



**Original Research**

## Impact of Aeromedical Evacuation on Combat Injuries Results

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### Abstract:

This review article explores the significance of aeromedical evacuation in modern warfare and its impact on combat injury outcomes. Swift and efficient transportation of wounded soldiers from the battlefield to advanced medical facilities is crucial, as it directly influences survival rates and long-term well-being. This review delves into existing research, focusing on the success dimensions and challenges of aeromedical evacuation. Through an analysis of relevant literature, the synthesis of studies reveals multiple facets of success and complexities. The role of aeromedical evacuation, highlighted by various research studies, is paramount in bridging the gap between battlefield injuries and specialized medical attention. However, challenges include time sensitivity, physiological stressors, resource constraints, interdisciplinary collaboration, risk prioritization, data collection, casualty volume, environmental factors, continuity of care, and ethical considerations. Understanding these challenges informs strategies to optimize military medical responses, enhance patient outcomes, reduce suffering, and safeguard the well-being of combat personnel. Further research directions encompass exploring physiological stressors' impacts, evaluating delayed evacuation's feasibility, enhancing interdisciplinary collaboration, implementing innovative technologies, and addressing ethical considerations surrounding resource allocation. Therefore, while aeromedical evacuation is pivotal, its intricacies demand ongoing research and adaptable strategies to ensure optimal care for combat-injured personnel.

**Keywords:** Aeromedical evacuation, military medicine, medavac, combat injuries, military casualty care

## Background and Significance:

Aeromedical evacuation, commonly referred to as "medevac," represents a pivotal pillar within the framework of contemporary military healthcare systems. Medavac constitutes a sophisticated and indispensable approach to swiftly transporting wounded soldiers from the initial site of injury to advanced medical facilities, utilizing specially equipped aircraft staffed with skilled medical professionals. This integration of aviation expertise with comprehensive medical care is engineered to ensure prompt and tailored treatment for combat-injured individuals, thereby mitigating the severity of their injuries and heightening the prospects of their survival.

In the sphere of combat injuries, the imperative for streamlined and effective aeromedical evacuation cannot be overstated. Military engagements subject personnel to a myriad of injuries, often ranging from acute traumatic wounds to gravely life-threatening conditions. The urgency for rapid evacuation is underscored by the necessity to bridge the precarious gap between the battlefield and the specialized medical attention available at established healthcare facilities. Protracted delays in transportation can have dire consequences, including the exacerbation of injuries, heightened morbidity rates, and even potential fatalities.

Consequently, comprehending the intricacies inherent to aeromedical evacuation and its tangible impact on combat injuries is indispensable. This understanding holds the

potential to revolutionize casualty care strategies by informing the optimization of evacuation protocols, the enhancement of medical equipment on transport aircraft, and the fine-tuning of medical personnel's training. Ultimately, a more profound grasp of the medevac process can substantially elevate the efficacy of military medical responses, leading to improved patient outcomes, reduced suffering, and the safeguarding of the well-being of the individuals who courageously serve on the front lines of defense.

## Literature Review:

A Literature Review section of this discourse underscores the evolving understanding of the multifaceted implications of aeromedical evacuation on combat injuries through recent investigations. For instance, the work of Maddry et al. (2020) delves into the potential integration of unmanned aerial vehicles (UAVs) for prehospital combat casualty evacuation, as highlighted in "Advancing Prehospital Combat Casualty Evacuation." This retrospective analysis brings to light a noteworthy revelation - a substantial 47% of traumatically injured patients received life-saving interventions (LSIs) during the evacuation process (Maddry et al., 2020). Furthermore, a salient correlation emerges between patients exhibiting the highest abbreviated injury scale (AIS) severity scores in the head/neck region and their experiences of uneventful flights. Consequently, this finding amplifies the paramount importance of timely evacuation, particularly for individuals harboring potentially life-threatening injuries.

TABLE I.

