Contributing Factors to Total Mission Time for Medical Evacuation Missions during Operation Iraqi Freedom II

Blanchfield Army Community Hospital

Fort Campbell, Kentucky

MAJ Jack R. Leech III

Medical Service Corps, United States Army

May 2007

STANDARD FORM 298

REPORT DOCUMENTATION PAGE

Form Approved OMB No. 0704-0188

1. REPORT DATE *(DD-MM-YYYY)*	2. REPORT TYPE	3. DATES COVERED *(From - To)*
05-04-2007	**Final Report**	**July 2006 to July 2007**

4. TITLE AND SUBTITLE
Contributing Factors to Total Mission Time for Medical Evacuation Missions during Operation Iraqi Freedom II

5a. CONTRACT NUMBER

5b. GRANT NUMBER

5c. PROGRAM ELEMENT NUMBER

6. AUTHOR(S)
Jack R. Leech III, MAJ, Medical Service Corps

5d. PROJECT NUMBER

5e. TASK NUMBER

5f. WORK UNIT NUMBER

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
Blanchfield Army Community Hospital, 650 Joel Drive, Fort Campbell, KY 42333
Residency Site
Fort Campbell, Kentucky

8. PERFORMING ORGANIZATION REPORT

9. SPONSORING / MONITORING AGENCY NAME(S) AND ADDRESS(ES)
US Army Medical Department Center and School
BLDG 2841 MCCS-HFB (Army-Baylor Program in Health & Business Administration)
3151 Scott Road, Suite 1411
Fort Sam Houston, TX 78234-6135

10. SPONSOR/MONITOR'S ACRONYM(S)

11. SPONSOR/MONITOR'S REPORT NUMBER(S)
12-07 (SEE SPECIAL INSTRUCTIONS)

12. DISTRIBUTION / AVAILABILITY STATEMENT
Approved for public release; distribution is unlimited.

13. SUPPLEMENTARY NOTES

14. ABSTRACT
During Operation Iraqi Freedom II from March to September of 2004, the patient evacuation team (PET) of the 1st Marine Expeditionary Force recorded 1133 missions during the evacuation of 2010 casualties. They recorded Total Mission Time and other key characteristics of the missions such as the evacuation category of the casualties and the amount of flight time it took to evacuate the casualty to the next echelon of care. The average mission involved 1.77 casualties. The average Urgent flight took just 39 minutes; however, the Total Mission Time was over one and one half hours. Several predictor (independent) variables were used in attempt to explain the total amount of time that it took to complete the mission. This model explained 46% (R^2 = .459) of the Total Mission Time. The model produced a regression equation, F (10, 1122) = 95.38, (p < .001). The variable contributing the most was Urgent Casualty (t = -21.42, p < .001). Future planners should use all of these contributing factors to train their Marines and Soldiers on casualty assessment and proper evacuation request procedures.

15. SUBJECT TERMS
Medical Evacuation, MEDEVAC, Total Mission Time, Flight Time, Urgent, Priority, Routine, Golden Hour, Commander's Guidance

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON Education Technician
a. REPORT	b. ABSTRACT	c. THIS PAGE			19b. TELEPHONE NUMBER *(include area code)*
unclassified	unclassified	unclassified	UU	52	(210) 221-6443

Running Head: Contributing Factors to Total Mission Time during OIF II

U.S. Army Baylor University Graduate Program in

Health & Business Administration

Graduate Management Project

Contributing Factors to Total Mission Time for Medical Evacuation Missions during Operation Iraqi Freedom II

Presented to A. David Mangelsdorff, Ph.D., M.P.H.

In partial fulfillment of the requirements for a dual

Masters Degree in Health & Business Administration

by

MAJ Jack R. Leech III

Acknowledgements

I wish to acknowledge the continuous and persistent support and encouragement of my preceptor, Colonel Jerome Penner III. Without your consistent mentoring and leadership, I would not have stayed focused to complete this on time.

I am also thankful to have such an intelligent and inspirational faculty advisor, GMP reader and mentor, Dr. A. David Mangelsdorff, Ph.D., M.P.H. Your ability to push me to find answers while considering intuition and statistics will never be forgotten.

Additional thanks to Lieutenant Colonel Larry Fulton for his guidance on this project and Major Kevin King for his insight from a medical perspective.

Finally, to my wife, Nicole, and my children, you inspire me to do all I do. Without your unconditional support and patience, I would not have completed this. Thank you!

Abstract

During Operation Iraqi Freedom II from March to September of 2004, the patient evacuation team (PET) of the 1st Marine Expeditionary Force recorded 1133 missions during the evacuation of 2010 casualties. They recorded Total Mission Time and other key characteristics of the missions such as the evacuation category of the casualties and the amount of flight time it took to evacuate the casualty to the next echelon of care. The average mission involved 1.77 casualties. The average Urgent flight took just 39 minutes; however, the Total Mission Time was over one and one half hours. Several predictor (independent) variables were used in attempt to explain the total amount of time that it took to complete the mission. This model explained 46% ($R^2 = .459$) of the Total Mission Time. The model produced a regression equation, $F(10, 1122) = 95.38$ ($p < .001$). The variable contributing the most was Urgent Casualty ($t = -21.42$, $p < .001$). Future planners should use all of these contributing factors to train their Marines and Soldiers on casualty assessment and proper evacuation request procedures.

Table of Contents

List of Tables

List of Figures

CONTRIBUTING FACTORS TO TOTAL MISSION TIME FOR MEDICAL EVACUATION MISSIONS DURING OPERATION IRAQI FREEDOM II

Introduction

In modern warfare, the evacuation of casualties to a higher echelon of medical care presents a tremendous challenge for medical planners and especially commanders. Planners must consider the number of troops deployed, the location of forward resuscitative care, the number of evacuation platforms available, and the distance from the front lines to the next level of resuscitative care. In Marine Corps operations, senior ground, air, logistics, and medical staff attempt to develop the best system for the coordination and movement of casualties; ultimately the placement and employment of these assets is decided by the senior ground Commander (Chambers, et al., 2005; Stevens, Bohman, Baker, & Chambers, 2005). In 2004 approximately 35,000 Marines and Sailors from the 1st Marine Expeditionary Force (I MEF), deployed to the Al Anbar Province for Operation Iraqi Freedom (OIF) II. During OIF II, dedicated Army air ambulances and Marine Corps tactical helicopters supported I MEF operations. Medical evacuation (MEDEVAC) and casualty evacuation (CASEVAC) crews evacuated Soldiers and Marines from the battlefield and many lives were saved. Unfortunately, this was not always the case as some died from their wounds because they were not evacuated to a location that possessed initial resuscitative surgery fast enough. In this exploratory study of 1133 missions, several contributing factors were analyzed to determine what added to the delay of the evacuation of Marines and Soldiers off the battlefield.

The purpose of this study is to determine what variables had the greatest effect on a MEDEVAC's Total Mission Time during Operation Iraqi Freedom II from March through September 2004. This is important because there are few studies available to determine the contributing factors that delay medical and casualty evacuation. If planners and operators know what variables affect evacuation time, they can train their personnel to minimize these factors and expedite the evacuation. In this retrospective analysis of data collected during Operation Iraqi Freedom II, several variables were analyzed so future medical operators can make more informed decisions on medical evacuation. If these factors can be minimized or controlled in combat, coalition forces can be evacuated faster and more lives can be saved. Further, identifying variables that do not affect Total Mission Time will be useful to planners and operators when making decisions about where to place forward resuscitative assets and evacuation platforms.

Literature Review

During ground combat operations medical evacuation of combat casualties is always a difficult task (Beekley & Watts, 2004; Burkle, Newland, Orebaugh, & Blood, 1994; Burkle, Orebaugh, & Barendse, 1994; Curry, 1999; Dorland, Nanney, & Center of Military History, 1982). Treating a casualty under combat conditions, often during hours of darkness, places great strain on the unit. U.S. military commanders attempt to minimize the time from injury until the casualty reaches definitive care by pushing care forward or expediting evacuation to an appropriate level of care.

Brief History of the Management of Combat Casualties

Throughout the history of war fighting, casualty management has been a challenge for commanders. Baron Dominique Jean Larrey (1766-1842), Napoleon's military surgeon, is cited for introducing a casualty support system that remains recognized today. It involved rapid management of the wounded who would be treated at the scene of battle or transported to a nearby facility. These transports were conducted via the so-called flying ambulance—a vehicle with the speed and mobility of light artillery, made as comfortable for patients as possible, and staffed with technicians trained to render specialized care immediately (Noe, 2006). Noe further explained how early during the U.S. Civil War, Jonathan Letterman, Medical Director of the Army of the Potomac, made tremendous strides in organizing how the U.S. military treats battlefield casualties. Letterman devised an infrastructure that included the placement of mobile field hospitals near battlefields, stratified organization of combat care, and outfitted boats and railroad cars to transport the wounded in relative comfort and safety. He also introduced dedicated logistical resources and vehicles to support the evacuation of the wounded and trained medics to clear the battlefield.

The Letterman system strongly influenced not only care provided during the American Civil War but also military medicine worldwide. During World War II, the U.S. military pushed medical capabilities forward toward the front line and made tremendous improvements in developing an infrastructure to facilitate the evacuation of casualties to the rear. Nazi Germany first used the helicopter during WWII for reconnaissance missions. However, the U.S. Army and the Air Force began training on and using helicopters for logistical purposes in the 1950s. During the Korean Conflict, the Army established semi-permanent field hospitals immediately behind the front lines that allowed wounded soldiers to receive complete medical treatment after only a short helicopter flight. Helicopters evacuated more than 22,000 patients in Korea as part of an increasingly swift medical transport system, ensuring the injured would receive treatment within two to four hours of being wounded (Noe, 2006).

Following its introductory use for medical evacuation during the Korean War, helicopter utility grew during each subsequent conflict starting with Vietnam. The helicopter revolutionized military medical care. Helicopters facilitated immediate extrication of the wounded and rapid transit to medical treatment facilities where resuscitation and treatment could begin. This usually took place within a couple of hours. Throughout most major U.S. conflicts, the ratio of casualties to available resources has been so favorable that the harsh realities of triage have rarely been experienced (Blagg, 2004). The U.S. military places such a high value on the fighting soldier; they dedicate tremendous resources to the treatment and evacuation of their casualties.

Pushing Care Forward

Critically injured soldiers, most requiring resuscitation, must be evacuated to higher levels of care to receive proper treatment. In the Army, medical personnel at the battalion aid station (BAS) or forward support medical company (FSMC) rendered that care. In Korea and Vietnam, definitive resuscitative care was only available at the division rear area from combat support hospitals (CSHs) and mobile army surgical hospitals (MASHs). The division rear area was the farthest forward the MASH or the CSH could be deployed. Due to their large logistical footprint, even the smallest of these hospitals, the MASH, was not able to contribute to combat operations until four to five days after the start of the war. In the 1990s, with the U.S. Army deploying to remote areas around the world with smaller than division-sized units, the need for surgical capability with a much smaller logistical footprint became apparent. This led to the establishment of the modern Forward Surgical Team (FST). The FST is comprised of 20 health care professionals, including a commander, executive officer, detachment sergeant, surgeons and nurse anesthetists. The teams play an integral role in saving lives by providing emergency resuscitative surgery on the battlefield for up to 30 critical patients in a 72-hour period before requiring reconstitution of medical supplies and rest. This effectively pushed the operating room capability forward from the division rear to the brigade Casualty Collection Point (CCP) and solved the treatment plan for the critically wounded ten percent who could not survive transport to the CSH or MASH. The FST, although limited to lifesaving surgery only, could easily be inserted with the initial assault force and deployed forward to the Battalion Support Area (BSA) (Stinger & Rush, 2003).

