Timelines for Reaching Injured Personnel in Africa

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Preface

Conducting medical evacuations and other personnel recovery missions for military and support personnel is a critical task for the U.S. Department of Defense. Providing this capability is particularly challenging in Africa because of its vast geographic scope and the small number of U.S. personnel scattered across the continent. In Africa, a very large area needs to be covered with relatively limited resources. Even if very significant additional resources were available, achieving a medical response network such as the one that existed in the later parts of Operation Enduring Freedom would simply be infeasible in Africa.

While it is true that reaching an injured person faster is always better, the degree to which greater speed improves the *rescuability* (the likelihood that a person is still surviving until rescue forces arrive) of such a person needs to be quantified. In other words, what is the likelihood that a faster arrival will make a meaningful difference in the chances of rescuing someone? Absent information relating rescuability to time, it is not possible to quantify the effectiveness (and thus the cost-effectiveness) of changes in the way rescues are conducted. This report seeks to close this gap.

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Summary

Conducting medical evacuations and other personnel recovery missions for military and support personnel is a critical task for the U.S. Department of Defense (DoD). Providing this capability is especially challenging in Africa because its vast geographic scope, limited basing options, and the small number of U.S. personnel scattered across the continent. In Africa, a very large area needs to be covered with relatively limited resources.

While it is always better to reach an injured person faster, the degree to which greater speed improves the *rescuability* of a person needs to be quantified.[1] Absent information that relates rescuability to time, it is not possible to quantify the effectiveness (or cost-effectiveness) of changes in the way a rescue is conducted. This report seeks to fill this gap by deriving the relationship between the passage of time and an injured personnel's rescuability. This current analysis is limited to the time between injury and initial rescue, as discussed in Chapter One.

By quantifying the value of time to reach injured personnel, it will be possible to compare investments in rescue assets with investments in medical resources—in terms of cost, as well as increased likelihood of rescue (net benefit). Similarly, the cost-effectiveness of enhanced rescue assets or medical resources can then be compared with that of other potential rescue-related investments, such as increased reliance on contractor rescue capabilities, improved communication, improved

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[1] We define *rescuability* as the likelihood that a person is still rescuable (i.e., surviving) until rescue forces arrive.

command and control, and indigenous medical capabilities. The most cost-effective options among all these alternatives can then be pursued.

In the context of this analysis, we define *rescue* as the entire sequence of events, from the time of incident to the final disposition of the injured personnel. More narrowly, we define *incident response* as just the first part of the sequence, from the time of incident to the first arrival of rescue forces, be they on missions of casualty evacuation, medical evacuation, personnel recovery, or combat search and rescue. Of course, the mere arrival of rescue forces does not guarantee that an injured person will survive. A much broader analysis would need to be conducted to evaluate the probability of the person surviving the injuries.

Methodology

Our methodology, which builds on past RAND research, has two components. First, we use the Joint Medical Planning Tool (JMPT) for clinical information about mortality curves associated with injuries of different mortality risk levels and with incident responses involving different tiers of medical care (or, to use military terminology, different medical-care *roles*). Second, we use the Medical Planners' Toolkit (MPTk) for information about the *distribution* of mortality risk levels associated with injuries suffered across a sampling of recent military operations. In this way, both the military medical information about mortality curves and the historical information about injury distributions inform our findings regarding the effects of speed on personnel rescue missions.

Figure S.1 portrays our methodology schematically. Essentially, we take an average of the JMPT mortality rates (for each level of injury severity and each role of medical care), weighted by the MPTk injury distributions (of low, medium, and high mortality risks from a given historical operation). The end product is a *rescuability curve* or a *rescuability timeline* for each operation. Note that a JMPT mortality curve is more specific than a rescuability curve. Whereas a JMPT mortality

Figure S.1
Multiplying Mortality Rates by Injury Distributions to Produce Rescuability Timelines
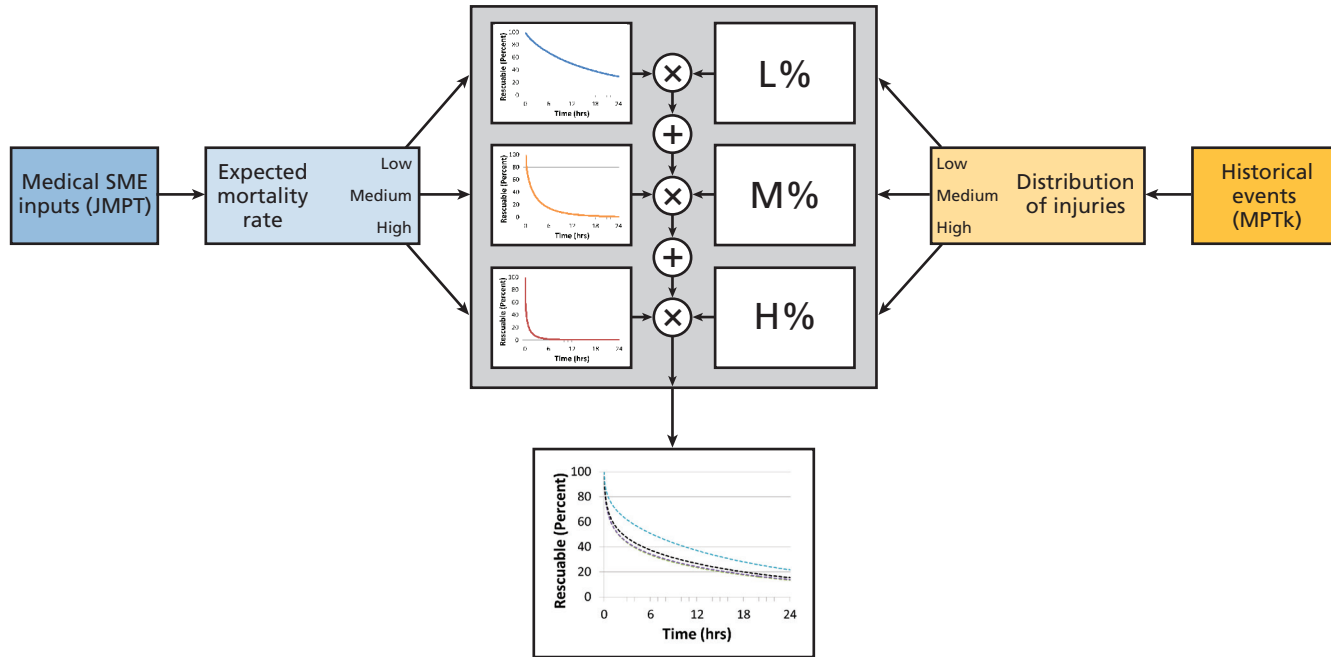
NOTE: SME = subject-matter expert.

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curve represents a single mortality risk level, a rescuability curve represents an *average distribution* of risks across the mortality risk levels.

Results

We found the rescuability rates to be highly consistent across the historical, operational, and clinical cases that we examined. Therefore, we concluded that an aggregate portrayal of the entire set of data across all of the examined cases could fairly represent the likely effects of faster or slower incident responses on rescuability rates, regardless of the historical, operational, or clinical settings. The aggregate results appear in Figure S.2.[2] The bounds shown in Figure S.2 represent the range

Figure S.2
Effects of Incidence Response Time on Rescuability Rates in General, Relative to Six Hours
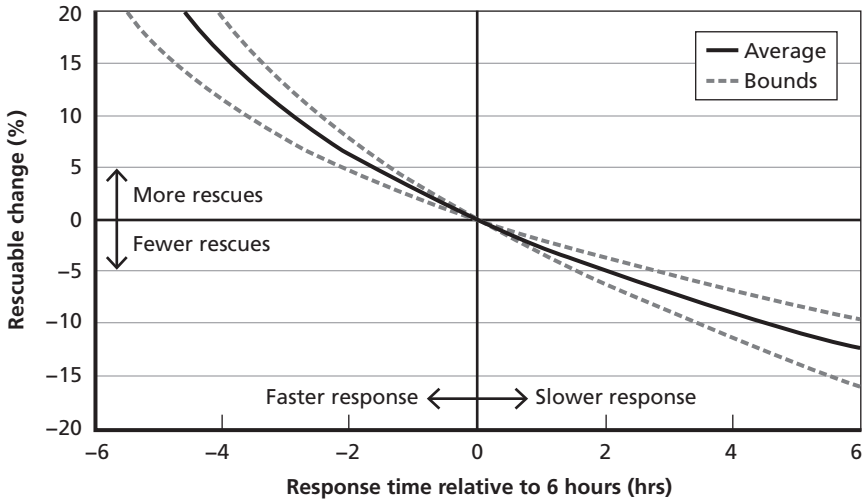
NOTE: *Rescuable* is defined as the probability that an injured person is still alive.
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[2]   Chapter Two presents details on the rescuability curves across a wide range of assumptions. Given the similarity of results across these assumptions, and the uncertainty with regard to the assumptions themselves, we show a simple average here.

of potential rescuability rates across the two scenarios types and the three medical-care roles we considered. Six hours is chosen as a baseline for these results because it represents a potentially achievable objective across the U.S. Africa Command (AFRICOM) area of responsibility (AOR), making time an operationally relevant reference point.

On average, as shown in Figure S.2, accelerating the incident response time by two hours (faster than the six-hour standard for injured personnel with access to any kind of medical care across all historical cases and operational settings) raised the rescuability rate about 7 percent, while accelerating the incident response time by four hours raised the rescuability rate about 16 percent. On average, decelerating the response time by two hours reduced the rescuability rate about 5 percent, while decelerating the response time by four hours reduced the rescuability rate about 9 percent.

The results presented in Figure S.2 serve to benchmark potentially achievable response times across the AFRICOM AOR. These results establish a medically sound and historically validated reference point from which to compare the effects of alternative rescue strategies. Those strategies could vary greatly across Africa. Given the continent's vastness and geographic diversity, the preferred strategies could vary by distance or region; for instance, faster responses with lower roles of care might work better in some regions, whereas slower responses with higher roles of care might work better in others. Future RAND analyses will use the aggregated rescuability timelines charted here as the basis for assessing potential alternative rescue options, either for Africa as a whole or for specific regions. By analyzing patient survivability, from injury to definitive care (i.e., the completion of recommended treatment), along with the myriad of rescue options potentially available, the benefits of speed and improved care can be measured along with their associated operational, clinical, and financial costs.

In some cases in Africa, a six-hour response time would be operationally infeasible. Therefore, we also looked at the average results using a 12-hour response time as a point of reference. Again, we compared the results given marginal changes in response times up to six hours in either direction (faster or slower). The marginal changes in response rates with a 12-hour point of reference were generally half as large as they were with a six-hour point of reference.

The baseline results from the overall rescuability timelines are as follows:

- Relative to a standard six-hour response time, marginal increases in response speeds of two to four hours could increase rescuability rates roughly 7 to 16 percent, on average, while marginal decreases in response speeds of two to four hours could decrease rescuability rates roughly 5 to 9 percent, on average.
- Relative to a standard 12-hour response time, marginal increases in response speeds of two to four hours could increase rescuability rates roughly 3 to 7 percent, on average, while marginal decreases in response speeds of two to four hours could decrease rescuability rates roughly 3 to 5 percent, on average.
- As indicated in Figure S.2, a six-hour response time would result in 9 to 16 percent more personnel being rescued than would a 12-hour response time.[3] Likewise, a two-hour response time would result in 12 to 20 percent more personnel being rescued than would a six-hour response time.

As noted, future analyses will use these baseline results to assess the rescuability rates associated with alternative rescue options. The relative cost and effectiveness of each potential option will then be determined and compared. The analysis will recognize that the arrival of rescue assets, no matter how fast, will not guarantee that an injured person will survive. The analysis will also account for the different roles of care that could be performed by the rescue asset, as well as the initial military treatment facility. Faster will always be better when it comes to personnel rescues, but the policy question will continue to revolve around balancing the benefits of speed and improved care with the operational, clinical, and financial costs.

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[3]   Reading Figure S.2, we see, for example, that the average curve is 0-percent change in rescuability at our reference point of six hours (0 on the x-axis). If we go to the far right of the x-axis, which corresponds to a response time of 12 hours (+6 on the x-axis), we see that the average rescuability change is –12 percent. Hence, a 12-hour response time, compared with a six-hour response time, corresponds to an average 12-percent decrease in the number of personnel who are likely still rescuable.

