.S. combat operations. However, capturing individual-level data to evaluate medical and non-medical factors that influence combat casualty mortality has historically proven difficult. The Department of Defense (DoD) Trauma Registry, developed as an integral component of the Joint Trauma System during recent conflicts in Afghanistan and Iraq, has amassed individual-level data that have afforded greater opportunity for a variety of analyses and comparisons. Although aggregate statistics are easily calculated and commonly used across the DoD, other issues that require consideration include the impact of individual medical interventions, non-medical factors, non-battle-injured casualties, and incomplete or missing medical data, especially for prehospital care and forward surgical team care. Needed are novel methods to address these issues in order to provide a clearer interpretation of aggregate statistics and to highlight solutions that will ultimately increase survival and eliminate preventable death on the battlefield. Although many U.S. military combat fatalities sustain injuries deemed non-survivable, survival among these casualties might be improved using primary and secondary prevention strategies that prevent injury or reduce injury severity. The current commentary proposes adjustments to traditional aggregate combat casualty care statistics by integrating statistics from the DoD Military Trauma Mortality Review process as conducted by the Joint Trauma System and Armed Forces Medical Examiner System.

Keywords: *combat casualty care statics; injury survivability mortality; trauma; battle injury; disease, non-battle injury*

Introduction

The seminal article entitled "Understanding Combat Casualty Care Statistics" was published by Holcomb et al. in 2006.[1] Subsequent application and interpretation of statistics outlined by this article have varied between studies through time.[2-6] This well-described heterogeneity includes the variable presence of medical and non-medical confounders (e.g., injury survivability, death preventability, environmental considerations), and these confounders are important when interpreting the effectiveness of medical interventions in reducing death.[4,5,7] Additionally, of 7,076 U.S. military fatalities from recent conflicts in Afghanistan and Iraq,[8] nearly a quarter (1,601; 23%) resulted from non-battle injury, and these are, by definition, excluded from traditional combat casualty care statistics. Although opportunities for improvement and prevention may differ, disease non-battle-injured fatalities (DNBI) also need ongoing surveillance and review. There are three main objectives of this article:

1. Review use of traditional combat casualty care statistics;
2. Discuss how traditional combat casualty care statistics can be integrated with mortality review statistics to better understand medical and non-medical solutions to reduce preventable death; and
3. Reiterate the importance of reducing DNBI death.

Traditional Combat Casualty Care Statistics

Holcomb et al.[1] delineated three combat casualty care statistics specific to battle-injured casualties: case fatality rate (CFR), percentage killed in action (%KIA; battle-injured prehospital deaths), and percent died of wounds (%DOW; battle-injured

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hospital deaths) (Table 1). The CFR for battle-injured casualties is described as "a measure of the overall lethality of the battlefield in those who receive combat wounds." As a summary statistic, the specific attribution of a decrease or increase in the battle-injured CFR must include an understanding of the %KIA, %DOW, percentage wounded in action (%WIA), and individual-level data on medical and non-medical interventions. An example that illustrates the importance and need for additional data and metrics is a graph on the cover of a journal published in 2013 that showed a decreasing trendline in the battle-injured CFR accompanied by an increasing trendline in the overall average injury severity score. While the accompanying narrative associated with the graph[2] acknowledged that the decrease in the battle-injured CFR was "multifactorial," it