The U.S. Marine Corps' (USMC) current doctrine involves frequent use of expeditionary maneuver warfare. This translates to combat units moving very rapidly and often bypassing less significant opposing forces to engage key targets. Using these tactics, Marines often travel hundreds of miles ahead of supporting units including traditional surgical units provided by the U.S. Navy. To prevent these tactics from leading to delays in critically injured Marines reaching surgical intervention, the USMC and U.S. Navy developed the Forward Resuscitative Surgical System (FRSS) (Chambers et al., 2005). The FRSS is an eight-person team, composed of two surgeons, an anesthesiologist, a critical care nurse, two surgical technicians, an independent duty corpsman or physician assistant, and a basic corpsman. The system can be set up in approximately one hour and is capable of performing up to 18 major surgical procedures over 48 hours without relief or resupply. The FRSS team is usually collocated with a shock trauma platoon (STP) to assist with triage and initial resuscitation. The STP is a 25-personnel team that functions as a forward emergency department. As the military pushes their surgical capabilities to new levels, more pressure is placed on Commanders to ensure they can evacuate their troops to these facilities as fast as possible.

The "Golden Hour" Still Drives Commander's Guidance

The first 60 minutes after the onset of an acute illness or trauma is termed the "golden hour." The concept of the "golden hour" comes from U.S. military wartime experience, particularly in the Vietnam War. R. Adams Cowley stated that rendering medical aid within the first hour after a major traumatic injury occurs, statistically increases chances for survival (Lerner & Moscati, 2001). There are few if any references to research to the term "golden hour" and it may be based on a cardiogenic shock study conducted using canines. However, the "golden hour" refers to the importance of timely intervention that increases the chances of saving life and limb. If a severely injured person is not rendered emergency surgical care, the opportunity of a positive outcome critically lessens. Pamerneckas, Macas, Vaitkaitis, and Gudeniene (2003) suggest the concept of the "golden hour" remains relevant because of its importance in rendering emergency aid for severely injured patients is emphasized in the most updated standards. The "golden hour" justifies much of the current trauma system in the United States. Out of hospital care concepts such as 'scoop and run', aeromedical transport and trauma center designations with trauma teams in place are predicated on the idea that time is the critical factor in the management of injured patients. Some researchers question if there is enough empirical evidence to prove that the "golden hour" is a relevant planning factor. Lerner and Moscati (2001) found definitive references are generally not provided when this concept is discussed. It remains unclear whether objective data exist. One of the primary reasons for this is the inability to record the exact time of trauma. After the first responders reach a casualty, there is usually an estimate of elapsed time. Further, there are always administrative and logistical requirements to request transportation to evacuate the patient to an appropriate level of care.

Regardless or not if the "golden hour" is a legitimate planning standard, many Army and Marine Corps Commanders use the concept during planning of ground combat operations. Carr (2004) points out that hemorrhage is responsible for 50% of combat deaths, although there are few studies about coagulation monitoring among combat patients. A relatively new concept referred to as the 'platinum 5 minutes,' refers to the first five minutes that are critical in treating hemorrhage after trauma. Carr (2004) argues there are many challenges of treating hemorrhage during combat, so it is extremely important for military medical personnel to understand their options for treating hemorrhage quickly and efficiently. This highlights the reason why any delay in evacuation is critical. If a casualty loses a leg for example, it is incumbent upon the combat lifesavers and medics to apply a tourniquet immediately and then request the medical evacuation. For some casualties in OIF II, tourniquets and other immediate lifesaving measures were not taken and the wounded died before the aircraft ever reached them.

Time

If too much time is expended on unnecessary tasks during a medical evacuation, it may cost Marines and Soldiers their lives. Harman, Tomoko, and Gackstetter (2005) noted that the pace of military medical operations during combat operations is almost always frantic and the need to treat, stabilize and evacuate casualties to higher echelons of care is fundamental to saving lives and minimizing disability. Variables affecting evacuation time are often discussed but few studies of this nature have been conducted to analyze the data. Recent studies focused on the aeromedical evacuation from Level III facilities in theater to higher levels of care in Germany and the United States. Harman et al. (2005) suggest that disease and non-battle injuries were six times as common as battle injuries and 94% were classified as routine evacuees. However, their study focused on aeromedical evacuation missions from level II and primarily level III treatment facilities out of the Central Command area of operations using the U.S. Transportation Command's Regulating and Command and Control Evacuation System (TRAC^{2}ES). Few databases include information on missions and track casualties from the point of injury through admission to level I, II and III facilities.

If the variables that contribute to Total Mission Time can be controlled, Marines and Soldiers can be evacuated to the next echelon of care faster, and their chances of survival will increase. Numerous studies focus on pre-hospital care of trauma patients and their outcomes. Many researchers continue to debate which procedures are useful in the pre-hospital setting. There are constant arguments on the trade-off between field-time versus benefit of the procedure. Jacobs, Sinclair, Beiser and D'Agostino (1984) suggest that time to definitive operative treatment is the single most vital factor in influencing outcome following injury. Their study was followed by Deakin and Allt-Graham (1993) who concluded that definitive airway management and cervical spine immobilization is best carried out immediately at the scene. However, the authors claimed that despite studies involving large numbers of patients, there is little evidence that pre-hospital initiation of intravenous (IV) fluid replacement is of any benefit. Hypovolemic shock is a condition caused by a sudden decrease in the volume of fluid in the body's blood circulatory system. This condition can be fatal. Combat lifesavers and corpsman must be trained to identify signs of shock and be prepared to initiate an intravenous infusion to add fluid to the casualty's circulatory system. In some cases, the sooner the casualty receives IV fluids, the more rapid the improvement in his condition. Deakin and Allt-Graham (2003) went on to say that with longer transit times in rural areas in the United States, evidence points to 'scoop and run' approach versus a 'treat and run' method. Still, rapid evacuation from the scene of injury would currently appear to offer the trauma patient the best chance of survival. Moreover, Koehler, Smith and Bacaner (1994) also suggest the evacuation time of an urgent casualty from point of injury (POI) to forward resuscitative care is the critical factor in determining their medical outcome. These authors found transportation times for evacuation to second echelon surgical facilities to average 6-12 hours in World War II, 2-4 hours in Korea, 4.9 hours in Vietnam, 0.5-2.0 hours in 1973 Arab-Israeli War, and 4.9 hours during the Persian Gulf War.

Large variance in evacuation times may be a function of the terrain, enemy situation, weather and several other factors that will be addressed in this project. Chambers et al. (2005) provides data on a small sample of casualties during the initial ground movement in Operation Iraqi Freedom. They found that the median interval from injury to arrival at the FRSS for Marines was one hour with a range of 15 minutes to 40 hours. Some casualties categorized as routine may stay in their current treatment facility until the next available flight can evacuate them to a higher level of care. It is common to see routine casualties on missions that average 24 hours. Chambers et al. concluded eight out of their 21 critical casualties would have died had the patients not been evacuated and treated at the FRSS. The time of evacuation from forward resuscitative care to higher echelons of care is critical for casualties that require advanced care not present in the front-line units.

Lessons Shared Between Military and Civilian Experiences

Throughout history, stateside hospitals have used lessons learned in combat to guide some of the practices used on civilians. There are no large, well-controlled studies in the civilian population that either strongly support or refute the idea that faster is universally better in trauma care (Lerner & Moscati, 2001). Although evacuation of critically ill patients from one medical facility to another in a non-combat environment should lend itself to a straightforward study with simple results, few exist. Karanicolas et al. (2005) suggests several factors, other than distance to be traveled, determine the time required for inter-facility transfers of trauma patients. The authors state that a fixed distance threshold beyond which helicopter transport should be used does not exist and the decision to transport should be based on multiple factors including the distance traveled and ambulance availability. They also recommended trauma centers, that use an algorithm based on departure-to-arrival times, should revisit this practice to incorporate the time spent awaiting transport because they discovered that this can alter the time differential significantly. In their article about helicopter transfers of trauma victims in rural areas, the authors found patients had predictably worse outcomes when there was a delay in evacuation (Garrison, Benson & Whitley, 1989). They were unable to answer the question of why there was often a delay between the time of arrival at the referring hospital and the call for the emergency helicopter service. Two speculations by the authors are that the delays were caused by overwhelming multiple casualties and incorrect assessment of severity with subsequent patient deterioration. Both of these theories can be applied in the analysis of delays in medical evacuation during recent combat operations in Iraq and Afghanistan. A basic mission sequence for medical evacuation missions is presented as Figure 1.

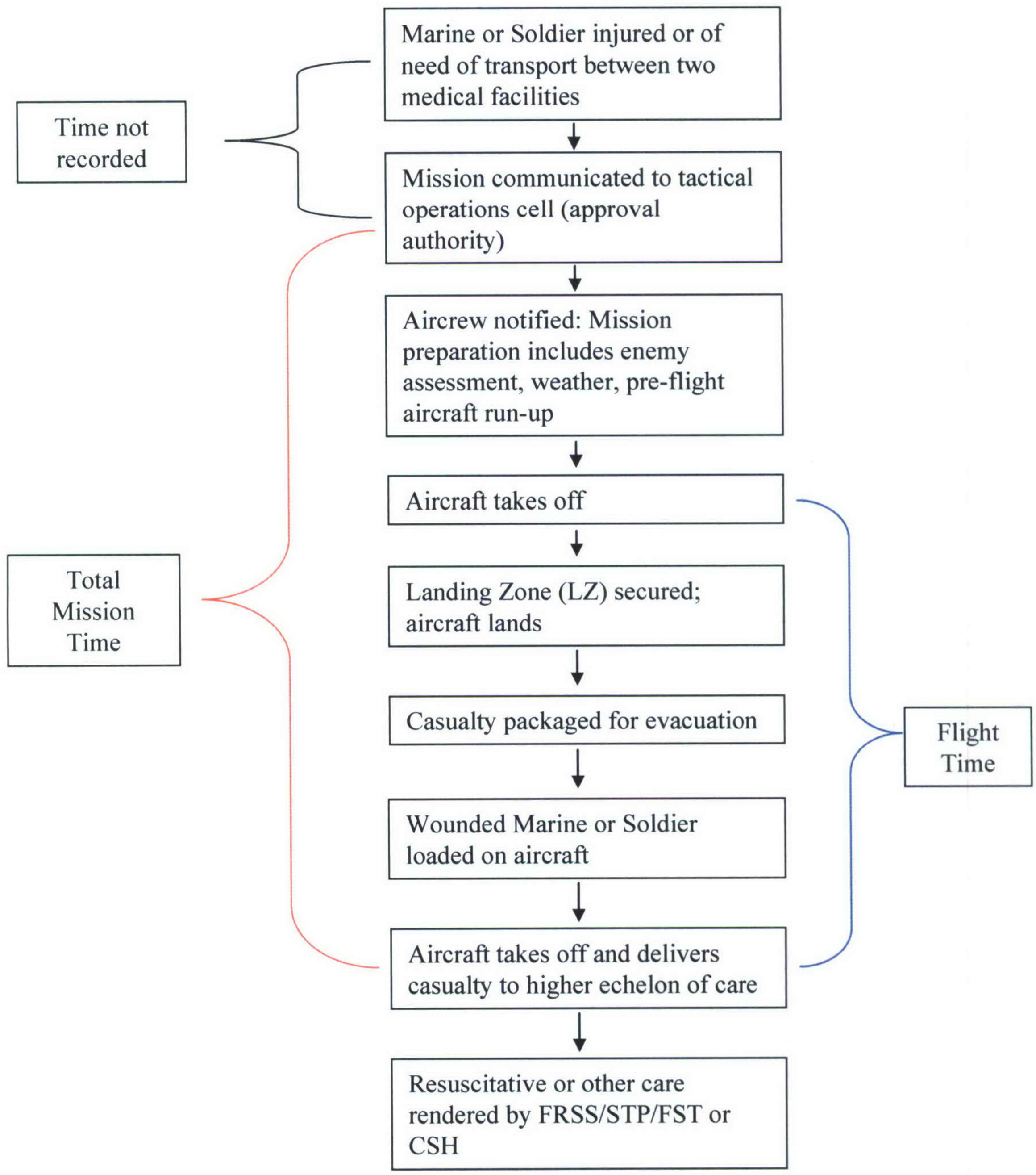

Figure 1. Basic mission sequence for a medical evacuation mission during Operation Iraqi Freedom II.