Acknowledgments

Introduction and Methodology

Motivation and Research Objectives

Conducting medical evacuations and other personnel recovery missions for military and support personnel is a critical task for the U.S. Department of Defense (DoD). Providing this capability is especially challenging in Africa because of its vast geographic scope and the small number of U.S. personnel scattered across the continent. A very large area needs to be covered with relatively limited resources.

While it is always better to reach an injured person faster, the degree to which greater speed can improve the *rescuability* of a person needs to be quantified.[1] Therefore, the objective of this research is to quantify the *rescuability window*—that is, the survivable length of time—for U.S. military, DoD civilian, and DoD contractor employees who are injured and in need of medical care. In the context of the U.S. Africa Command (AFRICOM) area of responsibility (AOR), life-threatening injuries could result from, for example, hostile fire while training African partner forces, a mortar or gunman attack on a forward operating base, or even a vehicular or industrial accident.[2] In any such event, a speedy response will be a priority. But absent information

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[1] We define *rescuability* as the likelihood that a person is still rescuable (i.e., surviving) until rescue forces arrive.

[2] Our modeling is based on a distribution of potential injury *levels*, rather than on specific combat injuries, since the precise causes of life-threatening injuries were generally not available in the Medical Planners' Toolkit (MPTk). The injury levels, however, capture all causes of injuries. In this analysis, the cause of an injury is not the critical factor; rather, it is the mortality risk associated with that injury.

regarding the relationship between rescuability and time, relative to the mortality risk and the care initially available for assistance, it is not possible to quantify the effectiveness (or cost-effectiveness) of changes in the way rescues are conducted.

By quantifying the value of time needed to rescue people under a variety of crisis conditions, it will be possible to compare investments in rescue assets with investments in medical resources—in terms of both cost and increased likelihood of rescue (net benefit). Similarly, the cost-effectiveness of these investments can then be compared with that of other rescue-related alternatives, such as increased reliance on contractor rescue capabilities, improved communication, improved command and control, and indigenous medical capabilities. Ultimately, the most cost-effective options among all the available alternatives could then be pursued.

In the context of this analysis, we define *rescue* as the entire sequence of events, from the time of incident to the final disposition of the injured personnel. More narrowly, we define *incident response* as just the first part of the rescue sequence, from the time of incident to the first arrival of rescue forces, be they on missions of casualty evacuation (CASEVAC), medical evacuation (MEDEVAC), personnel recovery (PR), or combat search and rescue (CSAR). Of course, the mere arrival of rescue forces does not guarantee that an injured person will survive. A much broader analysis would need to be conducted to evaluate the probability of the person surviving the injuries. In this report, we focus on just the early part of the sequence, illustrated in Figure 1.1.

It is also important to note that, because of doctrinal differences among MEDEVAC (the movement of injured personnel along with medical attendants for en route care, generally aboard dedicated aircraft), CASEVAC (the movement of injured personnel by other, expedient means), aeromedical evacuation (the movement of regulated and validated patients, along with time-sensitive en route care),[3] and PR (the

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[3] By *validated*, we mean that the injured personnel have been approved for aeromedical evacuation by medical personnel at the medical treatment facility (MTF), and by *regulated*, we mean that the injured personnel have been assigned to their next MTF destination in a deliberate way, including approval for receipt at that MTF.

Figure 1.1
Incident Response Covers Just the First Part of the Rescue Chain
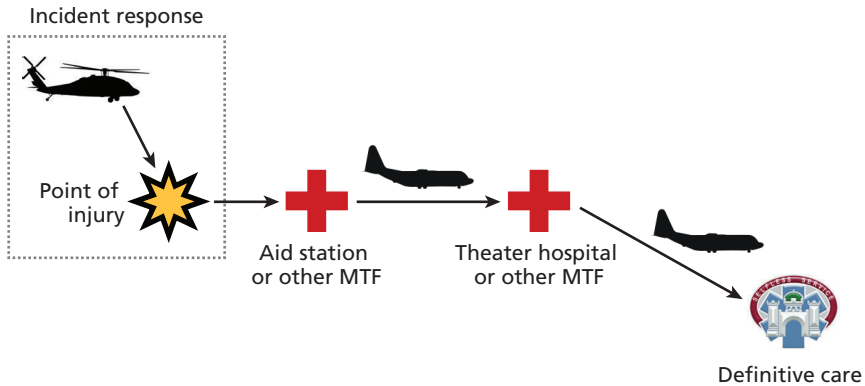
NOTE: This is a notional rescue chain. The aircraft involved, the military treatment facilities (MTFs) utilized, and other details can be highly variable. The research presented here focuses on just the incident response. *Definitive care* refers to the completion of recommended treatment.
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recovery and reintegration of distressed personnel who have become separated from their units or agencies), we use the terms *rescue* and *rescuability* to encompass the range of transport and medical-care options that may be utilized while attempting to save the life of a person with life-threatening injuries, regardless of mission type.[4]

Methodology

Our methodology has two components, both drawn from DoD-accredited planning tools. First, we use the Joint Medical Planning Tool (JMPT)[5] to derive clinical information about mortality curves

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[4]   Joint Publication 4-02, *Health Service Support*, Washington, D.C.: Joint Chiefs of Staff, July 26, 2012; and Joint Publication 3-50, *Personnel Recovery*, Washington, D.C.: Joint Chiefs of Staff, December 20, 2011.

[5]   Teledyne Brown Engineering Inc., *Joint Medical Planning Tool Methodology Manual*, Huntsville, Ala., Version 8.1, 2002–2015.

associated with injuries of different mortality risk levels and with incident responses involving different tiers of medical care (or, to use military terminology, different medical-care *roles*). The JMPT is a computer-based simulation program that plays a prominent role in the military medical literature.

Second, we use the Medical Planners' Toolkit (MPTk) for estimates of the *distribution* of mortality risk levels associated with injuries suffered across a sampling of historical military operations.[6] In this way, both the military medical information about mortality curves and the historical information about injury distributions inform our findings regarding the effects of incident response speed on PR missions.

Figure 1.2 schematically portrays our methodology. Essentially, we take an average of the JMPT mortality rates (for each level of injury severity and each role of medical care), weighted by the MPTk injury distributions (of low, medium, and high mortality risks from a given historical operation).[7] The end product is a *rescuability curve* or a *rescuability timeline* for each operation. Note that a JMPT mortality curve is more specific than a rescuability curve: The latter represents a single mortality risk level, while the former represents an average distribution across the mortality risk levels.

Our analysis and recommendations pertain exclusively to the *rescuability window* of injured personnel—in particular, those with life-threatening injuries. The *rescuability window* refers to the period only up until the moment that rescue assets arrive. We do not analyze the likelihood of personnel survival beyond this point of arrival. Even after the rescue assets arrive, survival will still depend on a number of factors, such as the capabilities of the rescue forces; however, these factors are beyond the scope of this analysis. These factors could be captured in future modeling efforts.

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[6]   See Naval Health Research Center, *Medical Planners' Toolkit (MPTk)*, San Diego, Calif., 2013.

[7]   MPTk provides the distribution of life-threatening injuries (low, medium, and high mortality risk), not the actual survival rates of the particular individuals involved in the conflicts.

Figure 1.2
Multiplying Mortality Rates by Injury Distributions to Produce Rescuability Timelines
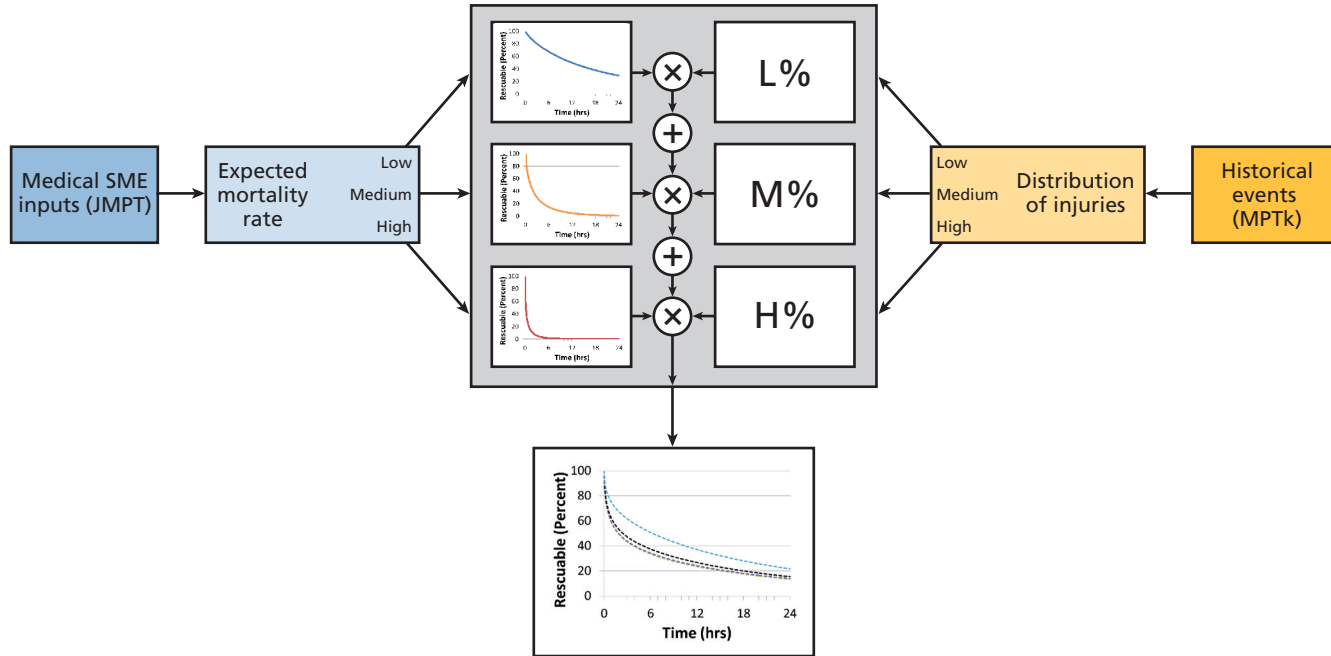
NOTE: SME = subject-matter expert.

Mortality Data from the JMPT

In the military medical literature, the mortality data contained within the JMPT serve as the basis for mortality modeling for numerous injury types. Developed by the Naval Health Research Center and Teledyne Brown Engineering, the JMPT is the official medical planning tool of the Defense Health Agency.

For each injury type, the JMPT provides a mortality curve representing the likelihood of a person with that injury type dying as a function of time, as well as the level of mortality risk and the role of medical care. The JMPT also assigns each injury type a condition code, known as an ICD-9 code (*ICD-9* stands for the *Ninth Revision of the International Classification of Diseases*).[8] More than 300 ICD-9 codes cover a wide range of medical conditions, from tetanus, to a closed fracture of nasal bones, to an open head wound with complications. A listing of medical conditions used in the JMPT, with their associated ICD-9 codes and mortality risks, appears in Appendix A.

The JMPT categorizes the hundreds of conditions into one of four mortality risk levels: high, medium, low, and non–life-threatening (NLT). The JMPT also distinguishes among seven medical-care roles, in order of clinical advancement: self-aid/buddy care (SABC), first-responder care, battalion aid station, emergency trauma care, forward resuscitative care, theater hospitalization, and definitive care (or completion of recommended treatment).

Because every ICD-9 is associated with one of just four mortality risks, it is the distribution among the four *risks*—and not the distribution among the hundreds of *injuries* or conditions—that is important in mortality modeling. In other words, the model does not need to know the difference between such disparate injuries as "a closed fracture of vault of skull without intracranial injury" and "a crushing injury of trunk," because both are modeled as having the same mortality risk (in this case, medium). Table 1.1 shows additional examples of dissimilar injuries placed into equivalent mortality risk categories by the JMPT.

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[8] World Health Organization, *Ninth International Classification of Diseases, Ninth Revision (ICD-9)*, Vol. 1, Geneva, 1978.

Table 1.1
Examples of JMPT Mortality Risk Categories

Mortality Risk Level	Example Injuries
High	Open fractures of skull or spine, intracranial injuries
	Pneumothorax (collapsed lung)
	Hemothorax (accumulation of blood around lungs)
	Amputation of leg
Medium	Closed fracture of skull or spine
	Injury to organs (liver, spleen)
	Amputation of arm
	Anaphylaxis (severe allergic reaction)
Low	Fractures of smaller bones
	Injury to organs (kidney, stomach)
	Burns
NLT	All diseases

SOURCE: JMPT.