TABLE 1 *Combat Casualty Care Statistics for Battle-Injured Casualties*

	Definition	Calculation	Limitations
Case fatality rate (CFR)	A measure of overall lethality of battlefield in those who receive combat wounds.	[(KIA + DOW)/(KIA + WIA)] × 100	Not a mortality rate, does not describe all deaths relative to population at risk. Insufficient granularity for detailed medical planning. Does not consider injury survivability or death preventability. Susceptible to administrative misclassification of battle versus disease non-battle injury for data not confirmed by forensic investigation. Susceptible to biased comparisons with previous conflicts that use different definitions and confounding from differences in medical and non-medical factors. Susceptible to biased longitudinal inferences, as injuries and deaths from specific theaters and operations are aggregated and cannot account for confounding from differences in medical factors, non-medical factors, injury survivability, and death preventability.
Percentage killed in action (%KIA)	A measure of (1) lethality of weapons, (2) effectiveness of prehospital care, and (3) availability of tactical evacuation.	{KIA/[KIA + (WIA – RTD)]} × 100	Does not consider injury survivability or death preventability. Susceptible to administrative misclassification of dead on arrival, KIA, and DOW for data not confirmed by forensic investigation. Susceptible to biased comparisons with previous conflicts that use different definitions and confounding from differences in medical and non-medical factors. Susceptible to biased longitudinal inferences, as injuries and deaths from specific theaters and operations are aggregated and cannot account for confounding from differences in medical factors, non-medical factors, injury survivability, and death preventability.
Percentage died of wounds (%DOW)	A measure of effectiveness of military treatment facility care and perhaps also the appropriateness of initial care, field triage, evacuation routes, and coordinated trauma system in mature settings.	[DOW/(WIA – RTD)] × 100	Does not consider injury survivability or death preventability. Susceptible to administrative misclassification of dead on arrival (DOA), KIA, and DOW for data not confirmed by forensic investigation. Susceptible to biased comparisons with previous conflicts that use different definitions and confounding from differences in medical and non-medical factors. Susceptible to biased longitudinal inferences, as injuries and deaths from specific theaters and operations are aggregated and cannot account for confounding from differences in medical factors, non-medical factors, injury survivability, and death preventability.
Potentially survivable (PS) injuries	An injury that the casualty might have survived if all required medical resources were available and appropriate medical care was optimally administered initially and throughout the continuum of care.	[S+PS/(S+PS+NS)] × 100	Susceptible to biased longitudinal inferences as injuries and deaths from specific theaters and operations are aggregated. By design, metric specific only to fatalities and not wounded in action. Does not assess the lethality from suicide and disease. Distinction between battle and non-battle injuries warranted.
Potentially preventable (PP) deaths	A death that occurred from a survivable or potentially survivable injury when the tactical situation was limited but did not prevent prompt and/or optimal medical care.	[P+PP/(P+PP+NP)] × 100	Susceptible to biased longitudinal inferences as injuries and deaths from specific theaters and operations are aggregated. By design, metric specific only to fatalities and not wounded in action. Does not assess the lethality from suicide and disease. Distinction between deaths from battle and non-battle injuries warranted.
Potentially survivable case fatality rate (PS-CFR)	A measure of the overall lethality of battlefield in those who receive potentially survivable combat wounds.	[(PS KIA + PS DOW)/ (PS KIA + PS WIA)] × 100	Susceptible to biased longitudinal inferences as injuries and deaths from specific theaters and operations are aggregated. Assumes all injured service members that survive (i.e., non-DOW wounded in action) do not have what would be considered non-survivable injuries (i.e., unexpected survivors). Does not assess the lethality from suicide, non-battle injuries, and disease. Distinction between battle and non-battle injuries warranted.
Potentially preventable case fatality rate (PP-CFR)	A measure of the overall lethality of battlefield in those who receive potentially survivable combat wounds.	[(PP KIA + PP DOW)/ (PP KIA + PP WIA)] × 100	Susceptible to biased longitudinal inferences as injuries and deaths from specific theaters and operations are aggregated. Assumes all injured Servicemembers that survive (i.e., wounded in action) do not have what would be considered non-survivable injuries. Does not assess the lethality from suicide, non-battle injuries, and disease. Distinction between deaths from battle and non-battle injuries warranted.

also stated that ". . . there is little doubt that this trend is in large part caused by the more systematic and rapid application of evidence-based trauma care to injured service personnel." Although the timely application of trauma care most certainly played a major part in the reduction of the CFR, how large a part trauma care actually played, and the degree to which each specific trauma care intervention contributed, is difficult to determine accurately given just the CFR. Also needing consideration for their part in reducing the CFR (i.e., preventive fraction) are non-medical interventions (e.g., logistics; tactics, techniques, procedures [TTPs]; personal protective equipment [PPE]).[7]