During tactical operations, the Patient Evacuation Team (PET) of the Medical Support Operations Center (MSOC) in the Marine Logistics Group is responsible for the centralized coordination and documentation of each MEDEVAC mission. The PET played a critical role ensuring the appropriate movement of casualties from the point of injury (POI) to forward resuscitative care and from the forward resuscitative care to a higher echelon of care (Chambers et al., 2005; Stevens et al., 2005). They recorded the Total Mission Time and other key characteristics of the mission such as the Evacuation Category of the casualties and the amount of Flight Time it took to evacuate the casualty to the higher echelon of care.

There are several significant concepts affecting evacuation time. First, from the moment that a Marine, Soldier or civilian is injured, his physiological clock starts ticking regardless of the medical infrastructure in place. Self-aid, buddy aid and Combat Life Savers provide the critical initial treatment in most cases. Second, the MEDEVAC request must be communicated to someone who has the authority to approve the mission. Next, Total Mission Time begins once the tactical operations cell (Battalion/Brigade Headquarters for the US Army or the Direct Air Support Center (DASC) for the USMC) receives the mission. Total Mission Time continues until the casualty arrives at the next higher echelon of care. Finally, Flight Time is one subcomponent of Total Mission Time. Flight Time is the duration from when the aircraft takes off to pick the casualty up until they are delivered to the higher echelon of care. Built into Flight Time is the patient packaging time usually accomplished by the combat medics or corpsman on the ground. Lack of training or a mass casualty situation could contribute to delays in this packaging time. Flight medics in MEDEVAC units will reassess the patient once he lands at the point of injury or forward treatment facility. Ground personnel may aid in transporting the casualty to the aircraft and loading them inside. Great variation may occur during this part of the process. Although a theoretical overview was not applicable for this study, a conceptual model for this study is presented as Figure 2.

Methods & Procedures

This study is a retrospective analysis of data collected during Operation Iraqi Freedom II from March 2004 through September 2004. Graphically this study is expressed as this:

X O

The X represents the treatment or evacuation missions recorded. The O represents the observation of those evacuation missions. This type of study suffers from many weaknesses in internal and external validity compared to other studies (Campbell & Stanley, 1966).

A maturation threat results because research participants are growing older, more experienced, wiser, or more skillful over time. Although units continuously rotate in and out of theater, for this study, the Army MEDEVAC unit supporting the Marine Corps and the supported Marine battalions were the same for the six months. This study did not use pretest and posttest results. The data was left unchanged in order to provide as pure results as possible. Consideration was given to remove missions with unusually large Total Mission Time or to compress the data by taking the natural log of the time variables. However, the data was not altered in order to obtain the most unadulterated results.

All descriptive statistics were computed along with a correlation matrix of the dependent and the independent variables. Consideration was given to all variables in regard to central tendency.

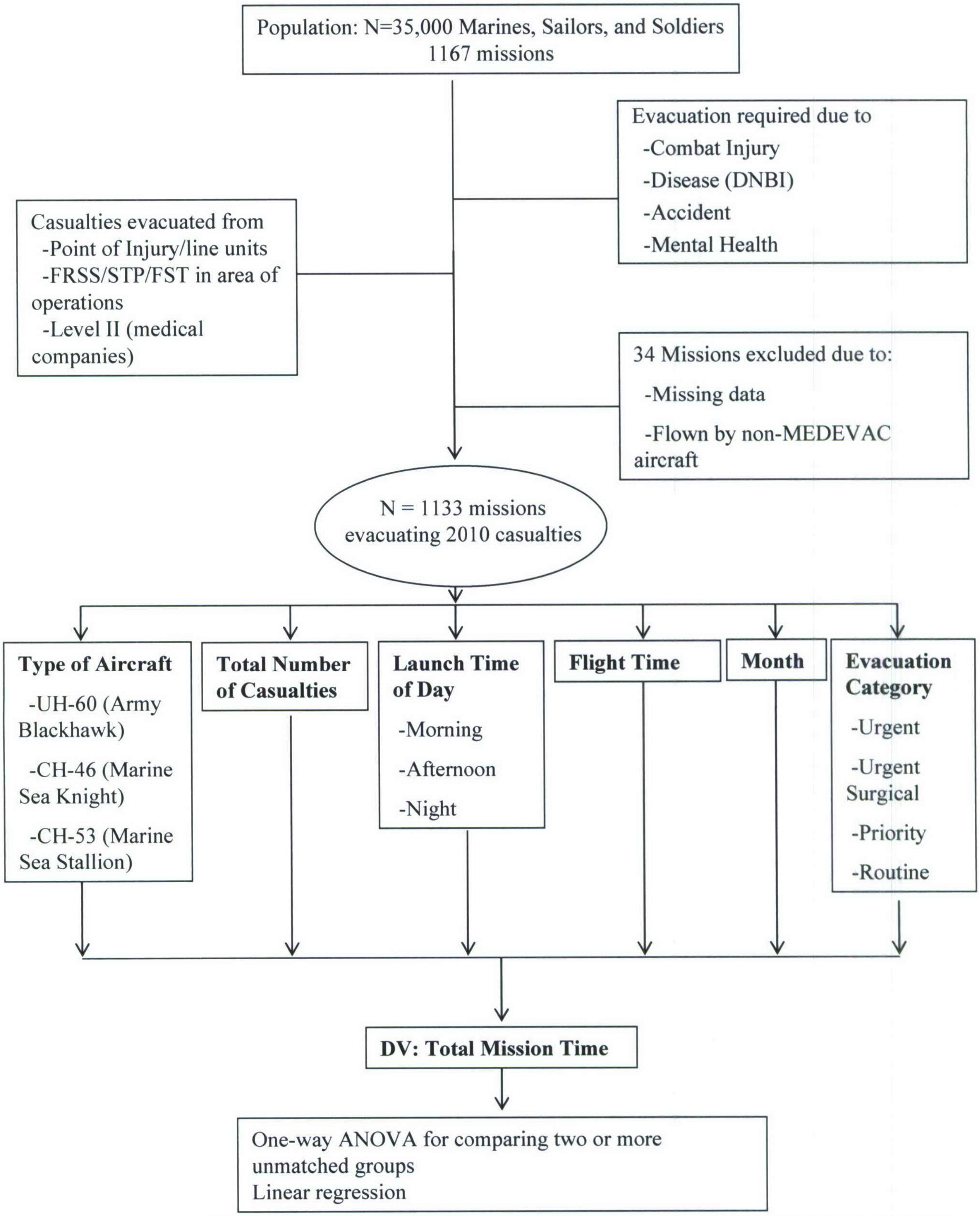

Figure 2. Conceptual model of contributing factors to Total Mission Time for medical evacuation (MEDEVAC) missions during Operation Iraqi Freedom II, March – September 2004, Al Anbar Province, Iraq.

Three variables (Type of Aircraft, Evacuation Category, and Launch Time of Day) were originally categorical variables. All three variables were transformed in SPSS into dichotomous variables in order to improve the results of regression. Analysis of variance (ANOVA) results based on these categorical variables are presented in the results section.

Linear regression analysis was used to determine the variables that had the greatest effect on Total Mission Time. The standard equation for multiple variable regression is:

$$\mathbf{Y = b_0 + b_1X_1 + b_2X_2 + b_3X_3 + b_4X_4 \ldots . b_nX_n + \in}$$

The methodological equation used in the study is as follows:

$$\textbf{Total Mission Time} = \mathbf{b_0} + \mathbf{b_1}\textbf{Urgent} + \mathbf{b_2}\textbf{UrgSurg} + \mathbf{b_3}\textbf{Priority} + \mathbf{b_4}\textbf{Routine} + \mathbf{b_5}\textbf{TotalCas} + \mathbf{b_6}\textbf{Morning} + \mathbf{b_7}\textbf{Afternoon} + \mathbf{b_8}\textbf{Night} + \mathbf{b_9}\textbf{AF1} + \mathbf{b_{10}}\textbf{AF2} + \mathbf{b_{11}}\textbf{AF3} + \mathbf{b_{12}}\textbf{FltTime} + \mathbf{b_{13}}\textbf{Month} + \in$$

This study is primarily explanatory. The dependent variable is Total Mission Time (TotTime) operationally defined as the time (in minutes) from when the PET received request for the mission until the casualty was delivered to the next echelon of care. b_0 is a constant and is located on the y-intercept if all other constants are zero. All of the independent variables are listed in Table 1. $\in$: represents random error from the regression analysis report.

There are three null hypothesis (H_0) statements for Regression Analysis:

1. The R^2 change = 0
2. The overall multiple correlation = 0
3. The individual regression coefficient = 0

The alternate hypothesis (H_a) is that at least one variable is different.

Regression analysis is a statistical technique applied to data to determine, for predictive purposes, the degree of correlation of a dependent variable with one or more independent variables. The linear model usually assumes the data are continuous. Multiple linear regression was chosen as the primary statistical tool because this study is looking to help predict the number of minutes in Total Mission Time.

Table 1

List and Definitions of the Independent Variables

Variable	**Abbreviation**	**Definition (Variable Type)**
Urgent Casualty	Urgent	Assigned to casualties requiring evacuation within two hours* (dichotomous)
Urgent Surgical Casualty	UrgSurg	Assigned to casualties who must receive far forward surgical intervention to save life and stabilize for permanent evacuation; These casualties need to be evacuated within a maximum of two hours (dichotomous)
Priority Casualty	Priority	Assigned to casualties needing evacuation within four hours to prevent them from falling into a more urgent category (dichotomous)
Routine Casualty	Routine	Assigned to sick and wounded personnel requiring evacuation but whose condition is not expected to deteriorate significantly; The sick and wounded in this category should be evacuated within 24 hours (dichotomous)
Total Number of Casualties	TotalCas	The total number of casualties evacuated during each MEDEVAC mission (continuous)
Morning Launch (0400-1159)	Morning	Missions where the aircraft took off between the hours of 0400-1159 (dichotomous)
Afternoon Launch (1200-1959)	Afternoon	Missions where the aircraft took off between the hours of 1200-1959 (dichotomous)
Night Launch (2000-0359)	Night	Missions where the aircraft took off between the hours of 2000-0359 (dichotomous)
UH-60 Blackhawk	AF1	Missions where a U.S. Army UH-60 Blackhawk conducted the medical evacuation mission (dichotomous)
CH-46 Sea Night	AF2	Missions where a U.S. Marine Corps CH-46 Sea Night conducted the casualty evacuation mission (dichotomous)
CH-53 Sea Stallion	AF3	Missions where a U.S. Marine Corps CH-53 Sea Stallion conducted the casualty evacuation mission (dichotomous)
Month	Month	Month of year the mission was flown
Flight Time	FltTime	The number of minutes it took the aircraft to fly the casualty to the next level of care (continuous)

Note: *Army doctrine states that casualties categorized as Urgent will be evacuated within two hours to save life, limb or eyesight (Army FM 4-02.26) although Commanders' guidance usually follow the "Golden Hour" rule.

Multiple regression is used to learn more about the linear relationship between several independent or predictor variables and a dependent or criterion variable. This study is not comparing two or multiple groups, but attempting to make predictions of the time it takes to evacuate soldiers from the battlefield.