## Patient Characteristics

Variable	No LSI en route (n=676)	Received LSI en route (n=591)	Difference (95% CI)
Male gender	663 (98.1)	585 (99.0)	-0.9 (-2.2 to 0.4)
Age	24.0 [22.0-28.0]	24.0 [21.0-27.0]	0.0 (0.0 to 1.0)
Injury type			
Blunt	22 (3.3)	4 (0.7)	2.6 (1.1 to 4.1)*
Blast	506 (74.9)	409 (69.2)	5.7 (0.7 to 10.6)*
Penetrating	157 (23.2)	188 (31.8)	-8.6 (-13.5 to -3.7)*
Burn	22 (3.3)	8 (1.4)	1.9 (0.3 to 3.5)*
Injury location			
Head	112 (16.6)	84 (14.2)	2.4 (-1.6 to 6.3)
Face	111 (16.4)	85 (14.4)	2.0 (-1.9 to 6.0)
Neck	39 (5.8)	31 (5.2)	0.5 (-2.0 to 3.0)
Chest	33 (4.9)	61 (10.3)	-5.4 (-8.4 to -2.5)*
Back	92 (13.6)	51 (8.6)	5.0 (1.5 to 8.4)*
Axilla	6 (0.9)	10 (1.7)	-0.8 (-2.1 to 0.5)
Abdomen	28 (4.1)	30 (5.1)	-0.9 (-3.3 to 1.4)
Pelvis	18 (2.7)	23 (3.9)	-1.2 (-3.2 to 0.7)
Groin	12 (1.8)	33 (5.6)	-3.8 (-5.9 to -1.7)*
Upper extremity	229 (33.9)	235 (39.8)	-5.9 (-11.2 to -0.6)*
Lower extremity/buttocks	373 (55.2)	396 (67)	-11.8 (-17.2 to -6.5)*
Amputation	44 (6.5)	116 (19.6)	-13.1 (-16.8 to -9.4)*
Military ISS	9.0 [5.0-14.0]	14.0 [6.0-25.0]	-4.0 (-5.0 to -3.0)*
Maximum AIS severity score	2.0 [2.0-3.0]	3.0 [2.0-4.0]	-1.0 (-1.0 to -1.0)*
Body region of maximum AIS			
1. Head/neck	126 (18.6)	72 (12.2)	6.5 (2.5 to 10.4)*
2. Face	43 (6.4)	17 (2.9)	3.5 (1.2 to 5.8)*
3. Chest	50 (7.4)	42 (7.1)	0.3 (-2.6 to 3.2)
4. Abdomen	53 (7.8)	32 (5.4)	2.4 (-0.3 to 5.2)
5. Extremities	330 (48.8)	318 (53.8)	-5.0 (-10.5 to 0.5)
6. External	66 (9.8)	58 (9.8)	-0.1 (-3.3 to 3.2)

(Maddy et al., 2020)

On the other hand, Straud et al. (2020) contribute to the understanding of suicide-related aeromedical evacuations among deployed military service members. Over the span of 2001 to 2013, their investigation uncovers a significant statistic - 34.4 out of every 1000 psychiatric aeromedical evacuations were directly linked to suicide. Moreover, the intricate interplay of gender, ethnicity, branch of service, occupation classification, and deployment theater emerge as influential factors shaping these suicide-related evacuations. This study's comprehensive assessment illustrates the complex landscape of mental health concerns within military contexts, highlighting the necessity for targeted intervention and support mechanisms.

Contrasting these findings, Luft et al. (2019) shed light on the French Strategic-AE system. Unlike doctrines that prioritize in-theater care, this approach pivots on the early and strategic transport of injured personnel to advanced medical facilities (Luft et al., 2019). This dichotomy highlights the divergent philosophies in aeromedical evacuation strategies - one emphasizing swift transition to advanced care centers, and the other placing priority on in-theater interventions. By delving into the French Strategic-AE system, Luft et al. reveal the intricacies of decision-making in evacuating wounded individuals and provide a broader perspective on the logistical considerations involved.