When a subsequent comprehensive review of available factors was published in 2019,[5] three military medicine efforts were attributed to reducing the battle-injured CFR: 1) increased use of limb tourniquets, 2) increased use of blood transfusions, and 3) rapid prehospital transport to facilities with surgical capabilities. Based on the available data, these three interventions accounted for an estimated 44% of the observed reduction in combat fatalities from 2001 to 2017.[5] The remaining 56% of the observed reduction was multifactorial and attributed to either other or unexplained factors. The other factors such as differences in mechanism of injury and injury severity may be proxies for non-medical factors that could not be assessed because of insufficient data for changes in environment, PPE, munitions, or offensive and defensive TTPs. Similarly, these unexplained factors may be improvements in medical care that lacked the adequate precision of documentation, data capture, and metrics to meaningfully evaluate these improvements. Notably, it was the focus on robust documentation and capture of tourniquet use and blood transfusions that allowed for the historically meaningful assessments of these interventions. Although the use of limb tourniquets and blood transfusions was a lesson relearned from prior conflicts and not unique military medical advancements of the 21st century, such interventions were first implemented in the hospitals and then used aggressively and ubiquitously during recent conflicts, resulting in improvements large enough to be reflected in the CFR.

Although primarily prehospital and resuscitative interventions were able to be measured, and not hospital or surgical interventions, the data support that reaching a surgical capability alive afforded survival benefit. Teasing out the individual contributions of the multiple simultaneous hospital-based interventions is difficult. Additionally, it can also be assumed that casualties that have life-saving prehospital interventions are reliant on subsequent timely and effective surgical interventions to affect ultimate survival. Thus, it is reasonable to hypothesize that casualty status transitions occurred due to non-medical, prehospital, and hospital interventions; that is, fatality categories were shifted from KIA to DOW, KIA to alive, and DOW to alive. Analyses of these transitions supported the interpretation that thousands of Servicemembers ultimately survived who would have otherwise died without non-medical, prehospital, and hospital interventions.[5] In turn, this suggests that hospital and surgical capabilities met the challenge of caring for more critically injured casualties who reached their facilities alive. However, the extent to which reductions in these aggregate statistics reflect adherence to current evidence-based trauma care practices or specific innovations or changes in hospital capability (e.g., novel procedures, standardized clinical practice guidelines, medical logistics, medical training, rapid transport to higher roles of care) remains difficult to discern.

Although there is no doubt that hospital care saves lives, data and metrics to measure the degree of impact of each life-saving hospital capability have been difficult to capture, as many hospital capabilities are interdependent and intertwined. While it is reasonable to hypothesize that hospital improvements occurred, it has been difficult to measure the impact of each specific hospital intervention on reducing the battle-injured CFR or %DOW because advancements in data and metrics to evaluate the trauma care system with this level of precision still need to be developed. Further, adequate assessment requires that a meaningful number of casualties with life-threatening injuries amenable to specific hospital interventions survive long enough to benefit from such care. Evidence of improvement in hospital care and outcomes certainly exists.[9] However, data and metrics are currently unable to tease out which specific hospital interventions were responsible for improvements that also had a large enough impact to be reflected in aggregate statistics such as the CFR or %DOW. This is an opportunity for improvement of data capture, metrics, and research on hospital combat casualty care.

Integrating Mortality Review Statistics

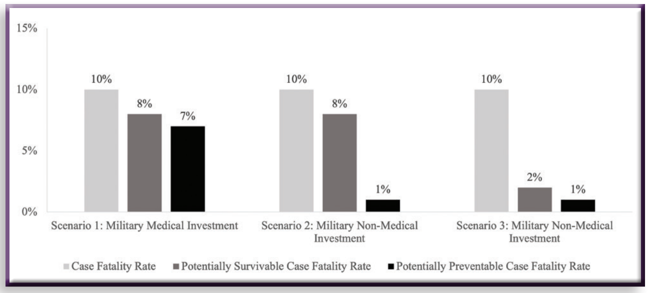
To better understand the specific impact of military medicine on reducing the battle-injured CFR, we recommend integrating the CFR with two additional statistics derived from the Military Trauma Mortality Review process[10–14]: percentage of fatalities with potentially survivable (PS) injuries and potentially preventable (PP) deaths (Table 1). Excluding fatalities deemed to have non-survivable injuries to formulate a PS case fatality rate (PS-CFR) and excluding fatalities deemed to have non-preventable deaths to formulate a PP case fatality rate (PP-CFR) allows for a clearer understanding of the optimal distribution of investments in medical and non-medical interventions that will yield a reduction in fatalities. The subtle but important distinction between PS-CFR and PP-CFR resides in the difference between the definitions of injury survivability and death preventability.[12–14] Injury survivability determinations (survivable [S], potentially survivable [PS], non-survivable [NS]) are based on assumptions of ideal circumstances, immediate knowledge of all injuries, and immediate availability of all Level I trauma center capabilities; whereas, death preventability determinations (preventable [P], potentially preventable [PP], non-preventable [NP]) are based on the reality of actual circumstances and the tactical influences of the environment and enemy, which impose limitations on optimal and timely care.