One of the strengths of regression analysis is it can be used it to determine the magnitude of the linear relationships between variables, and it can be used to make predictions based on the models. Multiple regression allows the researcher to determine the best predictor(s) of Total Mission Time during Operation Iraqi Freedom II. Using this type of methodology, this study attempts to ascertain if there is a strong or weak linear relationship between variables. Although regression cannot be used to determine causality, it may be used to explain, through the correlation coefficient (R^2) and adjusted R^2, how much of the dependent variable is explained by the various independent variables.

Using regression, the independent variable with the highest correlation can be identified with Total Mission Time. The overall R^2 gets bigger as more variables are added. Care was taken to not include too many variables. The goal is to find 100% of the variance.

The Statistical Package for the Social Sciences (SPSS) version 11.0.1, generates an analysis of variance (ANOVA) using Linear Regression (SPSS Inc., 2001). ANOVA is a collection of statistical models and their associated procedures that compare means by splitting the overall observed variance into different parts. ANOVA tests whether there is a significant linear relation between the independent variables and the dependent variable. An ANOVA test results in an F-value. The larger the F-value, the better the overall model is as a predictor. Correspondingly, if the alpha (α) level is set to $< .05$, and the resultant p-value is less than .05, then this indicates the regression model, or regression coefficients, could be as far from zero as they are by chance alone and therefore statistically significant. If the ANOVA tests result in a significant result, then post-hoc comparisons were conducted. This allows the researcher to determine which of the means contributed to the effect or which groups are particularly different from each other. Post-hoc comparison techniques specifically take into account the fact that more than two samples were taken.

It is assumed that ground forces requesting MEDEVAC aircraft become more experienced over time in combat, as do the operators and crews executing the missions. The variable labeled Month (Figure 2) is used to determine if Total Mission Time decreased from March to September. Analysis of variance is used in order to assess this potential learning curve effect.

The Code Sheet (Appendix A) lists all of the variables and explains how they were coded prior to being entered in SPSS along with their relationship to the literature. A sampling plan was not required for this study because the data represents a large *N*. The results section of this study may be used for future operations and planning factors and is discussed in the conclusion.

The data used for this analysis was generated by the PET to coordinate and report medical evacuation status throughout OIF II. All of the data is unclassified separately, but the analysis could be sensitive in nature so caution has been taken to protect it. Some missions may not have been executable due to enemy threat, weather, or it was more feasible for a ground ambulance to evacuate the casualty. For example, if a request for a MEDEVAC came into the Direct Air Support Center (DASC) but the leadership determined it would be more suitable to transport the casualties by ground evacuation, that mission was logged into the database but cancelled by air. Cancelled missions (34) were removed from the database.

A secondary data source, obtained from the commander of the Army MEDEVAC unit flying some of these missions, was used to verify times, distances and general consistency of the data. This is important because validating the data in the primary database improves the likelihood the variables are measuring what they are supposed to measure. Validity implies reliability or the consistency of the data. A valid measure must be reliable, but a reliable measure need not be valid. Validity refers to getting results that accurately reflect the concept being measured. An independent t-test was run to verify the primary data source with the secondary source. The t-test assesses whether the means of two groups are statistically different from each other.

All alpha (α) levels were set at the $p < .05$ level and all statistical analyses were conducted utilizing SPSS.

Expectations & Limitations

The early expectations of this study are that most of the independent variables contribute to the amount of Total Mission Time. A higher number of total casualties should cause the mission time to increase. Missions categorized Urgent or Urgent Surgical should be executed faster than Priority or Routine missions. Missions flown during hours of darkness should take longer than missions flown during daylight hours. Missions flown by the smaller, faster UH-60 Blackhawk should be executed faster than the other two airframes. Missions requiring longer Flight Times should increase the Total Mission Time. As evacuation crews and operators work in this environment, mission times should decrease due to their experience. Even if some of the independent variables are not statistically significant, this could still be very practical or relevant information.

The medical outcomes of the 2,010 casualties aboard the 1133 missions in this study could not be obtained. Casualty or patient identification was not obtained at the point of injury in most instances so the medical outcome could not be determined. Because medical outcomes were not acquired in combat, an assumption was made that casualties flown on missions with lower Total Mission Time have a greater chance of survival and better outcomes based on the literature review. It is understood in combat that the faster a casualty is evacuated to the appropriate level of care, the greater his chances of survival. If this assumption is not true, then the purpose of this study is questionable.

The time from the initial injury until the PET logged the mission in their database was not captured as indicated in Figure 1. If healthy Marines or Soldiers accompanying the injured failed to request or did not know how to request a MEDEVAC aircraft, this delay was not captured in the dependent variable, Total Mission Time. Packaging time at the point of injury was not captured, so that time must be included in the Flight Time variable.

Although the pick up and drop off locations were recorded in the original data set, it was difficult to determine the specific grid coordinates of many of the point of injury missions. Therefore, these variables were not included in the regression equation. Pick up and drop off location frequencies are found in Appendix D.

Flight Time and Total Mission Time are contingent upon the aircrews recording when they delivered a casualty to the next echelon of care. If that information was not recorded properly, deviations in the times will exist.

The data collected for this study was gathered from March through September 2004, during Operation Iraqi Freedom II. It was over a year after initial combat operations during the assault from Kuwait through southern Iraq to Baghdad and on to other operational locations. The data was recorded during static combat operations and should not be used as a template for operational planning during initial ground wars because level II and level III facilities may not be as mature as they were during OIF II.

The nature of the results of this study is sensitive given the ongoing combat operations in Afghanistan and Iraq. Even if some of the findings are not statistically significant, they could be practically significant and potentially harmful to coalition soldiers. Therefore, these results will be checked to ensure compliance with current Office of the Surgeon General (OTSG) policy, prior to publication. The data set did not include any demographic or patient identifiable information.

Results

The results of this study are indicative of the medical evacuation requirements of the 1st Marine Expeditionary Force operating in the Al Anbar province from March through September 2004. All descriptive statistics are presented in Table 2. After assessing the means and standard deviations of all of the variables, several of them had high standard deviations in relation to their means. Several linearity diagnostics were performed for parametric tests. P-P Plots and histograms were run for every variable. The Kolmogorov-Smirnov test confirmed that several variables had numbers close to zero and this may result in a Type I error, but the decision was made to continue with the raw data.

All Pearson correlations were less than .80, indicating there is no multicollinearity among the variables. The Pearson correlation for Total # of Casualties per Mission was -.047. Pearson's r detects direction and magnitude. It is a negative number, so it is negatively correlated with the dependent variable, Total Mission Time. If a mission involved a larger number of casualties, say 3 instead of 1, it would actually decrease Total Mission Time.

For many of the independent variables, the standard deviation nearly matched the mean. The mean of Total Mission Time was 391.5 minutes or 6.5 hours with a standard deviation of 384 minutes. The mean Flight Time of a mission was 55 minutes, with a standard deviation of nearly 37 minutes. This indicates that once a MEDEVAC crew received the mission and took off, it took under one hour to deliver the casualty to the next higher level of care. The average evacuation mission included 1.77 casualties. Of the 1133 missions, CH-46 Sea Knights flew 60.4%, UH-60 Blackhawks flew 36.3%, and CH-53 Sea Stallions flew 3.3%. Missions flown by

UH-60 Blackhawks were faster (308 minutes) compared to their CH-46 and CH-53 counterparts. Most evacuation missions were categorized as Routine, 39.5%, while Priority missions made up a quarter (25.4%) of the missions.

Table 2

Descriptive Statistics for Aeromedical Evacuation Missions during Operation Iraqi Freedom II (N = 1133)

Variable	*N*	%	Mean	± Std. Deviation	*r*	*p*
Dependent Variable:						
Total Time (minutes)	1133	100	391.50	384.56	-	-
Independent Variables:						
Type of Aircraft						
UH-60 Blackhawk (Army)	411	36.3	307.97	373.73	-.164	.000**
CH-46 Sea Knight (USMC)	684	60.4	438.08	378.41	.150	.000**
CH-53 Sea Stallion (USMC)	38	3.3	456.74	459.83	.032	$.144^{(ns)}$
Evacuation Category						
Urgent	241	21.3	97.34	97.59	-.398	.000**
Urgent Surgical	156	13.8	76.03	39.63	-.328	.000**
Priority	288	25.4	371.97	281.26	-.030	$.159^{(ns)}$
Routine	448	39.5	672.16	396.84	.590	.000**
Launch Time of Day						
Morning (0400-1159)	211	18.6	397.22	427.47	.007	$.406^{(ns)}$
Afternoon (1200-1959)	275	24.3	329.88	431.72	-.091	.001**
Night (2000-0359)	647	57.1	415.79	344.20	.073	.007*
Casualties per Mission			1.77	.07	-.047	$.058^{(ns)}$
Month (of Year)			5.98	1.51	.144	.000**
Flight Time (minutes)			55.17	36.79	.365	.000**

Notes. * Values for Mean and Standard Deviation are in minutes. r is Pearson *r* values for the variable's correlation with the dependent variable Total Mission Time (in minutes). * indicates significance of $p < .05$, ** indicates significance of $p < .01$, ^{ns} indicates no significance.

Urgent and Urgent Surgical missions were executed faster than priority or routine missions, as expected. The majority of missions were flown during the night, 57.1%, while only 18.6% were flown in the morning. Visually comparing the means, the missions flown during hours of daylight were slightly faster than those flown at night.

A one-way ANOVA yielded a significant difference among the Type of Aircraft means, $F(2,1130) = 15.655$, $p = <.001$. Table 3 represents the analysis of variance summary. A post hoc analysis (see Appendix C, Table C1) using Scheffe procedure ($p = .05$) revealed the means for Type of Aircraft group 1 (UH-60 Blackhawk) was significantly lower than group 2 (CH-46 Marine Sea Knight). Group 2 (CH-46 Marine Sea Knight) was significantly higher than group 1 (UH-60 Blackhawk). Group 3 (CH-53 Marine Sea Stallion) was not significantly different than groups 1 or 2. All post-hoc results are located in Appendix C.

Table 3

Analysis of Variance for Type of Aircraft and Total Mission Time

	Sums of Squares	df	Mean Square	*F*	Sig.
Between Groups	4513474.294	2	2256737.147	15.655	<.001
Within Groups	162891074.938	1130	144151.394		
Total	167404549.232	1132			

A one-way ANOVA yielded a significant difference among the Evacuation Category group means, $F(3,1129) = 282.486$, $p = <.001$. Table 4 represents the analysis of variance summary. A post hoc analysis (see Appendix C, Table C2) using Scheffe procedure ($p = .05$) revealed the mean for Evacuation Category group 1 (Urgent) was significantly lower than groups 3 (Priority) and 4 (Routine). Group 2 (Urgent Surgical) was significantly lower than groups 3 (Priority) and 4 (Routine) as well. Group 3 (Priority) was significantly higher than groups 1 (Urgent) and 2 (Urgent Surgical), but significantly lower than group 4 (Routine). Group 4

(Routine) was significantly higher than groups 1 (Urgent), 2 (Urgent Surgical) and 3 (Priority). There was no significant difference between groups 1 (Urgent) and 2 (Urgent Surgical).

Table 4

Analysis of Variance for Evacuation Category and Total Mission Time

	Sums of Squares	df	Mean Square	*F*	Sig.
Between Groups	71779043.352	3	23926347.784	282.486	<.001
Within Groups	95625505.880	1129	84699.297		
Total	167404549.232	1132			

A one-way ANOVA yielded a significant difference among the Launch Time of Day means, $F(2,1130) = 4.866$, $p = <.001$. Table 5 represents the analysis of variance summary. A post hoc (see Appendix C, Table C3) analysis using Scheffe procedure ($p = .05$) revealed the mean for Launch Time of Day group 2 (Afternoon Launch 1200-1959) was significantly lower than group 3 (Night Launch 2000-0359). Group 3 (Night Launch 2000-0359) was significantly higher than group 2 (Afternoon Launch 1200-1959). Group 1 (Morning Launch 0400-1159) was not significantly different than groups 2 or 3.