The seven medical-care roles in the JMPT comprise four prehospital roles and three hospital roles.[9] Prehospital care encompasses the lower roles of 1, 1A, 1B, and 1C. Hospital care encompasses the three higher roles of 2, 3, and 4, as shown in Table 1.2.[10]

In creating the JMPT simulation program, the Naval Health Research Center and Teledyne Brown Engineering constructed 28 mortality curves, one for each pairing of the four risk levels and seven care roles. As one would expect, the higher the role of care received, the greater the likelihood of survival achieved. (As a patient progresses

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[9]   Based on definitions provided in Joint Publication 4-02, 2012.

[10]   Complete details on the seven care roles can be found in Borden Institute and Office of the Surgeon General, *Emergency War Surgery*, 4th U.S. revision, Fort Sam Houston, Tex.: U.S. Army Medical Department Center and School; Falls Church, Va.: U.S. Army, 2013.

Table 1.2
Prehospital and Hospital Roles of Care

Prehospital and Hospital	Role	Definition of Care	Examples
Prehospital	1	SABC	
	1A	First-responder care	Combat medic, medical technician
	1B	Aid-station care	Battalion aid station, squadron medical element
	1C	Emergency trauma care	Shock trauma platoon
Hospital	2	Forward resuscitative care	Forward surgical team, Expeditionary Medical Support–Health Response Team
	3	Theater hospitalization	Combat support hospital, Expeditionary Medical Support +25
	4	Definitive care	Continental United States hospital, Landstuhl Regional Medical Center

SOURCE: JMPT.

NOTE: Definitive care = completion of recommended treatment.

through one or more clinical steps toward higher roles of care, the mortality curve associated with each higher role of care affords the patient better odds of survival.)

The JMPT mortality curves are based either on expert opinion or on medical records. For the prehospital roles of care (roles 1 through 1C), the mortality curves are based on input from a panel of subject-matter experts. The experts were asked, for example, "Out of 100 patients with a particular ICD-9 code, receiving only first responder care, how many of those 100 would you expect to survive a half hour after injury? Three hours?" The results were then fitted to Weibull curves.[11]

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[11] Ray Mitchell, Mike Galarneau, Bill Hancock, and Doug Lowe, *Modeling Dynamic Casualty Mortality Curves in the Tactical Medical Logistics (TML+) Planning Tool*, San Diego, Calif.: Naval Health Research Center, Report No. 04-31, 2004.

For patients receiving surgical and hospital care (roles 2 and 3), the mortality curves were derived from patient data from Operation Enduring Freedom (OEF) and Operation Iraqi Freedom (OIF), covering about the first six or 24 hours postinjury, respectively. The results were then fitted to lognormal curves.

Our focus of concern is the provision of life-saving or life-preserving medical care for injured personnel *prior* to the arrival of a rescue team. In the context of AFRICOM, injured personnel would very likely face severely constrained medical options: SABC, possibly first-responder care, and, at most, a battalion aid station. The opportunities for emergency trauma care, forward resuscitative (surgical) care, and theater hospital care would generally not be available for injured personnel in Africa, other than at specific locations. Moving forward, therefore, we will compare the likely effects on survival of only the three lowest roles of care: roles 1 through 1B.

Historical Data from the MPTk

The MPTk is a companion planning tool to the JMPT. The MPTk provides the distribution of injury risks for a typical conflict scenario. The distribution of injury risks across historical events depends on the specifics of each historical scenario.

In addition to reviewing the overall JMPT mortality curves associated with the three lowest roles of care for injuries of different mortality risk levels, we look closely at data from about half of the relevant historical combat events that are contained within the MPTk for information about the real-world distribution of injury risks. We focus on five historical data sets, three of which are recent (from OEF and OIF) and one of which contains data from Africa. We recognize that the available data may or may not be representative of the conditions that rescue missions would be expected to encounter in Africa.[12]

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[12] We are limited to the historical event data contained within the MPTk. While we believe that these data represent a wide range of historical operations, we acknowledge that this may be insufficient to cover the entire range of potential military operations. In Appendix B, we discuss the full set of events for which data are available.

However, as we will later show, our results are fairly insensitive to the precise nature of each conflict. Because very few rescue missions involving personnel with life-threatening injuries have recently been conducted in Africa, and because the known details about such missions are limited at any rate, we are not able to constrain our data set to Africa but must instead rely on a collection of historical cases representing a range of locations and conditions. The five historical data sets we selected for this purpose are as follows:[13]

- OEF (U.S. Army data from Afghanistan from October 2001 to December 2014)
- Operation Gothic Serpent (the Battle of Mogadishu, Somalia, including the "Black Hawk down" incident, from August to October 1993)
- the Mayaguez incident (the Khmer Rouge seizure of the SS *Mayaguez*, anchored offshore a Cambodian island, in May 1975)
- OEF/OIF (multiservice data from Afghanistan and Iraq during the 2008–2009 surge in Iraq)
- the Second Battle of Fallujah (a joint American, Iraqi, and British offensive in Iraq, in November and December 2004).

The MPTk combined Operation Gothic Serpent and the Mayaguez incident under the term *raid*; therefore, these two events appear as a single case, as shown in Table 1.3. We also confine our analysis to the distribution of injuries posing low, medium, and high mortality risks across the five historical missions. We exclude NLT injuries from the analysis, because such injuries have no time urgency and thus are not germane to urgent PR missions (although a speedy response would, of course, be highly desirable in these cases as well).

Table 1.3 shows that the NLT injuries,[14] which we excluded, had originally accounted for the majority of injuries in every historical case.

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[13] Appendix B includes details on additional historical events. Given the overlap and similarity between the OEF and OIF data sets, we should not be surprised to see a great deal of similarity between these events.

[14] The MPTk considers all diseases to be NLT. While this is obviously not always true, it is true that few diseases will kill within hours of the symptoms first appearing—i.e., the time horizon of a rescue mission.

Table 1.3
Distribution of Mortality Risks Across Four Historical Cases

Event	NLT Injury (%)	Life-Threatening Injury (%)	Breakdown of Life-Threatening Injuries, by Mortality Risk (%)		
			Low	Medium	High
OEF (Army)	58	42	45	16	38
Gothic Serpent/Mayaguez	85	15	74	5	22
OEF/OIF (2008–2009)	51	49	47	13	40
Second Battle of Fallujah	56	44	52	12	36

SOURCE: MPTk.

NOTE: These numbers are rounded and do not always sum to 100.

For purposes of clearer distinctions among the three remaining categories of mortality risk, therefore, we converted their percentage shares to total 100 percent, as indicated in the right portion of Table 1.3. In three of these four resulting totals, roughly one-half of the life-threatening injuries were of low mortality risk, one-eighth were of medium mortality risk, and three-eighths were of high mortality risk. The exception to the rule is the combined Gothic Serpent/Mayaguez data set.

By combining the JMPT mortality curves with the MPTk distributions of life-threatening injuries across the historical events, we could begin to plot real-world relationships between rescuability and time for personnel with different kinds of life-threatening injuries who receive different kinds of medical-care responses. Chapter Two takes a step-by-step approach to showing how we combined the JMPT curves with the MPTk distributions to plot the historical relationships between rescuability and time. These plotted relationships are what we refer to as *rescuability timelines*.

Rescuability Data and Results

Mortality Curves

The JMPT mortality curves serve as the initial building blocks for our rescuability timelines. The JMPT mortality curves show survival timelines as a function of mortality risk levels and medical-care roles. Our rescuability timelines then incorporate MPTk historical data on the distribution of mortality risk levels associated with injuries suffered in Afghanistan, Cambodia, Somalia, and Iraq to estimate the *overall* relationships between rescuability and time for injured personnel in each operational setting.

It is important to note that the distribution of injury levels in these combat operations may not be predictive of the particular life-threatening injuries that may be expected in AFRICOM in the present or in the future.[1] However, the historical operations do serve as useful cases to illustrate the impacts of different rescue alternatives across a distribution of mortality risk levels. Again, the cause of each individual injury is not important for this analysis. What is important is the distribution of mortality risk levels across the life-threatening injuries. We know that we should not expect all injuries in AFRICOM to be low mortality risk, medium mortality risk, or high mortality risk; rather,

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[1] It is important to note that we are focusing on the distribution of mortality risk and not the distribution of injuries. A preliminary analysis of AFRICOM injury data for 2015 shows injuries that are fundamentally different from those seen in OEF and OIF; however, the distribution of mortality risk seen in the AFRICOM data is not inconsistent with the distribution of mortality risk seen in OEF and OIF.

the distribution of injury levels will be some mix of low, medium, and high. Therefore, we use as much historical data as are available in the MPTk to infer what this mix could potentially be. Planners might find the distributions used here to be unsuitable to Africa, so Figures 2.1 through 2.3 show the underlying data as a direct function of each mortality risk level, and these curves could be combined with any desired distribution of mortality risk levels to generate updated or customized rescuability timelines.

Figure 2.1 shows the JMPT mortality curves for personnel with life-threatening injuries who receive only role 1 care (SABC) for life-threatening injuries of low, medium, or high mortality risk. Nearly 70 percent of personnel with injuries of *low* mortality risk are likely to survive six hours with SABC alone, while just 15 percent of personnel with injuries of *medium* mortality risk are expected to survive six hours with this type of care. Almost no personnel with injuries of *high* mortality risk are expected to survive six hours with this type of care, based on the JMPT data.

Figure 2.1
Role 1—JMPT Mortality Curves with SABC
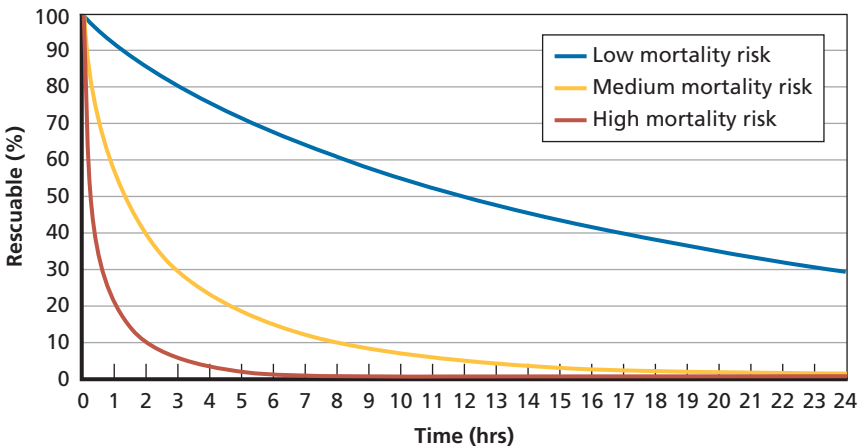
SOURCE: JMPT.
NOTE: *Rescuable* is defined as the probability that an injured person is still alive.
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Figure 2.2 shows the improved JMPT mortality curves for personnel with life-threatening injuries who receive role 1A care (first-responder care) for life-threatening injuries of low, medium, or high mortality risk. According to this prediction, more than 75 percent of personnel with injuries of low mortality risk will likely survive (and thus remain rescuable) for six hours, given first-responder care. The comparable six-hour survival rates for personnel receiving this type of care for injuries of medium and high mortality risk are about 50 percent and 15 percent, respectively.

Figure 2.3 shows the further rise in JMPT mortality curves for personnel with life-threatening injuries who receive role 1B care (aid-station care) for life-threatening injuries of low, medium, or high mortality risk. According to this prediction, the six-hour survival rate for personnel receiving aid-station care for injuries of low mortality risk rises above 80 percent. Likewise, 65 percent of personnel with injuries of medium mortality risk are expected to survive six hours with aid-station care, while 40 percent of those with injuries of high mortality risk are expected to survive six hours with aid-station care. With aid-

Figure 2.2
Role 1A—JMPT Mortality Curves with First-Responder Care
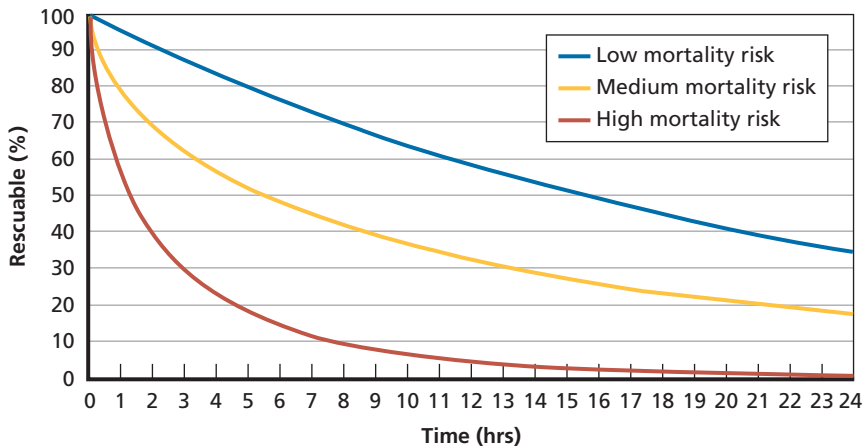
SOURCE: JMPT.