These revised combat casualty statistics highlight three main hypothetical scenarios (Figure 1). By incorporating data from both injury survivability and death preventability, these three scenarios can better inform the use of both medical and non-medical opportunities for improvements to reduce preventable death.

Hypothetical Scenario 1

Military medical investment argues for an opportunity to invest specifically in medical capabilities (e.g., revised prehospital and hospital clinical practice guidelines; increased medical personnel, training, and equipment; faster transport and more efficient hand-off of casualties) to reduce preventable death. The rationale is that the battle-injured CFR, PS-CFR, and PP-CFR statistics are similar. Therefore, in scenario 1 a high proportion of the fatalities sustained injuries deemed PS and did

FIGURE 1 *Combat casualty care statistic hypothetical scenarios to inform military and non-military investments to reduce death on the battlefield.*



not have optimal care delayed or prohibited by non-medical factors. That is, the graphs suggest that optimizing medical interventions will have a meaningful impact in reducing preventable deaths. An example might be ensuring that casualties with PS injuries receive care in accordance with recommended prehospital and hospital guidelines, as there are few non-medical factors either delaying or prohibiting implementation.

Hypothetical Scenario 2

Military non-medical investment argues for an opportunity to invest specifically in non-medical capabilities (i.e. TTPs; logistics of supply and resupply; environmental factors; PPE; experienced leadership) to allow optimal care for survivable injuries and reduce preventable death. This is because the battle-injured CFR and PS-CFR are similar, but the battle-injured PP-CFR statistic is meaningfully lower. This suggests that non-medical interventions are required before optimal medical care can be provided to casualties with PS injuries. That is, for medical interventions to be successful in reducing preventable deaths, the casualty must have the opportunity to receive optimal combat casualty care throughout the entire continuum of care. An example might be ensuring that a casualty with PS injuries in an austere environment (e.g., injured on the side of the mountain at night in extreme weather conditions) still has the opportunity via non-medical interventions to receive rapid prehospital, en route, and hospital care.

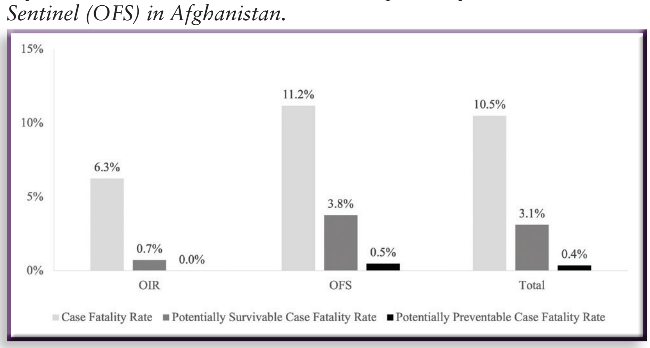
Hypothetical Scenario 3

Military non-medical investment is similar to scenario 2 and also argues for an opportunity to invest specifically in non-medical capabilities to reduce preventable death, albeit with a different rationale. In this case, the battle-injured CFR is meaningfully higher than both the battle-injured PS-CFR and PP-CFR. This means that the injuries sustained were highly lethal, resulting in catastrophic tissue destruction not amenable to current medical interventions. These fatalities are only amenable to primary and/or secondary interventions either preventing the battle injuries altogether or reducing the severity of injuries to a level deemed PS and then amenable to contemporary medical care. An example might be improved TTPs which prevent injuries from occurring or improvements in PPE which reduces the severity of an injury from NS to PS and thus amenable to medical intervention to prevent death.