Aeromedical evacuation, while crucial in combat casualty care, faces significant challenges and limitations that impact patient outcomes. In this context, the research by Maddry et al. (2019) provides a deeper understanding, particularly by focusing on traumatic brain injury (TBI) cases. First, the urgency to swiftly transport patients to definitive care stands as a formidable hurdle. The essential need for prompt evacuation collides with the intriguing proposition raised by the study that delayed evacuation for TBI patients might, surprisingly, yield benefits (Maddry et al., 2019). Consequently, this delicate equilibrium between

urgency and the requirement for adequate medical stabilization poses a multifaceted predicament.

### **Methodology:**

A systematic exploration spanned key academic databases, including PubMed, MEDLINE, and Military Medicine, augmented by a thorough manual survey of targeted journals. The inclusion criteria prioritized studies investigating the direct nexus between aeromedical evacuation and combat injury outcomes. The inclusion criteria also included publications over the past five years, encompassing articles from 2018 to 2023 to ensure contemporary relevance.

Utilizing a strategic combination of keywords—such as "aeromedical evacuation," "medevac," "combat injuries," and "military casualty care"—facilitated an expansive yet precise literature search. Exclusion criteria were implemented to filter out non-English articles and those lacking peer-reviewed validation, maintaining the rigor of the selection process. Rigorous screening, incorporating abstract and full-text evaluations, was applied to identify studies that not only adhered to quality standards but also contributed substantively to the review's objectives.

### **Results:**

The results derived from the explored literature present critical insights, offering nuanced perspectives on diverse aspects of aeromedical evacuations. For instance, Peterson et al. (2018) highlight the profound impact of mental health concerns during aeromedical evacuations in "Psychiatric Aeromedical Evacuations of Deployed Active Duty U.S. Military Personnel." Their study underscores that psychiatric conditions significantly propel aeromedical evacuations, with nearly 3% attributed to suicidal ideation and related behaviors (Peterson et al., 2018). This alarming statistic points to the urgent need for mental health support within military contexts.

On a related note, Roberts et al. (2019) delve into coagulation monitoring during aeromedical evacuation through "Thromboelastography on-

the-go: Evaluation of the TEG 6s device during ground and high-altitude Aeromedical Evacuation." Their animal model study substantiates the efficacy of the TEG 6s device in providing vital coagulation information during dynamic transport conditions. This technological advancement offers promising prospects for enhancing medical management during evacuations, particularly in critical situations involving potential bleeding complications (Roberts et al., 2019). Furthermore, Maddry et al. (2018) delve into the "Impact of Critical Care Air Transport Team (CCATT) ventilator management

on combat mortality," unraveling the pivotal role of ventilator management by Critical Care Air Transport Teams (CCATTs) in minimizing combat mortality. Their retrospective chart review unequivocally demonstrates the significance of adhering to ARDSNet guidelines. The results reflect improved outcomes associated with compliance, including reduced ventilator days, ICU stays, and 30-day mortality rates (Maddry et al., 2018). This finding underscores the paramount importance of meticulous ventilator management protocols to ensure optimal patient care during aeromedical evacuations.

Descriptive summary of study population: US casualties transported from point-of-injury to MTF via MEDEVAC (% 95 CI (count) or median [IQR])