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Figure 2.3
Role 1B—JMPT Mortality Curves with Aid-Station Care
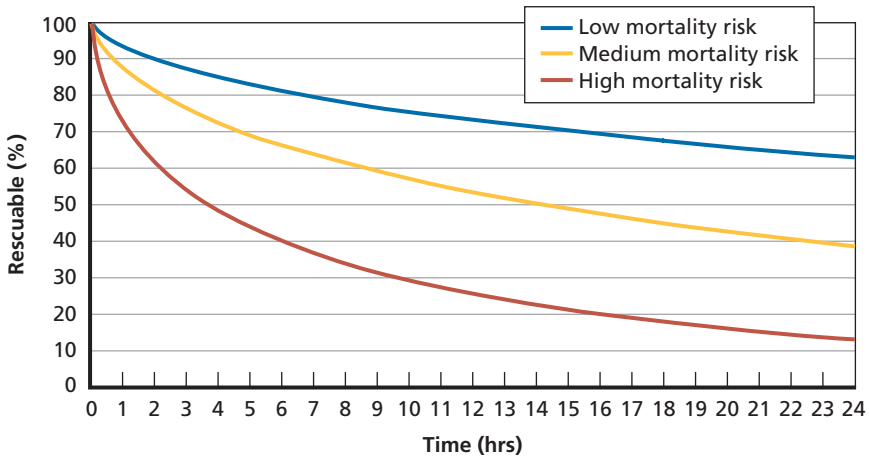
SOURCE: JMPT.
RAND *RR1536-2.3*

station care, the survival rates for personnel with injuries of all levels also improve markedly over longer periods. For instance, the expected survival rate at 24 hours for personnel with injuries of low mortality risk nearly doubles with aid-station care relative to first-responder care, jumping from 35 percent with first-responder care to almost 65 percent with aid-station care.

Injury Distributions

To plot the relationships between rescuability and time in an operationally meaningful way, we draw on our MPTk historical cases, specifically their distributions of life-threatening injuries of different mortality risks.[2] As noted in Chapter One, the MPTk merged Operation

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[2]   The historical cases are used only to provide information about the distribution of injuries, not to directly fit a survival curve. That is to say, it is the *combination* of MPTk historical injury distributions with JMPT expected survival curves for each level of injury that generates the rescuability timelines.

Gothic Serpent (in Somalia) and the Mayaguez incident (in Cambodia) into a single case, while the distribution of life-threatening injuries across the other three events was about one-half low mortality risk, one-eighth medium mortality risk, and three-eighths high mortality risk, as reflected in Table 2.1. The combined Gothic Serpent/Mayaguez case is the exception, with nearly three-quarters of its life-threatening injuries being of low mortality risk. Additional historical cases are presented in Appendix B, with distributions largely consistent with the three OEF/OIF events studied here.

Rescuability Timelines

The next three figures show the merging of life-threatening injury distributions from the MPTk historical cases with the JMPT mortality curves into what we call *rescuability timelines*.[3] We do *not* show three different rescuability timelines to represent three different roles of mortality risk experienced by injured personnel in each historical event. Instead, our rescuability timelines show the *weighted average* results across the three mortality risk levels experienced in each event, based on the unique distributions of mortality risk levels of life-threatening

Table 2.1
Distribution of Life-Threatening Injuries Across Historical Cases

Event	Breakdown of Life-Threatening Injuries by Mortality Risk (%)		
	Low	Medium	High
OEF (Army)	45	16	38
Gothic Serpent/Mayaguez	74	5	22
OEF/OIF (2008–2009)	47	13	40
Second Battle of Fallujah	52	12	36

SOURCE: MPTk.

NOTE: Numbers do not always sum to 100 because of rounding.

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[3] Results for additional cases, as shown in Appendix B, are consistent with the results shown in the main body of the report.

injuries suffered in each event.[4] (This averaging naturally produces
curves that fall somewhere between the JMPT's low and high mortal-
ity risk curves.)

Figure 2.4 shows the averaged, weighted rescuability timelines
for personnel with life-threatening injuries receiving only role 1 care
(SABC) for all types of life-threatening injuries and for all four his-
torical data sets. The markedly higher curve for the Gothic Serpent/
Mayaguez data set reflects the markedly higher proportion of low-
risk injuries in that particular data set compared with the others.
This pattern appears repeatedly across Figures 2.4 through 2.6. In
Figure 2.4, we see that, overall, 50 percent of personnel facing any
severity of life-threatening injury in the Gothic Serpent and Maya-
guez cases survived six hours with SABC, whereas only about 35 per-
cent of personnel facing any severity of life-threatening injury in the
other historical cases survived six hours with this type of care.

Figure 2.4
Role 1—Rescuability Timelines with SABC
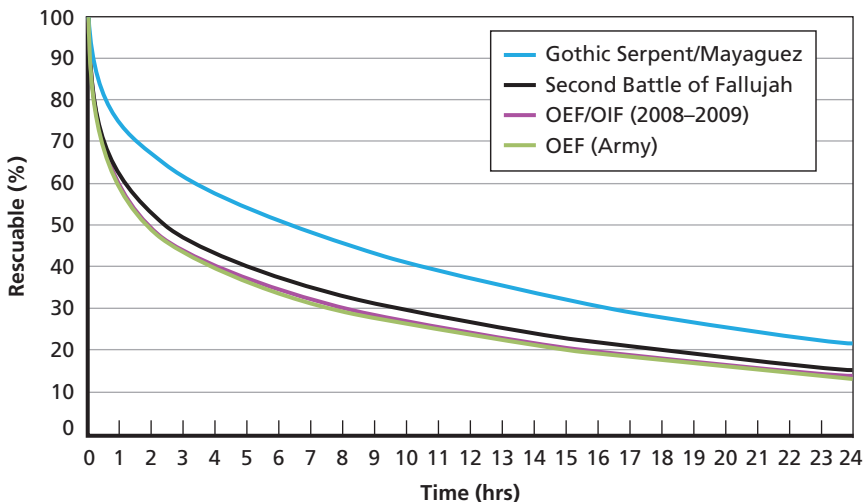
RAND *RR1536-2.4*

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[4]   Again, these curves are based not on the individual injuries suffered in the conflicts but
rather on the distribution of life-threatening injuries (of low, medium, and high mortality
risk) that occurred in the conflicts.

Figure 2.5 illustrates the across-the-board improvements that came with first-responder care relative to SABC. In the historical cases, an overall 60 percent of personnel facing any severity of life-threatening injury in the Gothic Serpent and Mayaguez cases survived six hours with first-responder care, whereas about 50 percent of personnel facing any severity of life-threatening injury in the other historical cases survived six hours with this type of care. Note that the purple OEF/OIF (2008–2009) curve does not appear to be visible in Figure 2.5 at all, because that curve is essentially identical to the green OEF (Army) curve.

Figure 2.6 illustrates the continued improvements that came with aid-station care relative to first-responder care. In these historical cases, an overall 70 percent of personnel facing any severity of life-threatening injury in the Gothic Serpent and Mayaguez cases survived six hours with aid-station care, while roughly 65 percent of personnel facing any severity of life-threatening injury in the other historical cases survived six hours with this type of care. Once again, the greatest marginal benefit of aid-station care appears with longer periods.

Figure 2.5
Role 1A—Rescuability Timelines with First-Responder Care
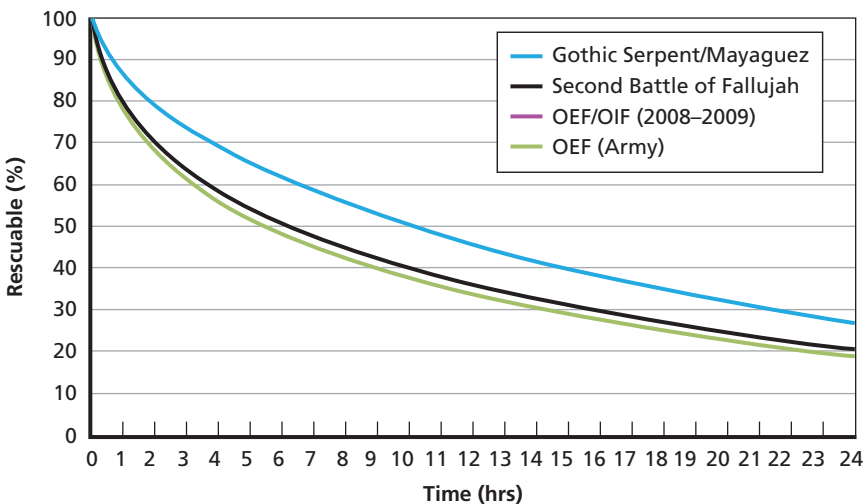
Figure 2.6
Role 1B—Rescuability Timelines with Aid-Station Care
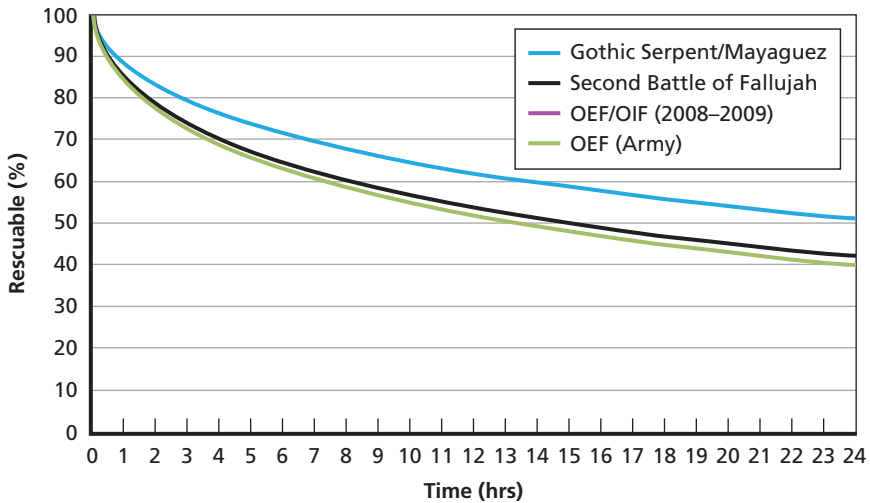
Whereas the 24-hour rescuability rates for injured personnel receiving first-responder care ranged from roughly 20 to 25 percent across the historical events, the 24-hour rescuability rates for such personnel receiving aid-station care nearly doubled, ranging from about 50 to more than 60 percent across the events. Also once again, the purple OEF/OIF (2008–2009) curve does not appear in the figure, because that curve is essentially identical to the green OEF (Army) curve.

Toward Comparisons of Cost-Effectiveness

The final step in summarizing our results is to establish baselines for comparing the cost-effectiveness of alternative approaches to PR in Africa. Because the results from three of the historical cases—OEF (Army), OEF/OIF (2008–2009), and the Second Battle of Fallujah—are very similar across all three medical-care roles, we consolidate the results from these cases into an aggregated data set called "OEF/OIF."

The similarity across these cases is not surprising given their similar distributions of life-threatening injuries.

In addition, following the naming convention used in the MPTk, we henceforward refer to the Gothic Serpent/Mayaguez curve simply as "Raid" to connote a limited operation to secure a modest objective. This distinction allows us to detect whether there are any different effects of PR response alternatives in the context of raids versus campaigns.

In the following series of figures, there are three further visual changes that allow us to focus on the effects of accelerating or decelerating the response timelines.[5] First, we restrict the timelines to the first 12 hours, because policy debates are most likely to concentrate on this time frame. Second, we shift our horizontal point of reference (for response time) from zero hours to relative to six hours because a six-hour response time is a potentially achievable objective across the AFRICOM AOR, making it operationally relevant to focus on the likely effects of response times that are faster or slower than this point of reference. This shift also deemphasizes the large differences that appear in rescuability timelines in the first few hours—a time in which it is unlikely for rescue forces in Africa to arrive at all. Third, we recast our vertical point of reference, from rescuability rate to *change* in rescuability rate. By focusing on the marginal changes in this way, it is easier to see that the benefit of accelerating the response timelines does not vary across historical cases or care roles after the first few hours— once again, a time in which rescue forces are unlikely to arrive.