Mortality Review Statistics from Combat Operations

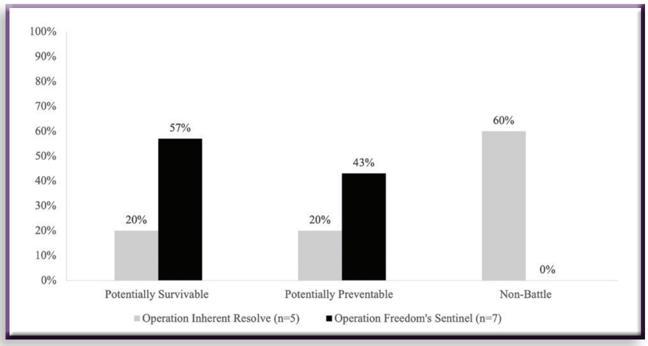
It is important to highlight that none of these scenarios argue for full investment in either strictly non-medical or medical improvements. Nor do they argue that improvements in medical care cannot be made among casualties with NS battle injuries. However, when a large proportion of battle injury fatalities are deemed to have either NS or PS injuries but NP death, this highlights non-medical solutions and primary and secondary prevention strategies that can potentially yield the largest decrease in preventable combat deaths. It also allows for the relatively limited medical research and training resources to be directed to areas where military medicine might have the largest impact. At this time, the full Military Trauma Mortality Review process has only been applied to fatalities from U.S. Special Operations Command, Operations New Dawn, Freedom's Sentinel (OFS), and Inherent Resolve (OIR). Ideally, the goal would be to use aggregate combat casualty care metrics along with individual-level data to inform opportunities for improvement in real time, which is a reasonable objective despite the potential limitations of small sample size among the fatalities evaluated to date. The application of these statistics to the two recent operations, OIR in Iraq and OFS in Afghanistan,[14] supports scenario 3 (Figure 2) or specific investment in non-medical solutions. It should be noted that this does not suggest divesting from lessons learned during recent conflicts to improve Tactical Combat Casualty Care, transfusion of blood products, and time to surgical and hospital capabilities (which includes a multitude of diagnostic and therapeutic interventions).

FIGURE 2 *Battle-injured case fatality rate, potentially survivable case fatality rate, and potentially preventable case fatality rate for Operation Inherent Resolve (OIR) in Iraq and Operation Freedom's Sentinel (OFS) in Afghanistan.*



It is for the complicated non-medical considerations highlighted above that a focus on the %DOW rather than the CFR has been touted as a more suitable metric to evaluate hospital care.[3,6] While it may carry important descriptive value, some have suggested that using %DOW as a measure of success or failure of hospital care is fundamentally flawed because confounding is not addressed.[4] While these limitations are acknowledged, investigators may potentially over-reach when comparing inter- and intra-conflict differences.[3,6] This is because a reliance on aggregate statistics fails to address critically important differences in anatomical wounding patterns, mechanisms of injury, severity of injuries, medical capabilities, weapon lethality, or tactical and operational differences. Additionally, implementation of the Military Trauma Mortality Review process,[12–14] rigorously designed to make determinations of injury survivability and death preventability, suggests that two-thirds of hospital combat fatalities from recent operations are NP. This is because hospital deaths are not universally associated with PS injuries and PP deaths (Figure 3). Two reasons for these results are: (1) administrative misclassifications and (2) casualties with NS injuries who nonetheless survive long enough to reach a military hospital. This may occur from rapid transport and/or heroic prehospital treatment. Administrative misclassifications in the DoD were reported to be more than 14%,[12] with the overwhelming majority being prehospital

FIGURE 3 *Non-suicide hospital trauma fatalities for Operation Inherent Resolve (OIR) in Iraq and Operation Freedom's Sentinel (OFS) in Afghanistan.*



deaths (KIA) misclassified as in-hospital deaths (DOW), thus artificially inflating the %DOW. This was caused by patients dead on arrival and patients with no return of spontaneous circulation after hospital arrival being classified as DOW when they were in fact KIA. Furthermore, 42% of hospital fatalities in OFS and OIR[14] were deemed to have PS injuries after the Military Trauma Mortality Review process was completed (Figure 3).