Table 5

Analysis of Variance for Launch Time of Day and Total Mission Time

	Sums of Squares	df	Mean Square	*F*	Sig.
Between Groups	1429530.560	2	714765.280	4.866	<.001
Within Groups	165975018.672	1130	146880.547		
Total	167404549.232	1132			

The independent variable Month is technically a continuous variable, but results in a categorical-type mean of 5.98. Table 6 represents the descriptive statistics for Month and Total Mission Time. A one-way ANOVA yielded a significant difference among the Month group means, $F(6,1126) = 7.378$, $p = <.001$. Table 7 represents the analysis of variance summary. A post hoc (see Appendix C, Table C4) analysis using Scheffe procedure ($p = .05$) revealed the means for group 1 (March) and group 9 (September) were not significantly higher or lower than the other groups. Group 4 (April) was significantly lower than groups 5 (May), 6 (June), 7 (July) and 8 (August).

Table 6

Descriptive Statistics for Month and Total Mission Time

Group	N	Mean	Std. Deviation	Std. Error	Minimum	Maximum
March	39	276.97	378.39	60.59	23	1890
April	198	241.90	273.69	19.45	19	1220
May	221	425.39	425.39	28.58	24	2898
June	212	433.87	343.76	23.61	20	1307
July	228	422.77	422.77	24.27	20	2319
August	226	432.85	444.35	29.56	9	2355
September	9	518.56	405.18	135.06	60	1005
Total	1133	391.50	384.56	11.43	9	2898

Table 7

Analysis of Variance for Month and Total Mission Time

	Sums of Squares	df	Mean Square	*F*	Sig.
Between Groups	6332040.681	6	714765.280	7.378	<.001
Within Groups	161072508.551	1126	143048.409		
Total	167404549.232	1132			

The overall model produced a regression equation, $F(10, 1122) = 95.38$, $p = <.001$. Table 8 represents the analysis of variance summary for the predictive model. ANOVA puts all the data into one number (*F*) and produces one *p* for the null hypothesis. The high *F* test result indicates there is a significant relation between the independent variables and the dependent variable.

Table 8

Analysis of Variance for Predictors of Total Mission Time

	Sums of Squares	df	Mean Square	*F*	Sig.
Between Groups	76921798.916	10	7692179.892	95.384	<.001
Within Groups	90482750.316	1122	80644.162		
Total	167404549.232	1132			

Basic linear regression using multiple variables was used and the default 'enter' method was selected. The ultimate regression equation as a whole accounts for 46% ($R^2 = .459$; Adjusted $R^2 = .455$) of the variance in the Total Mission Time variable. 46%-shared variance indicates this model explains roughly one-half of the Total Mission Time of aeromedical evacuation missions during Operation Iraqi Freedom II.

Table 9 displays the results of the linear regression test. Urgent Casualty (UrgentCas) contributed the most, $t = -21.47$ $p < .001$. Urgent Surgical Casualty (UrgSurg) resulted in $t = -19.19$, $p < .001$. The other variables are listed in descending order of contribution to the model.

Eight of the ten independent variables were statistically significant predictors of the dependent variable, Total Mission Time (TotTime). The Beta statistics, indicating the standardized partial regression coefficients, represent the relative importance of the predictor variables. Routine Casualty, UH-60 Blackhawk and Night Launch (2000-0359) were removed from the model automatically.

Table 9

Contributions of the Predictors of Total Mission Time of Aeromedical Evacuation Missions During Operation Iraqi Freedom (N = 1133)

Model	**Unstandardized Coefficients**		**Standardized Coefficients**		
	Beta	**Standard Error**	**Beta**	***t***	***Sig.***
Constant	430.997	48.918		8.811	.000
Urgent Casualty	-539.879	25.208	-.575	-21.471	.000
Urgent Surgical Casualty	-552.824	28.804	-.496	-19.192	.000
Priority Casualty	-294.772	22.061	-.334	-13.362	.000
Flight Time	1.415	.252	.135	5.618	.000
CH-46 Sea Knight	60.694	18.260	.077	3.324	.001
Total Casualties per Mission	19.028	6.682	.065	2.848	.004
Morning Launch (0400-1159)	59.016	22.983	.060	2.568	.010
CH-53 Sea Stallion	-108.831	49.343	-.051	-2.206	.028
Afternoon Launch (1200-1959)	39.960	20.993	.045	1.903	.057
Month (of Year)	10.188	5.787	.040	1.760	.079

Note: Enter method of Linear Regression used here and listed in order of significance. Dependent Variable: Total Mission Time in Minutes. Variables removed by Enter method: Routine Casualty, UH-60 Blackhawk, Night Launch (2000-0359).

Discussion

The 1st Marine Expeditionary Force commander's operational guidance in effect for this period was to evacuate urgent casualties within one hour of mission request. Further guidance was to deliver urgent surgical casualties to stabilization as soon as possible within one hour (to the nearest surgical facility), priority casualties to be evacuated within four hours, and routine casualties to be evacuated within 24 hours. This planning guidance was more stringent than the traditional doctrinal guidance and was issued with his intent to achieve the frequently stated civilian "golden hour" evacuation standard.

The average mission in this study took 391.5 minutes (6.5 hours) to complete. Routine missions (39.5%) only had to be executed within 24 hours. This helps explain why the Total Mission Time average was so high. For example, some missions were categorized as routine (within 24 hours to evacuate) but requested at 0400. Commanders may have decided not to fly those missions until the next night, nearly 24 hours later. This increased Total Mission Time significantly.

The 1st MEF operated in the Al Anbar province where the distance to the nearest combat support hospital was over 400 km (216 nm) from some locations. The average Flight Time of a mission was 55 minutes. This indicates once a MEDEVAC crew received the mission and took off, it took under one hour to deliver the casualty to the next higher level of care. All of the time preceding the actual MEDEVAC flight added the majority of time to Total Mission Time. The mission preparation time, mission clearance time and other administrative requirements caused the Total Mission Time to increase. This is clearly an area needing attention. Other Army medical evacuation companies and tactical Marine helicopter units operating in Iraq may not have experienced such long flight times (55 minutes) given their proximity to the Level II and Level III facilities.

Consistent with the operational guidance, urgent and urgent surgical casualties were evacuated considerably faster than lower priority casualties. However, only routine casualties (672 minutes or 11.2 hours) were evacuated within the commander's guidance. Despite this, the results achieved were better than the summary data for recent conflicts (Koehler, Smith, & Bacaner, 1994), though slower than the impressive MEDEVAC movements achieved with a small number of forward sites moving with infantry units during the initial ground movement of OIF (Chambers et al., 2005). This analysis indicates that in order to meet this operational guidance, the average 'non-Flight Time' processing (time from a unit's MEDEVAC request to aircraft launch) in the urgent category must be reduced to no more than 20 minutes; in the urgent surgical category 28 minutes; and in the priority category 181 minutes. This will require greater emphasis on streamlining centralized request procedures for the most critical casualties in the urgent and urgent surgical categories. The variables regarding Evacuation Category cannot be overstated. The Evacuation Category variables contributed more to the Total Mission Time than any other variables. They are essentially the drivers of the dependent variable. A casualty categorized as urgent or urgent surgical has a much greater chance of making it to the next higher level of care faster than those categorized priority or routine.

The difference in time with respect to airframe can be accounted for by airframe maximum speed limitations (UH-60 maximum speed of 160+ knots versus 143 knots for the CH-46 and 130 knots for the CH-53). Another time limiting factor for respective airframes was the high threat environment in certain air corridors. The CH-46s were equipped with additional aircraft survivability equipment (ASE), weapons and countermeasures the UH-60s did not possess. Preparing this equipment adds minutes to the time required to launch these aircraft but did allow the CH-46s and CH-53s to operate in higher threat areas more consistently.

The fact that Total # of Casualties per Mission was negatively correlated with both Total Mission Time and Flight Time was unexpected. Missions involving multiple casualties took less time than those with one casualty. Engagement with the enemy where many Soldiers or Marines were injured sometimes heightened the awareness and focus of the requesting and receiving units. Knowing a mission involves multiple casualties may have motivated operators and MEDEVAC crews to send the information and prepare the aircraft faster than missions involving fewer casualties. Clearly, the MEDEVAC crews flew those missions faster knowing more was at stake to deliver multiple casualties to the next echelon of care.

The expectation was a learning curve effect would take place in relation to performing medical evacuation missions. The learning curve effect states the more times a task has been performed the less time will be required on each subsequent iteration. As operators, aircrews and decision makers become more experienced and efficient, the time it takes to evacuate a casualty off the battlefield should decrease. However, from March to September, the Total Mission Time (means) increased from 277 minutes to 519 minutes. The ANOVA results (see Table 7) prove the differences in the Month variable are statistically significant. The primary differences are missions flown in the month of April were significantly lower than other months. It is important to understand from an operational perspective what was happening in the Al Anbar province during April 2004. In response to the killing of four American private military contractors and intense political pressure, the U.S. Marines commenced Operation Vigilant Resolve. They surrounded the city and attempted to capture the individuals responsible and others in the region that might have been involved in insurgency or terrorist activities. The Marines suffered a larger number of casualties and CH-46 Sea Knights and UH-60 Blackhawks evacuated them to nearby forward resuscitative surgical systems and the combat support hospital in Baghdad. The flight time from Fallujah to Baghdad is significantly less than the flight time from western Iraq to one of the supporting CSHs. The variable Month was not statistically significant in the regression model (p = .079). Therefore, it did not contribute to the model. Another reason why the learning curve effect may not have been experienced is that, as units consolidated in the spring and summer of 2004, the lines of communication (LOC) increased. March 2004 marked the one-year anniversary of the start of the war and many replacement units were assigned to centralized forward operating bases (FOB) in order to increase logistical efficiency. This may have caused an increase in Total Mission Time and discount the learning curve and increased efficiencies over time.

The three Launch Time of Day variables (Morning, Afternoon and Night) were run in regression as a categorical variable but it was not statistically significant. Therefore the time of day a MEDEVAC mission is executed is not a contributing factor to Total Mission Time. This is a very practical piece of information for operators and commanders to know. During OIF-II, the surface to air threat was higher during the day than during hours of darkness. Understanding that MEDEVAC crews will execute missions in about the same time no matter what time of the day they launch should build even more confidence in Marine and Army ground forces.

The various pickup locations were not used in the model because the point of injury (POI) mission pickups ($N = 180$ of 1133 missions, Appendix D, Figure D1) were not in the database; the Flight Time variable should have accounted for most of this.

The model explained 46% of the Total Mission Time required performing aeromedical evacuation missions. Using the natural logs of the time variables (Flight Time and Total Mission Time), R^2 increased to 63%. However, the decision was made to not transform any of the data.

Several of the primary contributing factors of Total Mission Time for MEDEVAC missions were explained in this model. The staff members of the U.S. Marine Corps who collected this data did not know a study of this type would be conducted. Fortunately, they captured many variables that would be expected to contribute to Total Mission Time. However, other factors may explain mission preparation or administrative time better in the future. Evacuation from the battlefield is a very critical first step in conserving the fighting strength of our ground forces. Providing rapid evacuation off the battlefield increases the chances of long-term, positive outcomes and will build confidence in our Marines and Soldiers. This confidence could be the critical advantage needed to fight and win our future wars.

Initial treatment of the casualty cannot be overstated. Combat lifesavers, corpsman, medics, and other first responders can often make a difference in the outcomes of the casualty.

Application of a tourniquet, treatment for shock and cardiopulmonary resuscitation are key tasks first responders must know how to do properly given the potential for delays in medical evacuation. Although there is little empirical evidence about the 'platinum five minutes' now, we may find those first five minutes immediately following trauma are more critical than any, regarding the ability of Marines or Soldiers to survive.