Figure 2.7 shows the results for role 1 care (SABC) across the historical cases. By definition, the OEF/OIF and Raid curves converge at 0 percentage change in rescuability rates at our baseline time of six hours. As one would expect, faster responses always lead to higher rescuability rates, while slower responses always lead to lower rescuability rates. But now that the marginal effects of speed can be seen on the actual changes in rescuability rates (relative to those at six hours), we

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[5]   As noted, in this analysis, *response* or *incident response* is defined as the time when the first rescue assets arrive, whether these missions are for CASEVAC, MEDEVAC, PR, or CSAR. *Initial response* is different from *ultimate survival*.

Figure 2.7
Role 1—Rescuability Timelines, Relative to Six Hours, with SABC
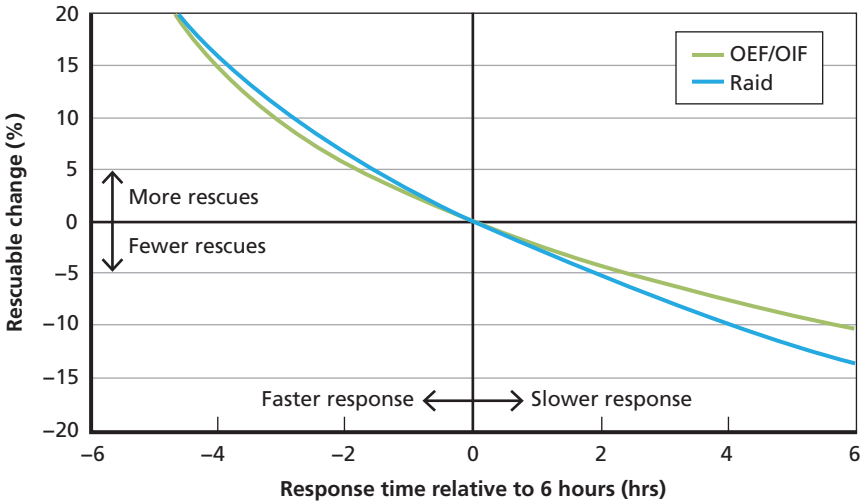
RAND *RR1536-2.7*

can ask: Would faster responses lead to enough of an improvement to justify their expense?

In Figure 2.7, we see that accelerating the response time by two hours for injured personnel with access to SABC alone raised the rescuability rate more than 5 percent in both types of operations, while accelerating the response time by four hours for these personnel raised the rescuability rate roughly 15 percent in both types of operations. Compared with accelerated response times, the decelerated response times caused slightly smaller changes in rescuability rates.

Faster responses prompted only slightly larger gains in the Raid curve than in the OEF/OIF curve, while slower responses prompted relatively larger losses in the Raid curve than in the OEF/OIF curve. However, the speed of responses had nearly the same overall impact regardless of the scenario, indicating that the relative change in rescuability, as a function of response speed, was fairly insensitive to the precise injury distribution represented by each scenario.

Figure 2.8 shows the results for role 1A care (first-responder care) across the historical cases. For injured personnel with access to first-

Figure 2.8
Role 1A—Rescuability Timelines, Relative to Six Hours, with First-Responder Care
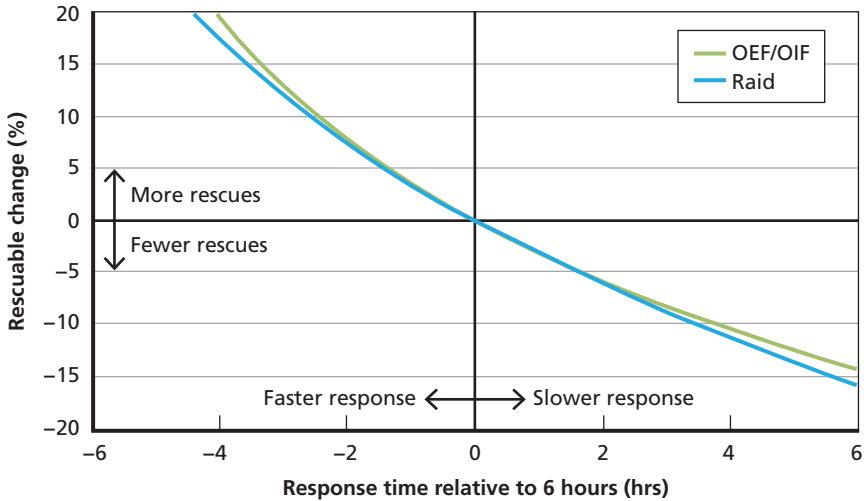
responder care, accelerating the response time by two hours raised the rescuability rate about 8 percent in both types of operations, while accelerating the response time by four hours raised the rate nearly 20 percent for both cases. Again, the curves were strikingly similar for both the OEF/OIF and the Raid data sets.

Figure 2.9 shows the results for role 1B care (aid-station care) across the historical cases. The results for aid-station care were somewhat counterintuitive. For injured personnel with access to aid-station care, the marginal improvements resulting from faster responses were actually less than they had been with first-responder care or even with SABC alone; conversely, the results from slower responses were better than they had been with the two lesser roles of care. We need to remember that the baseline rescuability rates with aid-station care were consistently superior to those attained with the lesser roles of care alone—and that a patient is less sensitive to the response time when he or she is the beneficiary of a greater initial role of care. For injured personnel with access to aid-station care, acceler-

Figure 2.9
Role 1B—Rescuability Timelines, Relative to Six Hours, with Aid-Station Care
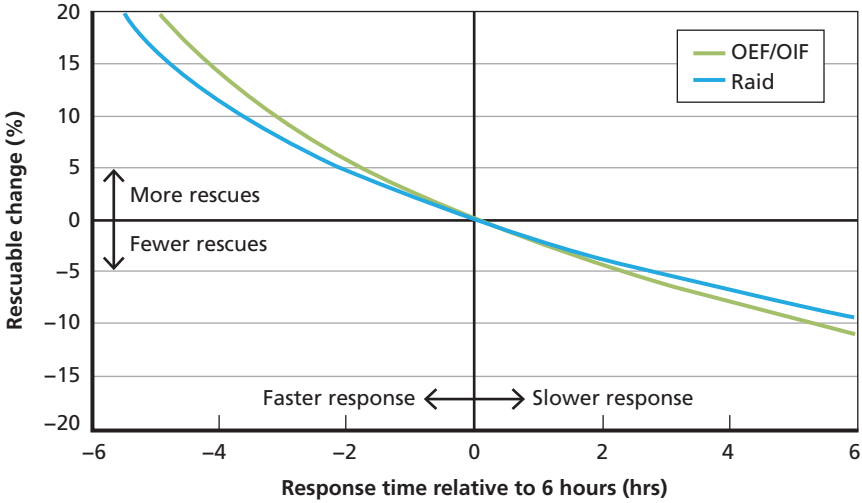
ating the response time by two hours raised the rescuability rate only about 5 percent in both types of operations, while accelerating the response time by four hours raised the rescuability rate between 10 and 15 percent. Yet again, the curves were very similar for both types of operations.

Overarching Observations on Rescuability

In Figures 2.7, 2.8, and 2.9, only minor differences appeared between the OEF/OIF and the Raid rescuability curves for personnel with life-threatening injuries. The differences between the two types of operations had seemed large initially (in Figures 2.4, 2.5, and 2.6), but those differences were confined to the first few hours. Afterward, the curves (and, specifically, the *changes* in curves) behaved quite similarly. In other words, the marginal benefits of speed were similar in both types of operations, assuming similar roles of care.

Slightly greater differences appear when comparing the results *across* the different roles of care. In Figure 2.10, we average the OEF/OIF and Raid curves for each role of care in Figures 2.7 to 2.9.[6] One insight from this chart is that first-responder care, on average, is the most sensitive to changes in response speed, with considerably improved rescuability given faster response speed and considerably worse rescuability given slower response speed. That makes some intuitive sense. First-responder care is sufficient to help a larger number of people survive the first few hours but not sufficient to allow those personnel to wait out the arrival of rescue forces for very long. With SABC alone, the overall likelihood of survival is lower; thus, the percentage of people surviving the initial hours is lower, and consequently there is a smaller pool of rescuable personnel who can benefit from a faster response. Finally, the aid-station role of care can offer a higher baseline likelihood of survival by stabilizing patients and putting them in a better position to wait

Figure 2.10
Rescuability Rates Across Three Roles of Care

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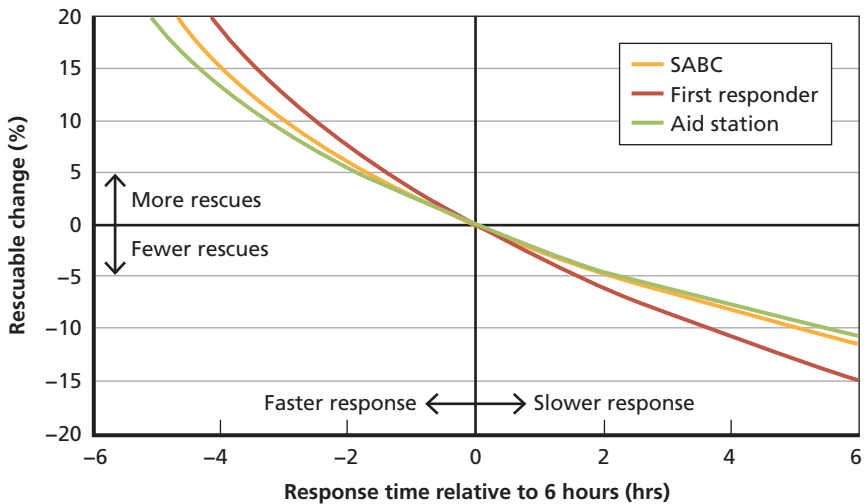
[6]   A three-fourth weight was used for the OEF/OIF case and a one-fourth weight for the Raid case.

for rescue forces to arrive, making this role of care the least sensitive to changes in response speed, whether they be faster or slower.[7]

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[7] With SABC, only 39 percent of injured personnel will survive for six hours. With first-responder care, only 52 percent will survive for six hours. This increases to 65 percent for aid-station care. This illustrates that the proportion of people for whom the difference between six hours and 12 hours is of relevance is lowest for those receiving SABC and highest for those receiving aid-station care. However, of those who do survive the first six hours, 71 percent will survive an additional six hours with SABC alone, 72 percent will do so with first-responder care, and 84 percent will do so with aid-station care. It is this combination of the proportion of people who survive the first six hours and their relative risk for the next six hours that gives rise to the effect seen in Figure 2.10.

Conclusions

This report has found strikingly consistent results of different response speeds across historical cases and care roles. Especially with a six-hour response time as a point of reference for reaching personnel with life-threatening injuries, the marginal changes in rescuability rates resulting from changes in response speeds of up to six hours in either direction (faster or slower) were very similar across the historical cases. Likewise, the performance of three different care roles did not produce dramatically different rescuability rates.

Because the rescuability rates were so consistent across the historical, operational, and clinical cases, we are confident that an aggregated portrayal of the entire set of data can legitimately represent the likely effects of faster or slower personnel responses on rescuability rates in general, regardless of the historical, operational, or clinical settings. Therefore, we aggregate our findings in Figure 3.1, which shows the extremes (or bounds) of the results from Figures 2.7, 2.8, and 2.9. Specifically, the bounds represent the highest and lowest likely changes in rescuability rates across the two types of scenarios and three types of care we considered. We also highlight the average of these consolidated results.