Not surprisingly, compared with prehospital combat deaths (where a casualty dies rapidly from a likely NS injury), a disproportionate number of fatalities with PS battle injuries and PP deaths occurred in hospital.[12–14] In our opinion, when the %DOW is compared longitudinally (e.g., over time, between subgroups of interest, etc.), a fair comparison requires inclusion of only casualties with PS battle injuries. Otherwise, it is not possible to determine whether an increase in %DOW is due to an increase in fatalities with PS battle injuries or simply an increase in the number of casualties arriving with NS battle injuries, systematic administrative misclassifications of KIAs as DOWs, etc. Therefore, while specific focus on an increase in %DOW is worthwhile to identify opportunities to improve hospital trauma care, this statistic must be supplemented with accompanying timely mortality reviews. In terms of mass casualty events and large-scale combat operations, any significant increase in the number of casualties or delays in casualty transport to a surgical capability can affect %DOW. For example, if prehospital casualty transport is significantly delayed, the hospital %DOW may actually improve as more critical casualties die before arriving at a hospital. Yet, such an improvement in %DOW would have nothing to do with any changes to hospital care.

Disease and Non-Battle Injury Death

These aggregate statistics (e.g., CFR, %DOW, %KIA) by definition exclude non-battle injuries and deaths. A separate statistic, DNBI has long been used to describe the important role of military medicine in reducing preventable deaths for all deployed Servicemembers. Non-battle injuries account for 1 in 3 injuries sustained in the deployed setting.[15] Further, these non-battle injuries along with disease from natural causes and suicide account for approximately 1 in 5 deaths of Servicemembers deployed in the theater of conflict.[16] DNBI has historically been a leading cause of death on the battlefield but has generally declined in more recent conflicts. As the goal of military medicine is to reduce death from all causes, metrics and mortality reviews for DNBI should receive renewed attention. It is for this reason we also recommend the use of the non-battle injury equivalents (CFR, %prehospital deaths, %hospital deaths, PS, PP, PS-CFR, PP-CFR). Because survivability and prevention of fatalities resulting from non-homicide manners of death (accident, natural causes, suicide) are inherently different from battle injury and homicide manner of death, we also recommend tracking the proportionate mortality from accident, natural causes, and suicide along with combat casualty care statistics. If the proportionate mortality from accident, natural causes, and suicide increases dramatically, as was the case during OIR,[14] then this warrants strategies to reduce mortality from these DNBI manners of death.

Summary and Conclusion

The majority of U.S. military combat fatalities have injuries deemed non-survivable. In addition to promoting advancements in all aspects of medical care, medical and non-medical leaders should strongly advocate for improving survival using primary and secondary prevention strategies that prevent injury or reduce injury severity. This may be especially appropriate during a conflict that lasts decades, requires Servicemembers to deploy multiple times, and places them at higher risk for chronic disease and premature mortality.

Accurate and complete data capture, from the point of injury through hospitalization and rehabilitation must be a priority in any future conflict. This includes collecting and analyzing data on all deaths using timely and comprehensive autopsies that incorporate advanced radiologic techniques. In addition to using these data for performance improvement, data along with recommendations should be shared with medical and non-medical leadership in near real time to inform decision-making. The integration of mortality review statistics can elucidate injury survivability and death preventability. This revised framework, alongside continuous mortality surveillance, may lead to an improved understanding of medical and non-medical solutions to save lives and eliminate preventable death.

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JCJ, RSK, JTH, and ELM conceived the concept and design of the commentary. All authors assisted in the acquisition, analysis, and interpretation of data. JCJ, RSK, JTH, and ELM contributed to the initial draft of the manuscript. All authors revised the manuscript for critically important intellectual content. All authors read and approved the final version of the manuscript to be published.

Disclaimer

The views, opinions, and findings contained in this article are those of the authors and should not be construed as official or reflecting views of the Department of Defense unless otherwise stated.

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