Conclusion

This study demonstrates there are many factors that contribute to Total Mission Time in medical evacuation during combat operations. Through descriptive statistics, many characteristics about medical evacuation missions during Operation Iraqi Freedom II were explained. CH-46 Sea Knights flew most missions during hours of darkness, although there was little difference in Total Mission Time based on when the aircraft launched. The Army's UH-60 Blackhawks were faster than the other airframes. An average of 1.77 casualties was evacuated on each mission. The average Urgent flight took just 39 minutes; however, the Total Mission Time was over one and one half hours. Several predictor (independent) variables were used in attempt to explain the total amount of time that it took to complete each mission. This model explained 46% ($R^2 = .459$) of the Total Mission Time. The model produced a regression equation, $F(10, 1122) = 95.38$ ($p < .001$). The variable contributing the most was Urgent Casualty ($t = -21.42$, $p < .001$). Flight Time, number of Total Casualties, several Evacuation Categories, Types of Aircraft, and the Launch Times of Day were all contributing factors to Total Mission Time. The Evacuation Category variables were the most contributing factors of all of the variables in the model. The learning curve effect was expected, but the analysis of variance proved Total Mission Time increased over time. Although this model did not explain 100% of Total Mission Time, it is a great start for future planners, operators, and commanders to use.

Recommendations

Through the advent of a radio frequency identification cards or personal identification carriers, the clinical outcomes of soldiers may be known in future conflicts. Therefore, subsequent studies should attempt to follow soldiers from point of injury, through all echelons of care and to recovery at their home station. The Army needs to continue to design and develop data collection devices suitable for combat environments.

Units must be trained on medical evacuation procedures including proper triage and categorization of casualties. Failure to have the proper equipment and correct frequencies or not following standing operating procedures can not only cause a delay in the evacuation of casualties, but can clearly impact the time it takes to evacuate Soldiers and Marines off the battlefield.

En route security for medical evacuation aircraft is necessary to ensure our precious resources are successfully delivered to the next level of care. The U.S. Marine Corps leadership provided security through AH-1W SuperCobras during OIF II. They sent two SuperCobras on every medical evacuation mission involving a U.S. Army UH-60 Blackhawk. This support allowed the Blackhawks and their crews to evacuate the wounded, provide en route treatment and deliver them to the next level of care. Without this critical combat support, it is likely more U.S. Army aircraft would have been lost due to enemy surface to ground fire.

Appendix A

Definition of Terms.

Term	Definition
Casualty Evacuation (CASEVAC)	Movement of casualties to initial treatment facilities or movement of casualties within the combat zone; Heavily utilized by the U.S. Marine Corps and manned by U.S. Navy Hospital Corpsman with little or no en route care.
Direct Air Support Center (DASC)	United States Marine Corps aviation command and control system and the air control agency responsible for the direction of air operations directly supporting ground forces.
Flight Time	The time from when a MEDEVAC aircraft takes off until the casualty is delivered to the next echelon of care.
Forward Resuscitative Surgery System (FRSS)	The FRSS is a flexible, resuscitative, surgery capability, used by the Navy and Marines that can be quickly configured and erected to support any tactical medical situation ashore in a forward combat environment.
Forward Surgical Team (FST)	Small Army medical unit that provides surgical intervention which enables the casualty to be stabilized and made transportable for evacuation to a hospital for definitive care.
Medical Evacuation (MEDEVAC)	The moving of a casualty either from the point of injury, or a casualty collection point, to a medical facility or between the different levels of care with en route medical care by ground or air (by air for this study).
Mission	A requirement to transport at least one casualties from a point-of-injury, casualty collection point or treatment facility to the next echelon of care.
Patient Evacuation Team (PET)	A group of medical personnel from the Navy that regulate and manage the evacuation of casualties in the Marines area of operation.
Shock Trauma Platoon (STP)	A medical unit that provides direct medical support to the Marine Expeditionary Force (MEF) including collecting, clearing, and evacuating casualties from supported MEF elements.
Total Mission Time	Total time from when the initial request is reported to a tactical operations cell or patient movement cell (Patient Evacuation Team) until the casualty arrives at the next echelon of care.

Appendix B

Code Sheet for Study of Predictors of Total Mission Time for Medical Evacuation Missions during Operation Iraqi Freedom II.

Variable and SPSS Variable Code	Variable Type	Description	SPSS Data Codes	Literature Source
Dependent Variable: Total Mission Time	DV+: Continuous	Defined as the amount of time in minutes, starting when the PET receives a mission until casualty is delivered to next level of care	Range from 9…. 2889 for N = 1133 missions	Beckley & Watts, 2004
Urgent Casualty (Urgent)	IV+: Dichotomous	Casualty requiring evacuation within 2 hours	1 = Urgent 0 = Otherwise	Dorland et al. (1982)
Urgent Surgical Casualty (UrgSurg)	IV: Dichotomous	Casualty requiring surgery + evacuation within 2 hours	1 = Urgent Surgical 0 = Otherwise	Dorland et al. (1982)
Priority Casualty (Priority)	IV: Dichotomous	Casualty requiring evacuation within 4 hours	1 = Priority 0 = Otherwise	Dorland et al. (1982)
Routine Casualty (Routine)	IV: Dichotomous	Casualty requiring evacuation within 24 hours	1 = Routine 0 = Otherwise	Dorland et al. (1982)
Total Number of Casualties (TotalCas)	IV: Continuous	Defined as the total number of casualties on each mission	Range from 1, 2, 3…14*	Burkle et al. (1994)
Morning Launch (Morning)	IV: Dichotomous	Missions where the aircraft launched between 0400-1159	1 = Morning 0 = Otherwise	N/A
Afternoon Launch (Afternoon)	IV: Dichotomous	Missions where the aircraft launched between 1200-1959	1 = Afternoon 0 = Otherwise	N/A
Night Launch (Night)	IV: Dichotomous	Missions where the aircraft launched between 2000-0359	1 = Night 0 = Otherwise	N/A
UH-60 Blackhawk (AF1)	IV: Dichotomous	Missions where a U.S. Army UH-60 Blackhawk executed	1 = AF1 0 = Otherwise	Chambers et al. (2005)
CH-46 Sea Night (AF2)	IV: Dichotomous	Missions where a U.S. Marine Corps CH-46 Sea Night executed	1 = AF2 0 = Otherwise	Chambers et al. (2005)
CH-53 Sea Stallion (AF3)	IV: Dichotomous	Missions where a U.S. Marine Corps CH-53 Sea Stallion	1 = AF3 0 = Otherwise	Chambers et al. (2005)

		executed		
Month (Month)	IV: Continuous	Month of the year based on normal calendar	Range from 3 (March) to 9 (September)	Ebbinghaus, H.
Flight Time (FltTime)	IV: Continuous	Defined as the amount of time in minutes, starting when the MEDEVAC aircraft takes off until the casualty was delivered to the next level of care	Range from 1…. 302	Beckley & Watts, 2004

Notes: + The dependent variable is what is affected by the independent variable(s). *One mission by a CH-53 involved 14 casualties.

Appendix C

SPSS Post Hoc Scheffe Significant Outputs

Table C1: *Post Hoc Scheffe Results of Aircraft Type and Total Mission Time.*

Dependent Variable: TOTTIME Total Elapsed Time in Minutes
Scheffe

(I) TYPEACFT Type of Aircraft	(J) TYPEACFT Type of Aircraft	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
1 UH-60 Blackhawk	2 CH-46 Marine Sea Knight	-130.11*	23.696	.000	-188.19	-72.03
	3 CH-53 Marine Sea Stallion	-148.77	64.375	.070	-306.55	9.01
2 CH-46 Marine Sea Knight	1 UH-60 Blackhawk	130.11*	23.696	.000	72.03	188.19
	3 CH-53 Marine Sea Stallion	-18.66	63.279	.957	-173.76	136.44
3 CH-53 Marine Sea Stallion	1 UH-60 Blackhawk	148.77	64.375	.070	-9.01	306.55
	2 CH-46 Marine Sea Knight	18.66	63.279	.957	-136.44	173.76

*. The mean difference is significant at the .05 level.

Table C2: *Post Hoc Scheffe Results of Evacuation Category and Total Mission Time.*

Dependent Variable: TOTTIME Total Elapsed Time in Minutes
Scheffe

(I) HCAT Highest Category	(J) HCAT Highest Category	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
1 Urgent	2 Urgent Surgical	21.31	29.906	.917	-62.42	105.04
	3 Priority	-274.64*	25.408	.000	-345.77	-203.50
	4 Routine	-574.82*	23.249	.000	-639.91	-509.73
2 Urgent Surgical	1 Urgent	-21.31	29.906	.917	-105.04	62.42
	3 Priority	-295.95*	28.932	.000	-376.95	-214.95
	4 Routine	-596.14*	27.056	.000	-671.88	-520.39
3 Priority	1 Urgent	274.64*	25.408	.000	203.50	345.77
	2 Urgent Surgical	295.95*	28.932	.000	214.95	376.95
	4 Routine	-300.19*	21.981	.000	-361.73	-238.65
4 Routine	1 Urgent	574.82*	23.249	.000	509.73	639.91
	2 Urgent Surgical	596.14*	27.056	.000	520.39	671.88
	3 Priority	300.19*	21.981	.000	238.65	361.73

*. The mean difference is significant at the .05 level.

Table C3: *Post Hoc Scheffe Results of Mission Launch Time of Day and Total Mission Time.*

Dependent Variable: TOTTIME Total Elapsed Time in Minutes
Scheffe

(I) GMT Time of Day (Launch)	(J) GMT Time of Day (Launch)	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval Lower Bound	95% Confidence Interval Upper Bound
1 0400-1159	2 1200-1959	67.24	35.075	.160	-18.73	153.21
	3 2000-0359	-18.57	30.383	.830	-93.04	55.90
2 1200-1959	1 0400-1159	-67.24	35.075	.160	-153.21	18.73
	3 2000-0359	-85.81*	27.589	.008	-153.43	-18.19
3 2000-0359	1 0400-1159	18.57	30.383	.830	-55.90	93.04
	2 1200-1959	85.81*	27.589	.008	18.19	153.43

*. The mean difference is significant at the .05 level.

Table C4: *Post Hoc Scheffe Results of Month and Total Mission Time.*

Dependent Variable: TOTTIME Total Elapsed Time in Minutes
Scheffe

(I) DATE2 Month	(J) DATE2 Month	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval Lower Bound	Upper Bound
3 March	4 April	35.08	66.260	1.000	-200.49	270.65
	5 May	-148.42	65.690	.531	-381.96	85.12
	6 June	-156.89	65.899	.462	-391.18	77.39
	7 July	-145.80	65.539	.551	-378.80	87.21
	8 August	-155.88	65.581	.464	-389.04	77.28
	9 September	-241.58	139.865	.811	-738.83	255.67
4 April	3 March	-35.08	66.260	1.000	-270.65	200.49
	5 May	-183.49*	37.010	.000	-315.07	-51.92
	6 June	-191.97*	37.379	.000	-324.86	-59.08
	7 July	-180.87*	36.741	.001	-311.49	-50.25
	8 August	-190.95*	36.816	.000	-321.84	-60.07
	9 September	-276.66	128.906	.595	-734.95	181.63
5 May	3 March	148.42	65.690	.531	-85.12	381.96
	4 April	183.49*	37.010	.000	51.92	315.07
	6 June	-8.47	36.360	1.000	-137.74	120.79
	7 July	2.62	35.703	1.000	-124.31	129.55
	8 August	-7.46	35.780	1.000	-134.67	119.75
	9 September	-93.16	128.614	.998	-550.41	364.09
6 June	3 March	156.89	65.899	.462	-77.39	391.18
	4 April	191.97*	37.379	.000	59.08	324.86
	5 May	8.47	36.360	1.000	-120.79	137.74
	7 July	11.10	36.085	1.000	-117.20	139.39
	8 August	1.01	36.162	1.000	-127.55	129.58
	9 September	-84.69	128.721	.999	-542.32	372.95
7 July	3 March	145.80	65.539	.551	-87.21	378.80
	4 April	180.87*	36.741	.001	50.25	311.49
	5 May	-2.62	35.703	1.000	-129.55	124.31
	6 June	-11.10	36.085	1.000	-139.39	117.20
	8 August	-10.08	35.502	1.000	-136.30	116.13
	9 September	-95.78	128.537	.997	-552.76	361.19
8 August	3 March	155.88	65.581	.464	-77.28	389.04
	4 April	190.95*	36.816	.000	60.07	321.84
	5 May	7.46	35.780	1.000	-119.75	134.67
	6 June	-1.01	36.162	1.000	-129.58	127.55
	7 July	10.08	35.502	1.000	-116.13	136.30
	9 September	-85.70	128.558	.998	-542.76	371.35
9 September	3 March	241.58	139.865	.811	-255.67	738.83
	4 April	276.66	128.906	.595	-181.63	734.95
	5 May	93.16	128.614	.998	-364.09	550.41
	6 June	84.69	128.721	.999	-372.95	542.32
	7 July	95.78	128.537	.997	-361.19	552.76
	8 August	85.70	128.558	.998	-371.35	542.76

*. The mean difference is significant at the .05 level.