On average, as shown in Figure 3.1, accelerating the response time by two hours (faster than the six-hour standard for injured personnel with access to any kind of care) across all historical cases and operational settings raised the rescuability rate about 7 percent, while accelerating the response time by four hours faster than this standard for these personnel raised the rescuability rate about 16 percent. On

Figure 3.1
Effects of Response Speed on Rescuability Rates in General, Relative to Six Hours
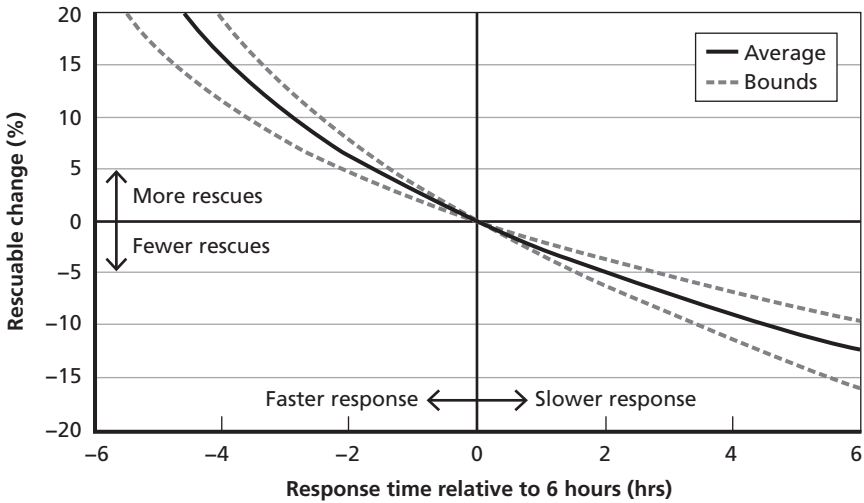
average, decelerating the response time by two hours reduced the rescuability rate about 5 percent, while decelerating the response time by four hours reduced the rescuability rate about 9 percent.

These results serve to benchmark operationally relevant response timelines for AFRICOM. These overall results establish a medically sound and historically validated reference point from which to compare the effects of alternative rescue strategies, which could vary greatly across Africa. Given the continent's vastness and geographic diversity, the preferred strategies could vary by distance or region; for instance, faster responses with lesser care capabilities arriving aboard the rescue asset might work better in some regions, whereas slower responses with greater care capabilities arriving aboard the rescue asset might work better in others. Future RAND analyses will use the aggregated rescuability timelines charted here as the basis for assessing the potential alternative rescue options either for Africa as a whole or for specific mission scenarios. This future analysis will provide a basis for compar-

ing the overall benefits of speed and improved care with the associated operational, clinical, and financial costs.

In some cases in Africa, a six-hour response time would be operationally infeasible. Therefore, we also looked at a 12-hour response as the baseline, and we again compared the results given marginal changes in response times up to six hours in either direction (faster or slower). The marginal changes in rescuability rates with a 12-hour point of reference were generally half as large as they were with a six-hour point of reference.

On average, as shown in Figure 3.2, accelerating the response time by two hours (faster than a 12-hour standard for personnel with life-threatening injuries and access to any kind of care) across all historical cases and operational settings raised the rescuability rate about 3 percent, while accelerating the response time by four hours faster than this standard for these personnel raised the rescuability rate about 7 percent. On average, decelerating the response time by two hours reduced

Figure 3.2
Effects of Response Speed on Rescuability Rates in General, Relative to 12 Hours

the rescuability rate about 3 percent, while decelerating the response time by four hours reduced the rescuability rate about 5 percent.
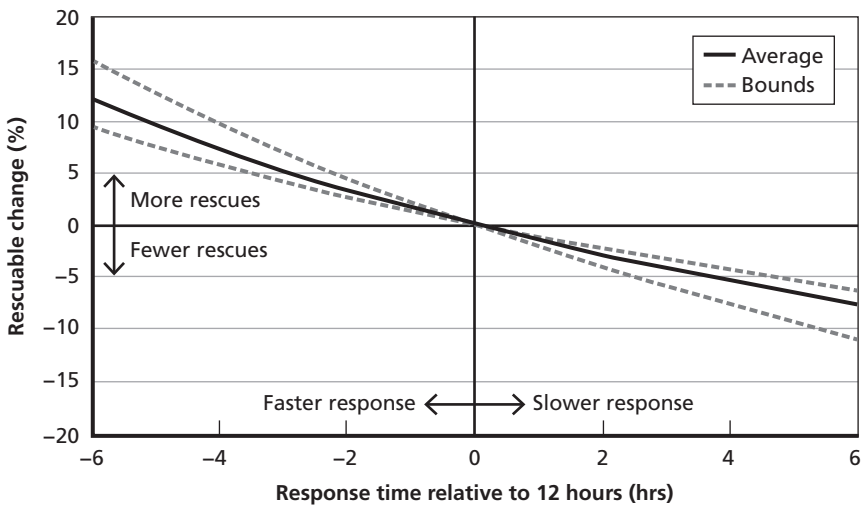
The timelines in both Figure 3.1 and Figure 3.2 indicate that, in absolute terms, 9 percent to 16 percent fewer injured personnel would survive 12 hours than would survive six hours while waiting to be rescued. In Figure 3.1, this range of outcomes appears on the right side. In Figure 3.2, the same range of outcomes appears along the left side.

In summary, the baseline results from the overall rescuability timelines are as follows:

- Relative to a standard six-hour response time, marginal increases in response speeds of two to four hours could increase rescuability rates roughly 7 to 16 percent, on average, while marginal decreases in response speeds of two to four hours could decrease rescuability rates roughly 5 to 9 percent, on average.
- Relative to a standard 12-hour response time, marginal increases in response speeds of two to four hours would increase rescuability rates roughly 3 to 7 percent, on average, while marginal decreases in response speeds of two to four hours would decrease rescuability rates roughly 3 to 5 percent, on average.
- As illustrated by the bounds along the left side in Figure 3.2, a six-hour response time would result in 9 to 16 percent more personnel being rescued than would a 12-hour response time. As illustrated by the bounds in Figure 3.1, a four-hour response time would result in 5 to 8 percent more personnel being rescued than would a six-hour response time. Likewise, as illustrated by the bounds in Figure 3.1, a two-hour response time would result in 12 to 20 percent more personnel being rescued than would a six-hour response time.

We observe that a faster response of six hours (relative to a 12-hour response time) would mean around a 12-percent improvement in the number of people potentially rescued. However, the costs to achieve

this improved rescuability timeline are likely significant. Judging these improvements against the costs will require further analysis.[1]

As mentioned, forthcoming analyses will use the aggregated rescuability timelines in Figures 3.1 and 3.2 to assess the rescuability rates associated with potential alternative rescue options. The relative cost and effectiveness of each option will then be determined and compared. This analysis will recognize that the arrival of rescue assets, no matter how fast, will not guarantee that an injured person will survive. The analysis will also consider the roles of care played throughout the entire rescue chain. This analysis will, for instance, compare faster responses with lesser roles of care against slower responses with greater roles of care. This forthcoming analysis will serve to answer the policy question of how to balance the benefits of speed and improved care with operational, clinical, and financial costs.

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[1] Had the improvement been 50 percent or 1 percent, the decision of whether or not to make the necessary investments might have been obvious.

List of ICD-9 Mortality Risks

Table A.1
Medical Conditions, ICD-9 Codes, and Mortality Risks

Patient Code	Category	Description	Mortality Risk
005	Infectious	Food poisoning bacterial	NLT
006	Infectious	Amebiasis	NLT
007.9	Infectious	Unspecified protozoal intestinal disease	NLT
008.45	Infectious	Intestinal infection due to clostridium difficile	NLT
008.8	Infectious	Intestinal infection due to other organism not classified	NLT
010	Infectious	Primary TB	NLT
037	Infectious	Tetanus	NLT
038.9	Infectious	Unspecified septicemia	NLT
042	Infectious	Human immunodeficiency virus (HIV) disease	NLT
047.9	Infectious	Viral meningitis	NLT
052	Infectious	Varicella	NLT
053	Infectious	Herpes zoster	NLT
054.1	Infectious	Genital herpes	NLT
057.0	Infectious	Fifth disease	NLT

Table A.1—Continued

Patient Code	Category	Description	Mortality Risk
060	Infectious	Yellow fever	NLT
061	Infectious	Dengue	NLT
062	Infectious	Mosquito-borne encephalitis	NLT
063.9	Infectious	Tick-borne encephalitis	NLT
065	Infectious	Arthropod-borne hemorrhagic fever	NLT
066.40	Infectious	West Nile fever, unspecified	NLT
070.1	Infectious	Viral hepatitis	NLT
071	Infectious	Rabies	NLT
076	Infectious	Trachoma	NLT
078.0	Infectious	Molluscom contagiosum	NLT
078.1	Infectious	Viral warts	NLT
078.4	Infectious	Hand, foot, and mouth disease	NLT
079.3	Infectious	Rhinovirus infection in conditions elsewhere and of unspecified site	NLT
079.99	Infectious	Unspecified viral infection	NLT
082	Infectious	Tick-borne rickettsiosis	NLT
084	Infectious	Malaria	NLT
085	Infectious	Leishmaniasis, visceral	NLT
086	Infectious	Trypanosomiasis	NLT
091	Infectious	Early primary syphilis	NLT
091.9	Infectious	Secondary syphilis, unspecified	NLT
094	Infectious	Neurosyphilis	NLT
098.5	Infectious	Gonococcal arthritis	NLT
099.4	Infectious	Nongonococcal urethritis	NLT
100	Infectious	Leptospirosis	NLT
274	Endocrine	Gout	NLT

Table A.1—Continued

Patient Code	Category	Description	Mortality Risk
276	Endocrine	Disorder of fluid, electrolyte + acid base balance	NLT
296.0	Mental Disorders	Bipolar disorder, single manic episode	NLT
298.9	Mental Disorders	Unspecified psychosis	NLT
309.0	Mental Disorders	Adjustment disorder with depressed mood	NLT
309.81	Mental Disorders	PTSD	NLT
309.9	Mental Disorders	Unspecified adjustment reaction	NLT
310.2	Mental Disorders	Post concussion syndrome	NLT
345.2	Sense	Epilepsy petit mal	NLT
345.3	Sense	Epilepsy grand mal	NLT
346	Misc	Migraine	NLT
361	Sense	Retinal detachment	NLT
364.3	Sense	Uveitis NOS	NLT
365	Sense	Glaucoma	NLT
370.0	Sense	Corneal ulcer	NLT
379.31	Sense	Aphakia	NLT
380.1	Sense	Infective otitis externa	NLT
380.4	Sense	Impacted cerumen	NLT
381	Sense	Acute nonsuppurative otitis media	NLT
381.9	Sense	Unspecified eustachian tube disorder	NLT
384.2	Sense	Perforated tympanic membrane	NLT
388.3	Sense	Tinnitus, unspecified	NLT
389.9	Sense	Unspecified hearing loss	NLT

Table A.1—Continued

Patient Code	Category	Description	Mortality Risk
401	Circulatory	Essential hypertension	NLT
410	Circulatory	Myocardial infarction	NLT
413.9	Circulatory	Other and unspecified angina pectoris	NLT
427.9	Circulatory	Cardiac dysryhthmia unspecified	NLT
453.4	Circulatory	Venous embolism/thrombus of deep vessels lower extremity	NLT
462	Respiratory	Acute pharyngitis	NLT
465	Respiratory	Acute upper respiratory infections of multiple or unspecified sites	NLT
466	Respiratory	Acute bronchitis and bronchiolitis	NLT
475	Respiratory	Peritonsillar abscess	NLT
486	Respiratory	Pneumonia, organism unspecified	NLT
491	Respiratory	Chronic bronchitis	NLT
492	Respiratory	Emphysema	NLT
493.9	Respiratory	Asthma	NLT
523	Digestive	Gingival and periodontal disease	NLT
530.2	Digestive	Ulcer of esophagus	NLT
530.81	Digestive	Gastroesophageal reflux	NLT
531	Digestive	Gastric ulcer	NLT
532	Digestive	Duodenal ulcer	NLT
540.9	Digestive	Acute appendicitis without mention of peritonitis	NLT
541	Digestive	Appendicitis, unspecified	NLT
550.9	Digestive	Unilateral inguinal hernia	NLT
553.1	Digestive	Umbilical hernia	NLT
553.9	Digestive	Hernia NOS	NLT
564.0	Digestive	Constipation	NLT

Table A.1—Continued

Patient Code	Category	Description	Mortality Risk
564.1	Digestive	Irritable bowel disease	NLT
566	Digestive	Abscess of anal and rectal regions	NLT
567.9	Digestive	Unspecified peritonitis	NLT
574	Digestive	Cholelithiasis	NLT
577.0	Digestive	Acute pancreatitis	NLT
577.1	Digestive	Chronic pancreatitis	NLT
578.9	Digestive	Hemorrhage of gastrointestinal tract unspecified	NLT
584.9	Genitourinary	Acute renal failure, unspecified	NLT
592	Genitourinary	Calculus of kidney	NLT
599.0	Genitourinary	Unspecified urinary tract infection	NLT
599.7	Genitourinary	Hematuria	NLT
608.2	Genitourinary	Torsion of testes	NLT
608.4	Genitourinary	Other inflammatory disorders of male genital organs	NLT
611.7	Genitourinary	Breast lump	NLT
633	Pregnancy	Ectopic pregnancy	NLT
634	Pregnancy	Spontaneous abortion	NLT
681	Skin	Cellulitis and abscess of finger and toe	NLT
682.0	Skin	Cellulitis and abscess of face	NLT
682.6	Skin	Cellulitis and abscess of leg except foot	NLT
682.7	Skin	Cellulitis and abscess of foot except toes	NLT
682.9	Skin	Cellulitis and abscess of unspecified parts	NLT
719.41	Musculoskeletal	Pain in joint shoulder	NLT
719.46	Musculoskeletal	Pain in joint lower leg	NLT
719.47	Musculoskeletal	Pain in joint ankle/foot	NLT