Item	All (n = 669)	AMP + NCTI (n = 72)	AMP (n = 104)	Non-AMP/NCTI (n = 493)	P value
Male	99, 98–100 (661/665)	100, 95–100 (72/72)	100, 96–100 (103/103)	99, 98–100 (486/490)	0.2935
Age (year)	24 [22–28]	23 [21–27]	24 [21–27]	24 [22–28]	0.1128
Injury to MTF (min)	41 [31–56]	34 [28–45]	34 [27–46]	44 [33–59]	< 0.0001
9-Line to MTF (min)	36 [29–47]	32 [25–40]	32 [27–44]	38 [30–51]	< 0.0001
Injury description*					
Blast	72, 69–76 (484/669)	100, 95–100 (72/72)	95, 89–98 (99/104)	63, 59–68 (313/493)	< 0.0001
Penetrating	26, 23–30 (177/669)	0, 0–5 (0/72)	4, 2–9 (4/104)	35, 31–39 (173/493)	< 0.0001
Blunt	1, 0.6–2 (8/669)	0, 0–5 (0/72)	1, 0.2–5 (1/103)	1, 0.6–3 (7/493)	0.7749
ISS (score)	17 [12–27]	33 [25–40]	18 [14–27]	17 [12–24]	< 0.0001
GCS of 3	3, 2–5 (17/552)	2, 0.2–8 (1/65)	3, 1–9 (3/89)	3, 1–6 (13/398)	0.7042
Head injury (AIS of head ≥2)	65, 56–74 (240/369)	74, 60–85 (32/43)	62, 50–73 (38/61)	64, 52–75 (170/265)	0.1169
Prehospital hypotension (SBP < 90 mmHg)	25, 21–29 (117/472)	47, 35–60 (26/55)	27, 18–37 (22/82)	21, 17–25 (69/335)	0.0015
30-day mortality	5, 3–7 (31/662)	8, 4–17 (6/72)	4, 2–10 (4/103)	4, 3–7 (21/487)	0.3045

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AMP+NCTI Traumatic amputation and non-compressible torso injury, AMP Traumatic amputation only, Non-AMP/NCTI Neither traumatic amputation nor non-compressible torso injury, CI Confidence interval, IQR Interquartile range, MTF Medical Treatment Facility, ISS Injury Severity Score, GCS Glasgow Coma Scale, AIS Abbreviated injury scale, SBP Systolic blood pressure; \*Blast, penetrating, and blunt are mutually exclusive

Consequently, these results accentuate key findings from distinct studies. Peterson et al. reveal the urgent need to address mental health concerns, with a notable percentage of aeromedical evacuations attributed to psychiatric conditions. Roberts et al.'s study showcases the potential of TEG 6s in coagulation monitoring during dynamic transport scenarios, while Maddry et al.'s investigation underscores the life-saving impact of appropriate ventilator management strategies by CCATTs. These cumulative insights underscore the significance of multidimensional approaches in improving patient outcomes during aeromedical evacuations.

### Discussion:

Examining the challenges and complexities inherent in aeromedical evacuation highlights the actual and potential far-reaching impact on patient outcomes. Drawing from Maddry et al.'s (2019) insights, the nuances of traumatic brain injury (TBI) cases illuminate the delicate equilibrium between the urgency for swift transport and the proposition of potential benefits from delayed evacuation. This dynamic underscores the intricate decision-making processes that underscore aeromedical evacuation protocols. Additionally, the physiological ramifications of aeromedical evacuation, though insufficiently comprehended, raise concerns about the potential for exacerbating injuries. The discourse surrounding transport-induced stressors and their effects on patients adds a layer of intricacy, necessitating a holistic approach to mitigate any adverse impacts. Furthermore, combat environments, characterized by limited medical facilities and essential resources, compound the challenge of delivering quality care during evacuations. This aspect underscores the necessity of adaptable strategies that can accommodate diverse scenarios while maintaining the highest standards of care. Prioritizing patients based on severity, medical conditions, and available resources introduces further complexity to the decision-making process, reflecting the intricate balance between ethical considerations and resource constraints.

### Conclusion:

The collective findings from the reviewed articles underscore the intricate dynamics surrounding aeromedical evacuation's impact on combat injuries. Swift evacuation remains vital, yet the notion of delayed transport for specific injuries, as suggested by Maddry et al. (2019), challenges conventional practices. Aeromedical evacuation plays a crucial role in bridging the gap between the point of injury and definitive care, with studies highlighting its potential to influence patient outcomes. The reviewed research reveals the need to balance time sensitivity with physiological stressors, optimize interdisciplinary collaboration, and address resource constraints. While recognizing the limitations and challenges of combat environments, these findings reinforce the imperative of continuous research, adaptable strategies, and data-driven approaches to enhance casualty care during aeromedical evacuation. Therefore, by evolving medical practices and refining evacuation protocols, military healthcare systems can optimize the chances of survival, recovery, and successful return to duty for combat-injured personnel.

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