Appendix D

Bar Graphs of Categorical Variables During OIF II.

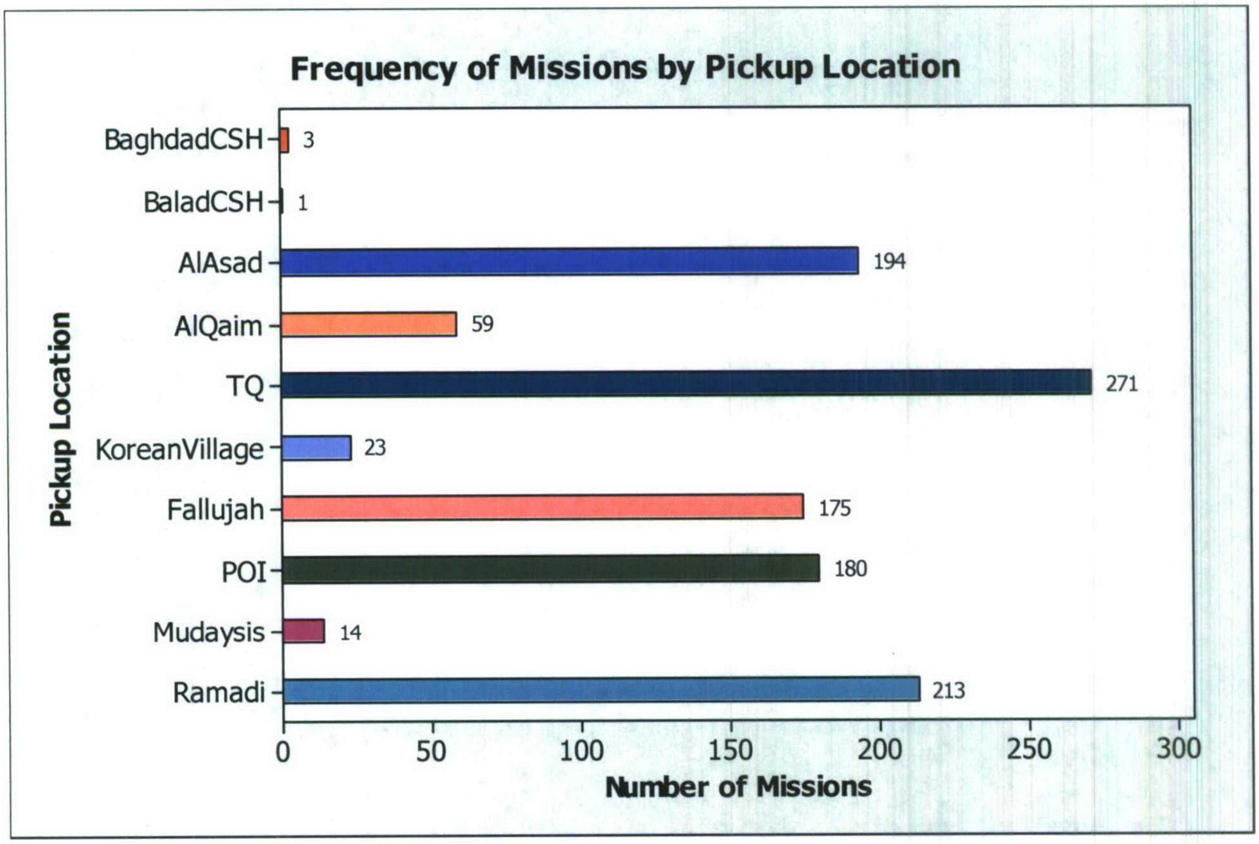

Figure D1. Frequency of missions by pickup location from March 04 – September 04.

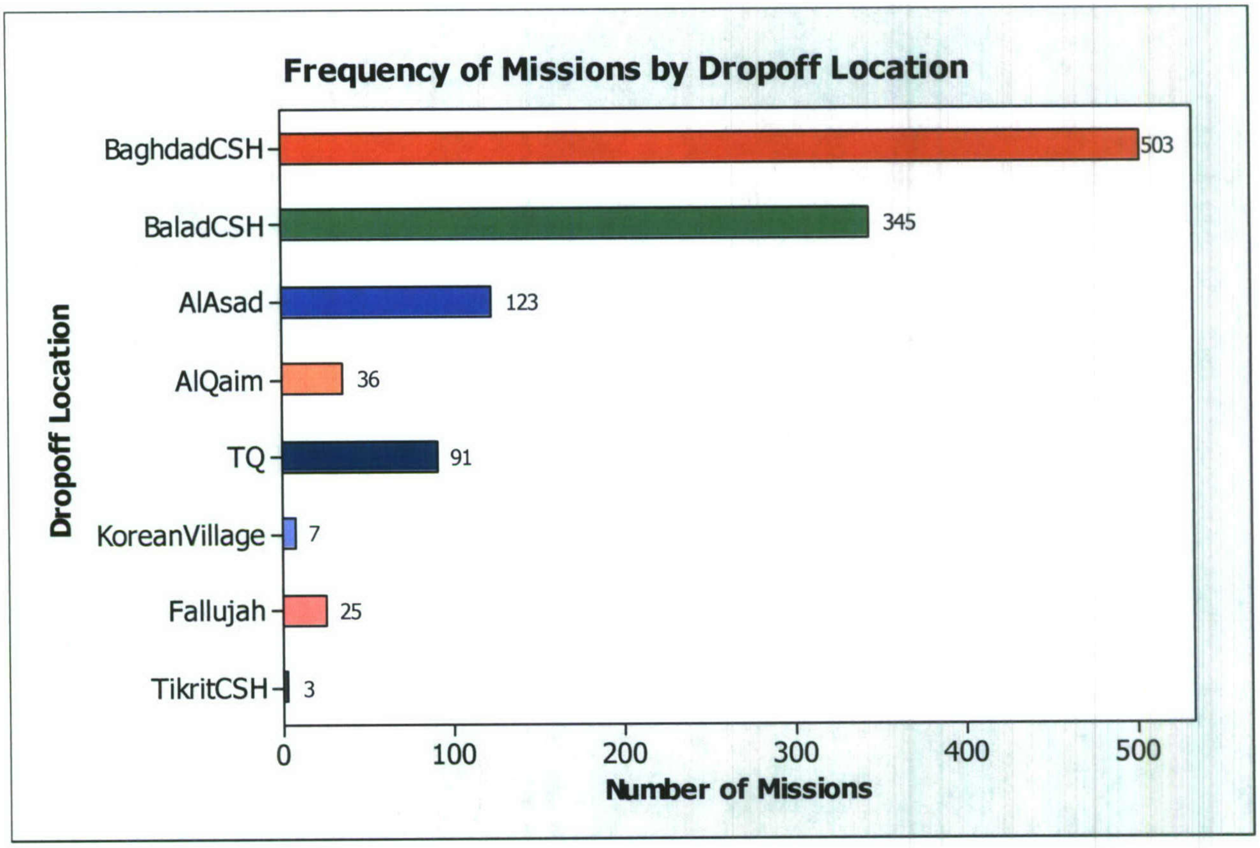

Figure D2. Frequency of missions by drop off location from March 04 – September 04.

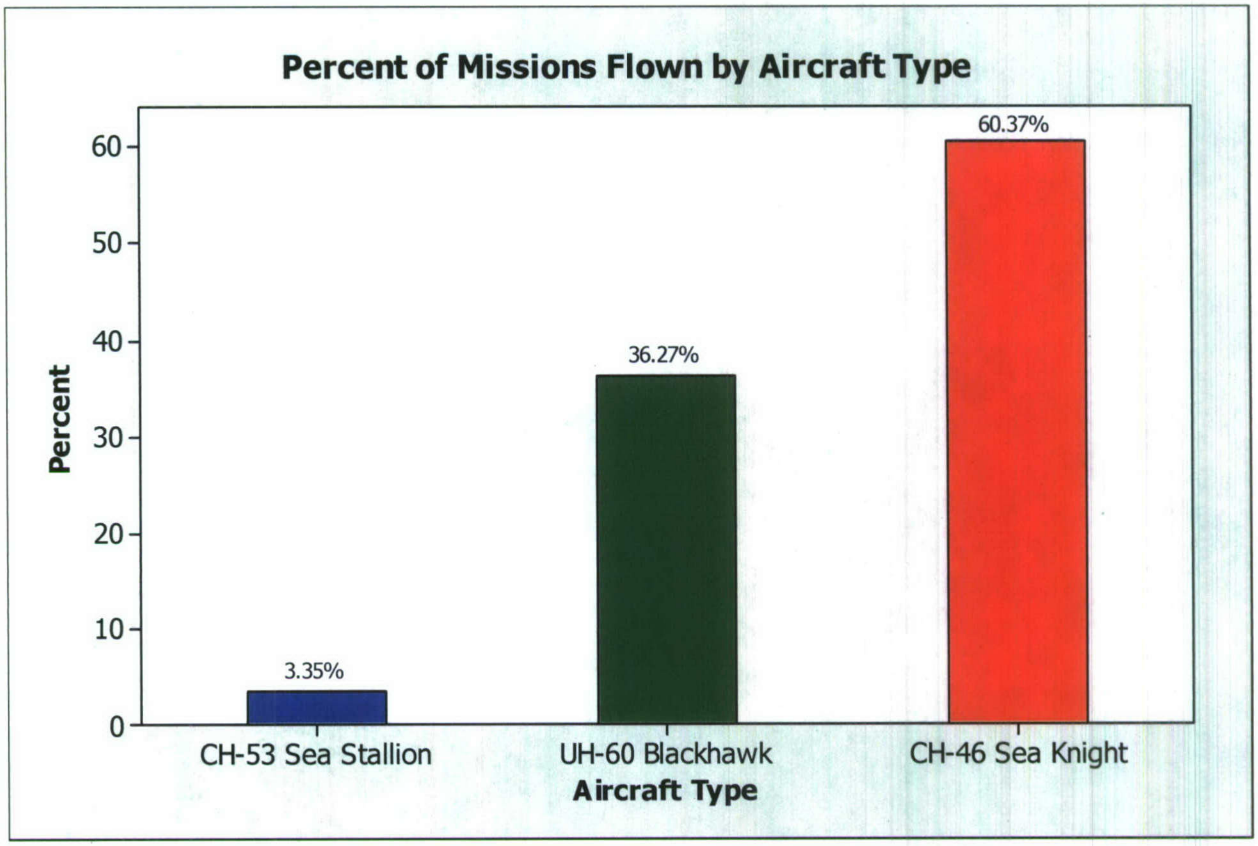

Figure D3. Percentage of Missions flown by Aircraft Type.