Table A.1—Continued

Patient Code	Category	Description	Mortality Risk
722.1	Musculoskeletal	Displacement lumbar intervertebral disc without myelopathy	NLT
723.0	Musculoskeletal	Spinal stenosis in cervical region	NLT
724.02	Musculoskeletal	Spinal stenosis of lumbar region	NLT
724.2	Musculoskeletal	Lumbago	NLT
724.3	Musculoskeletal	Sciatica	NLT
724.4	Musculoskeletal	Lumbar sprain (thoracic/lumbosacral) neuritis or radiculitis, unspecified	NLT
724.5	Musculoskeletal	Backache unspecified	NLT
726.10	Musculoskeletal	Disorders of bursae and tendons in shoulder, unspecified	NLT
726.12	Musculoskeletal	Bicipital tenosynovitis	NLT
726.3	Musculoskeletal	Enthesopathy of elbow region	NLT
726.4	Musculoskeletal	Enthesopathy of wrist and carpus	NLT
726.5	Musculoskeletal	Enthesopathy of hip region	NLT
726.6	Musculoskeletal	Enthesopathy of knee	NLT
726.7	Musculoskeletal	Enthesopathy of ankle and tarsus	NLT
729.0	Musculoskeletal	Rheumatism unspecified and fibrositis	NLT
729.5	Musculoskeletal	Pain in limb	NLT
780.0	Ill-defined	Alterations of consciousness	NLT
780.2	Ill-defined	Syncope	NLT
780.39	Ill-defined	Other convulsions	NLT
780.5	Ill-defined	Sleep disturbances	NLT
780.6	Ill-defined	Fever	NLT
782.1	Ill-defined	Rash and other nonspecific skin eruptions	NLT
782.3	Ill-defined	Edema	NLT
783.0	Ill-defined	Anorexia	NLT

Table A.1—Continued

Patient Code	Category	Description	Mortality Risk
784.0	Ill-defined	Headache	NLT
784.7	Ill-defined	Epistaxis	NLT
784.8	Ill-defined	Hemorrhage from throat	NLT
786.5	Ill-defined	Chest pain	NLT
787.0	Ill-defined	Nausea and vomiting	NLT
787.91	Ill-defined	Diarrhea NOS	NLT
789.00	Ill-defined	Abdominal pain unspecified site	NLT
800.0	Fractures	Closed fracture of vault of skull without intracranial injury	Medium
801.0	Fractures	Closed fracture of base of skull without intracranial injury	Medium
801.76	Fractures	Open fracture base of skull with subarachnoid, subdural and extradural hemorrhage with loss of consciousness of unspecified duration	High
802.0	Fractures	Closed fracture of nasal bones	Low
802.1	Fractures	Open fracture of nasal bones	Low
802.6	Fractures	Fracture orbital floor closed (blowout)	NLT
802.7	Fractures	Fracture orbital floor open (blowout)	Low
802.8	Fractures	Closed fracture of other facial bones	NLT
802.9	Fractures	Open fracture of other facial bones	Low
805	Fractures	Closed fracture of cervical vertebra without spinal cord injury	NLT
806.1	Fractures	Open fracture of cervical vertebra with spinal cord injury	High
806.2	Fractures	Closed fracture of dorsal vertebra with spinal cord injury	Medium
806.3	Fractures	Open fracture of dorsal vertebra with spinal cord injury	High

Table A.1—Continued

Patient Code	Category	Description	Mortality Risk
806.4	Fractures	Closed fracture of lumbar spine with spinal cord injury	Medium
806.5	Fractures	Open fracture of lumbar spine with spinal cord injury	High
806.60	Fractures	Closed fracture sacrum and coccyx with unspecified spinal cord injury	Medium
806.70	Fractures	Open fracture sacrum and coccyx with unspecified spinal cord injury	High
807.0	Fractures	Closed fracture of rib(s)	NLT
807.1	Fractures	Open fracture of rib(s)	Low
807.2	Fractures	Closed fracture of sternum	Low
807.3	Fractures	Open fracture of sternum	High
808.8	Fractures	Fracture of pelvis unspecified, closed	Low
808.9	Fractures	Fracture of pelvis unspecified, open	High
810.0	Fractures	Clavicle fracture, closed	NLT
810.1	Fractures	Clavicle fracture, open	High
810.12	Fractures	Open fracture of shaft of clavicle	High
811.0	Fractures	Fracture of scapula, closed	NLT
811.1	Fractures	Fracture of scapula, open	High
812.00	Fractures	Fracture of unspecified part of upper end of humerus, closed	NLT
813.8	Fractures	Fracture unspecified part of radius and ulna closed	NLT
813.9	Fractures	Fracture unspecified part of radius and ulna open	NLT
815.0	Fractures	Closed fracture of metacarpal bones	NLT
816.0	Fractures	Phalanges fracture, closed	NLT
816.1	Fractures	Phalanges fracture, open	NLT
817.0	Fractures	Multiple closed fractures of hand bones	NLT

Table A.1—Continued

Patient Code	Category	Description	Mortality Risk
817.1	Fractures	Multiple open fracture of hand bones	NLT
820.8	Fractures	Fracture of femur neck, closed	Medium
820.9	Fractures	Fracture of femur neck, open	High
821.01	Fractures	Fracture shaft femur, closed	Medium
821.11	Fractures	Fracture shaft of femur, open	Medium
822.0	Fractures	Closed fracture of patella	NLT
822.1	Fractures	Open fracture of patella	NLT
823.82	Fractures	Closed fracture of unspecified part of fibula with tibia	NLT
823.9	Fractures	Fracture of unspecified part of tibia and fibula open	Low
824.8	Fractures	Fracture ankle, NOS, closed	NLT
824.9	Fractures	Ankle fracture, open	Low
825.0	Fractures	Fracture to calcaneus, closed	Low
826.0	Fractures	Closed fracture of one or more phalanges of foot	Low
829.0	Fractures	Fracture of unspecified bone, closed	Low
830.0	Dislocations	Closed dislocation of jaw	NLT
830.1	Dislocations	Open dislocation of jaw	NLT
831	Dislocations	Dislocation shoulder	NLT
831.04	Dislocations	Closed dislocation of acromioclavicular joint	NLT
831.1	Dislocations	Dislocation of shoulder, open	NLT
832.0	Dislocations	Dislocation of elbow, closed	NLT
832.1	Dislocations	Dislocation of elbow, open	NLT
833	Dislocations	Dislocation of wrist closed	NLT
833.1	Dislocations	Dislocation of wrist, open	NLT

Table A.1—Continued

Patient Code	Category	Description	Mortality Risk
834.0	Dislocations	Dislocation of finger, closed	NLT
834.1	Dislocations	Dislocation of finger, open	NLT
835	Dislocations	Closed dislocation of hip	NLT
835.1	Dislocations	Hip dislocation open	NLT
836.0	Dislocations	Medial meniscus tear	NLT
836.1	Dislocations	Lateral meniscus tear	NLT
836.2	Dislocations	Meniscus tear of knee	NLT
836.5	Dislocations	Dislocation of knee, closed	NLT
836.6	Dislocations	Other dislocation of knee, open	NLT
839.01	Dislocations	Closed dislocation of first cervical vertebra	Medium
840.4	Sprains & Strains	Rotator cuff sprain	NLT
840.9	Sprains & Strains	Sprain, shoulder	NLT
843	Sprains & Strains	Sprains and strains of hip and thigh	NLT
844.9	Sprains & Strains	Sprain, knee	NLT
845	Sprains & Strains	Sprain, ankle	NLT
846	Sprains & Strains	Sprains and strains of sacroiliac region	NLT
846.0	Sprains & Strains	Sprain of lumbosacral (joint) (ligament)	NLT
847.2	Sprains & Strains	Sprain lumbar region	NLT
847.3	Sprains & Strains	Sprain of sacrum	NLT
848.1	Sprains & Strains	Jaw sprain	NLT
848.3	Sprains & Strains	Sprain of ribs	NLT
850.9	Intracranial Injuries	Concussion	NLT
851.0	Intracranial Injuries	Cortex (Cerebral) contusion without open intracranial wound	High

Table A.1—Continued

Patient Code	Category	Description	Mortality Risk
851.01	Intracranial Injuries	Cortex (Cerebral) contusion without open wound, no loss of consciousness	High
852	Intracranial Injuries	Subarachnoid subdural extradural hemorrhage injury	Low
853	Intracranial Injuries	Other and unspecified intracranial hemorrhage injury without open wound	High
853.15	Intracranial Injuries	Unspecified intracranial hemorrhage with open intracranial wound	High
860.0	Thorax Abdomen Injuries	Traumatic pneumothorax without open wound into thorax	High
860.1	Thorax Abdomen Injuries	Traumatic pneumothorax with open wound into thorax	High
860.2	Thorax Abdomen Injuries	Traumatic hemothorax without open wound into thorax	High
860.3	Thorax Abdomen Injuries	Traumatic hemothorax with open wound into thorax	High
860.4	Thorax Abdomen Injuries	Traumatic pneumohemothorax without open wound into thorax	High
860.5	Thorax Abdomen Injuries	Traumatic pneumohemothorax with open wound into thorax	High
861.0	Thorax Abdomen Injuries	Injury to heart without open wound into thorax	High
861.1	Thorax Abdomen Injuries	Unspecified injury of heart with open wound into thorax	High
861.2	Thorax Abdomen Injuries	Injury to lung, NOS, closed	High
861.3	Thorax Abdomen Injuries	Injury to lung, NOS, open	High
863.0	Thorax Abdomen Injuries	Stomach injury, without open wound into cavity	Low
864.10	Thorax Abdomen Injuries	Unspecified injury to liver with open wound into cavity	Medium
865	Thorax Abdomen Injuries	Injury to spleen	Medium

Table A.1—Continued

Patient Code	Category	Description	Mortality Risk
866.0	Thorax Abdomen Injuries	Injury to kidney without open wound	Low
866.1	Thorax Abdomen Injuries	Injury to kidney with open wound into cavity	Low
867.0	Thorax Abdomen Injuries	Injury to bladder and urethra without open wound into cavity	Low
867.1	Thorax Abdomen Injuries	Injury to bladder and urethra with open wound into cavity	Medium
867.2	Thorax Abdomen Injuries	Injury to ureter without open wound into cavity	Low
867.3	Thorax Abdomen Injuries	Injury to ureter with open wound into cavity	Medium
867.4	Thorax Abdomen Injuries	Injury to uterus without open wound into cavity	Low
867.5	Thorax Abdomen Injuries	Injury to uterus with open wound into cavity	Medium
870	Open Wounds	Open wound of ocular adnexa	NLT
870.3	Open Wounds	Penetrating wound of orbit without foreign body	NLT
870.4	Open Wounds	Penetrating wound of orbit with foreign body	NLT
871.5	Open Wounds	Penetration of eyeball with magnetic foreign body	NLT
872	Open Wounds	Open wound of ear	NLT
873.4	Open Wounds	Open wound of face, without mention of complication	NLT
873.8	Open Wounds	Open head wound, without complication	NLT
873.9	Open Wounds	Open head wound, with complications	Low
874.8	Open Wounds	Open wound of other and unspecified parts of neck, without complications	NLT
875.0	Open Wounds	Open wound of chest (wall), without complication	NLT