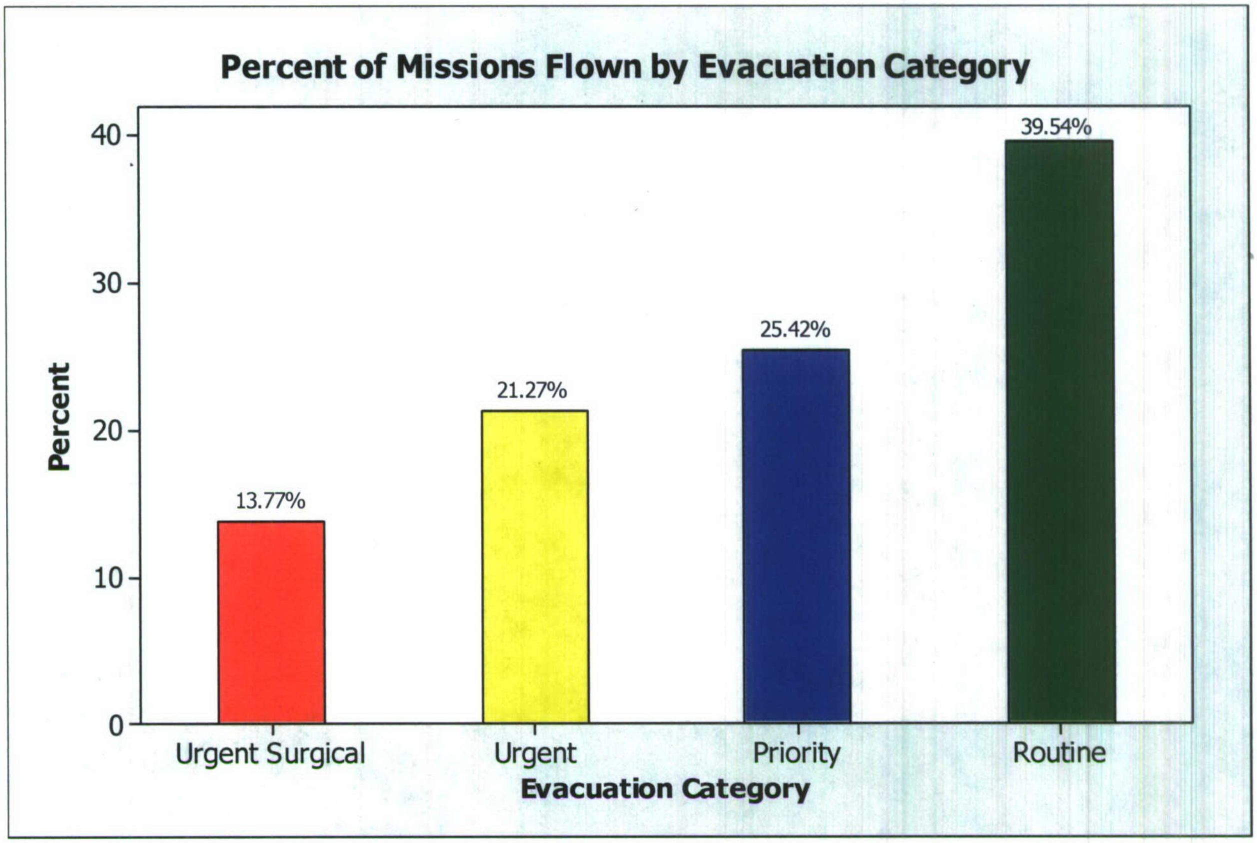

Figure D4. Percentage of missions flown by Evacuation Category.

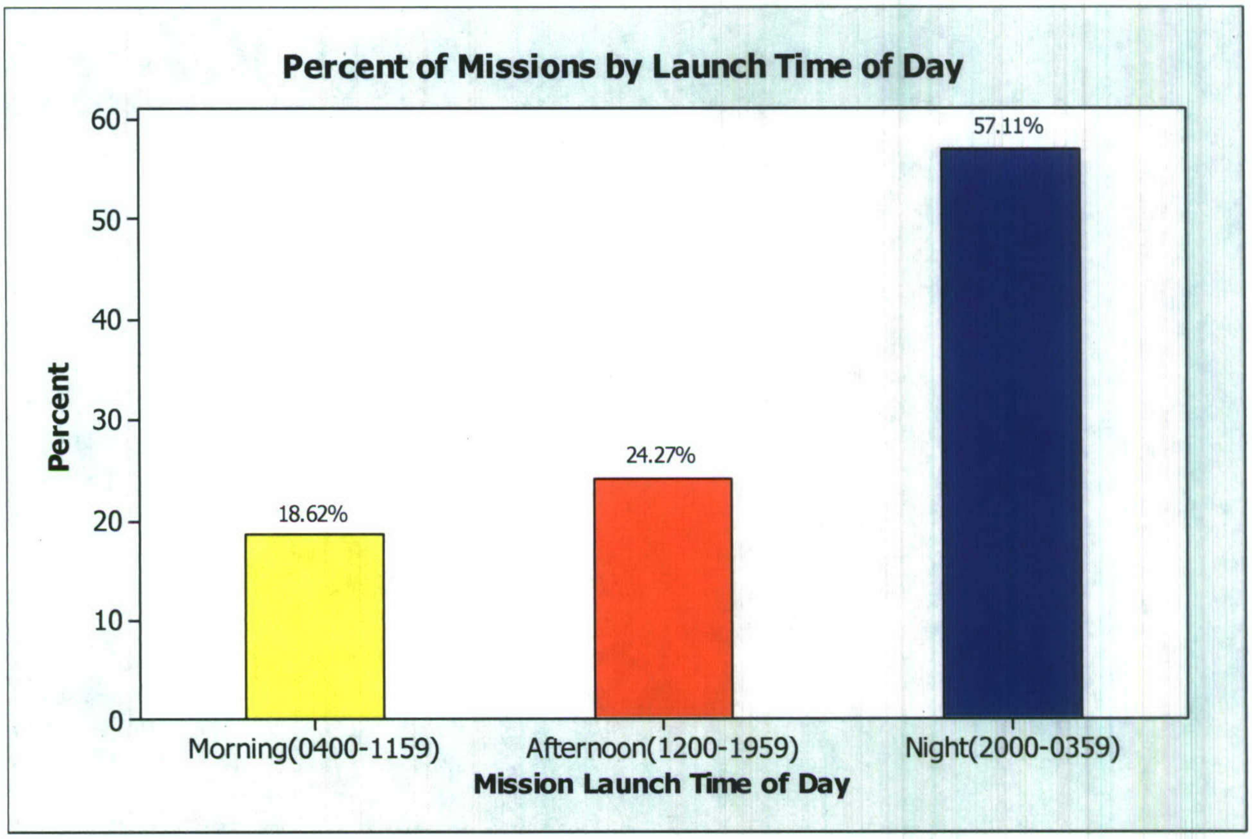

Figure D5. Percentage of missions flown by launch time of day.

References

Beekley, A. C., & Watts, D. M. (2004). Combat trauma experience with the United States Army 102nd Forward Surgical Team in Afghanistan. *American Journal of Surgery*, 187(5), 652-654.

Blagg, C. R. (2004). Triage: Napoleon to the present day. *Journal of Nephrology*, 17, 629-632.

Burkle, F. M., Jr., Newland, C., Orebaugh, S., & Blood, C. G. (1994). Emergency medicine in the Persian Gulf War--Part 2. Triage methodology and lessons learned. *Annals of Emergency Medicine*, 23(4), 748-754.

Burkle, F. M., Jr., Orebaugh, S., & Barendse, B. R. (1994). Emergency medicine in the Persian Gulf War--Part 1: Preparations for triage and combat casualty care. *Annals of Emergency Medicine*, 23(4), 742-747.

Campbell, D. T., & Stanley, J. C. (1966). Experimental and quasi-experimental designs for research. Chicago: Rand McNally.

Chambers, L. W., Rhee, P., Baker, B. C., Perciballi, J., Cubano, M., Compeggie, M., et al. (2005). Initial experience of U.S. Marine Corps forward resuscitative surgical system during Operation Iraqi Freedom. *Archives of Surgery*, 140(1), 26-32.

Chambers, L. W., Green, D. J., Gillingham, B. L., Sample, K., Rhee, P., Brown, C., et al. (2006). The experience of the U.S. Marine Corps' surgical shock trauma platoon with 417 operative combat casualties during a 12 month period of operation Iraqi freedom. *The Journal of Trauma, Injury, Infection, and Critical Care*, 60(6), 1155-1164.

Carr, M. E. (2004). Monitoring of hemostasis in combat trauma patients. *Military Medicine*, 169(12 Suppl):11-5, 4.

Cohen, J. (1977). *Statistical power analysis for the behavioral sciences* (revised edition). New York: Academic Press.

Curry, I. P. (1999). Helicopter Casevac, kill or cure? J R Army Med Corps, 145(1), 38-39.

Deakin, C. D., & Allt-Graham, J. (1993). Pre-hospital management of trauma patients: Field stabilization or scoop and run? *Clinical Intensive Care*, 4: 24-27.

Dorland, P., Nanney, J., & Center of Military History. (1982). Dust off : Army aeromedical evacuation in Vietnam. Washington, D.C.: Center of Military History, Superintendent of Documents, U.S. Government Printing Office.

Garrison, H. G., Benson, N. H., & Whitley, T. W. (1989). Helicopter use by rural emergency departments to transfer trauma victims: A study of time-to-request intervals. *American Journal of Emergency Medicine*, 7(4), 384-386.

Harman, D. R., Tomoko, I. H., & Gackstetter, G. D. (2005). Aeromedical evacuations from Operation Iraqi Freedom: A descriptive study. *Military Medicine*, 170(6), 521-527.

Jacobs, L. M., Sinclair, A. Beiser, A., & D'Agostinao, R. B., (1984). Prehospital advance life support: Benefits in trauma. *The Journal of Trauma, Injury, Infection, and Critical Care*, 24: 8-13.

Karanicolas, P. J., Pankaj, B., Williamson, J., Malthaner, R. A., Parry, N. G., Girotti, M, J., et al. (2006). The fastest route between two points is not always a straight line: An analysis of air and land transfer of nonpenetrating trauma patients. *The Journal of Trauma Injury, Infection, and Critical Care*, 61: 396-403.

Koehler, R. H., Smith, R. S., & Bacaner, T. (1994). Triage of American combat casualties: the need for change. *Military Medicine*, 159(8), 541-547.

Lerner, E. B., & Moscati, R. M. (2001). The golden hour: Scientific fact or medical "urban legend"? *Journal of Academic Emergency Medicine*, 8:578-760.

Noe, A. (2006). Extremity injury in war: A brief history. *Journal of the American Academy of Orthopaedic Surgeons*, 14, S1-S6.

Pamerneckas, A., Macas, A., Vaitkaitis, D., & Gudeniene, R. (2003). Golden hour – early postinjury period. *Medicina,* 39(9), 845-851.

SPSS Inc. (2001). SPSS 11.0.1 for Windows [Computer data and program.]. Chicago: SPSS.

Stevens, R. A., Bohman, H. R., Baker, B. C., & Chambers, L. W. (2005). The U.S. Navy's forward resuscitative surgery system during Operation Iraqi Freedom. *Military Medicine*, 170(4), 297-301.

Stinger, H. K., & Rush, R. M. (2003). Forward surgical team: The Army's ultimate lifesaving force. *Infantry Magazine*, Winter.

Thomas, R. W. (2006). Ensuring good medicine in bad places: Utilization of forward surgical teams on the battlefield. Strategic Research Project, U.S. Army War College.