Table A.1—Continued

Patient Code	Category	Description	Mortality Risk
876.0	Open Wounds	Open wound of back without complication	Low
877.0	Open Wounds	Open wound of buttock without complication	NLT
878	Open Wounds	Open wound of genital organs (external) including traumatic amputation	Low
879.2	Open Wounds	Open wound of abdominal wall anterior without complication	Low
879.6	Open Wounds	Open wound of other unspecified parts of trunk, without complication	Low
879.8	Open Wounds	Open wound(s) (multiple) of unspecified site(s), without complication	Low
880	Open Wounds	Open wound of the shoulder and upper arm	NLT
881	Open Wounds	Open wound of elbows, forearm, and wrist	NLT
882	Open Wounds	Open wound of hand except fingers alone	NLT
883.0	Open Wounds	Open wound of fingers, without complication	NLT
884.0	Open Wounds	Multiple/unspecified open wound upper limb, without complication	NLT
885	Open Wounds	Traumatic amputation of thumb (complete) (partial)	NLT
886	Open Wounds	Traumatic amputation of other finger(s) (complete) (partial)	NLT
887	Open Wounds	Traumatic amputation of arm and hand (complete) (partial)	Medium
890	Open Wounds	Open wound of hip and thigh	NLT
891	Open Wounds	Open wound of knee, leg (except thigh), and ankle	NLT
892.0	Open Wounds	Open wound of foot except toes alone, without complication	NLT

Table A.1—Continued

Patient Code	Category	Description	Mortality Risk
894.0	Open Wounds	Multiple/unspecified open wound of lower limb without complication	NLT
895	Open Wounds	Traumatic amputation of toe(s) (complete) (partial)	NLT
896	Open Wounds	Traumatic amputation of foot (complete) (partial)	Low
897	Open Wounds	Traumatic amputation of leg(s) (complete) (partial)	High
903	Blood Vessels	Injury to blood vessels of upper extremity	Low
904	Blood Vessels	Injury to blood vessels of lower extremity and unspecified sites	High
910.0	Superficial	Abrasion/friction burn of face, neck, scalp, without infection	NLT
916.0	Superficial	Abrasion/friction burn of hip, thigh, leg, ankle, without infection	NLT
916.1	Superficial	Abrasion/friction burn of hip, thigh, leg, ankle, with infection	NLT
916.2	Superficial	Blister of hip and leg	NLT
916.3	Superficial	Blister of hip, thigh, leg, and ankle, with infection	NLT
916.4	Superficial	Insect bite nonvenom hip, thigh, leg, ankle, without infection	NLT
916.5	Superficial	Insect bite nonvenom hip, thigh, leg, ankle, with infection	NLT
918.1	Superficial	Superficial injury cornea	NLT
920	Contusion	Contusion of face, scalp, and neck except eye(s)	NLT
921.0	Contusion	Black eye	NLT
922.1	Contusion	Contusion of chest wall	NLT
922.2	Contusion	Contusion of abdominal wall	NLT
922.4	Contusion	Contusion of genital organs	NLT
924.1	Contusion	Contusion of knee and lower leg	NLT

Table A.1—Continued

Patient Code	Category	Description	Mortality Risk
924.2	Contusion	Contusion of ankle and foot	NLT
924.3	Contusion	Contusion of toe	NLT
925	Crush Injuries	Crushing injury of face, scalp, and neck	Medium
926	Crush Injuries	Crushing injury of trunk	Medium
927	Crush Injuries	Crushing injury of upper limb	NLT
928	Crush Injuries	Crushing injury of lower limb	Low
930	Foreign Bodies	Foreign body on external eye	NLT
935	Foreign Bodies	Foreign body in mouth, esophagus, and stomach	NLT
941	Burns	Burn of face, head, neck	NLT
942.0	Burns	Burn of trunk, unspecified degree	Low
943.0	Burns	Burn of upper limb except wrist and hand, unspecified degree	NLT
944	Burns	Burn of wrist and hand	NLT
945	Burns	Burn of lower limb(s)	NLT
950	Nerves	Injury to optic nerve and pathways	NLT
953.0	Nerves	Injury to cervical nerve root	Low
953.4	Nerves	Injury to brachial plexus	NLT
955.0	Nerves	Injury to axillary nerve	NLT
956.0	Nerves	Injury to sciatic nerve	NLT
959.01	Complications	Other and unspecified injury to head	Low
959.09	Complications	Other and unspecified injury to face and neck	Low
959.7	Complications	Other and unspecified injury to knee, leg, ankle, and foot	Low
989.5	Toxic Non-Medicinal	Toxic effect of venom	Low
989.9	Toxic Non-Medicinal	Toxic effect of unspecified substance, chiefly nonmedicinal as to source	Low

Table A.1—Continued

Patient Code	Category	Description	Mortality Risk
991.3	External	Frostbite	NLT
991.6	External	Hypothermia	NLT
992.0	External	Heat stroke and sun stroke	Low
992.2	External	Heat cramps	NLT
992.3	External	Heat exhaustion anhydrotic	NLT
994.0	External	Effects of lightning	NLT
994.1	External	Drowning and nonfatal submersion	NLT
994.2	External	Effects of deprivation of food	NLT
994.3	External	Effects of thirst	NLT
994.4	External	Exhaustion due to exposure	NLT
994.5	External	Exhaustion due to excessive exertion	NLT
994.6	External	Motion sickness	NLT
994.8	External	Electrocution and nonfatal effects of electric current	NLT
995.0	External	Other anaphylactic shock not elsewhere classified	Medium
E991.2	Not Assigned	Injury due to war ops from other bullets (not rubber/pellets)	NLT
E991.3	Not Assigned	Injury due to war ops from antipersonnel bomb fragment	NLT
E991.9	Not Assigned	Injury due to war ops from other unspecified fragments	NLT
E993	Not Assigned	Injury due to war ops by other explosion	NLT
V01.5	Supplementary	Contact with or exposure to rabies	NLT
V79.0	Mental Disorders	Screening for depression	NLT

SOURCE: World Health Organization, *Ninth International Classification of Diseases, Ninth Revision (ICD-9)*, Vol. 1, Geneva, 1978.

NOTE: NOS = not otherwise specified.

Additional Rescuability Timelines

Beyond the five historical cases considered in the main document, we looked at five additional ones, four of which were drawn from OEF/OIF and one from Vietnam. These are shown in the bottom half of Table B.1 and in Figures B.1 to B.3. This expanded collection of cases represents the entire universe of MPTk data available on the injury distributions from historical conflicts.

The additional OEF/OIF rescuability timelines fall, perhaps as expected, closely alongside those of the other OEF/OIF rescuability timelines. The Vietnam timeline falls almost halfway between the OEF/OIF timelines and the combined Gothic Serpent/Mayaguez timeline. The contiguity of all of these timelines further strengthens the argument that the cases considered in this research and the results presented are robust across conflicts.

Table B.1
Distribution of Life-Threatening Injuries Across Additional Historical Cases

Event	Breakdown of Life-Threatening Injuries by Mortality Risk (%)		
	Low	Medium	High
OEF (Army)	45	16	38
Gothic Serpent/Mayaguez	74	5	22
OEF/OIF (2008–2009)	47	13	40
Second Battle of Fallujah	52	12	36
OIF (Army)	47	14	39
OIF (Marines)	48	16	36
OEF (Marines)	47	13	41
Vietnam (1965–1971)	62	10	28
OEF (2010)	44	12	44

SOURCE: MPTk.

Figure B.1
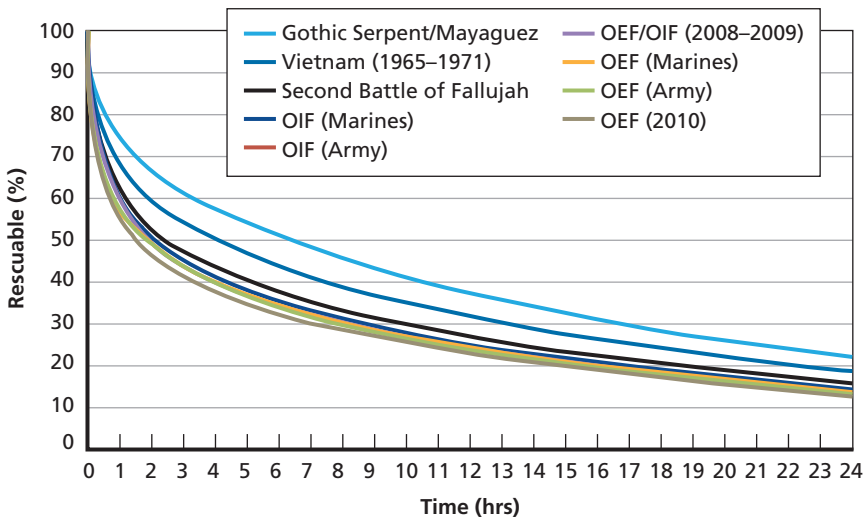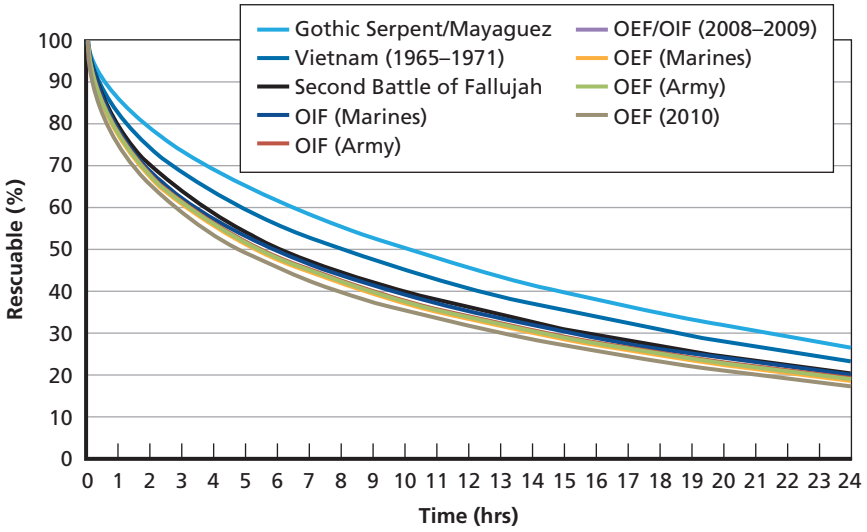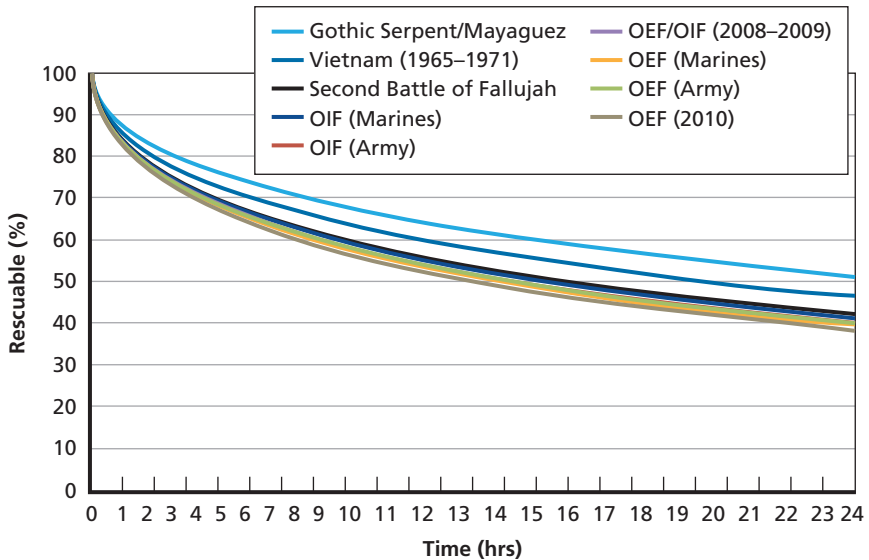**Role 1—Additional Rescuability Timelines with SABC**

RAND *RR1536-B.1*

Figure B.2
Role 1A—Additional Rescuability Timelines with First-Responder Care

RAND *RR1536-B.2*

Figure B.3
Role 1B—Additional Rescuability Timelines with Aid-Station Care

RAND *RR1536-B.3*

Abbreviations

AFRICOM	U.S. Africa Command
AOR	area of responsibility
CASEVAC	casualty evacuation
CSAR	combat search and rescue
DoD	U.S. Department of Defense
ICD	International Classification of Diseases
JMPT	Joint Medical Planning Tool
MEDEVAC	medical evacuation
MPTk	Medical Planners' Toolkit
MTF	military treatment facility
NLT	non–life-threatening
OEF	Operation Enduring Freedom
OIF	Operation Iraqi Freedom
PR	personnel recovery
SABC	self-aid/buddy care
SME	subject-matter expert

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Conducting medical evacuations and other personnel recovery missions in Africa is challenging because of the continent's vast geographic scope and the small number of U.S. personnel scattered across it. This report studies the military medical literature and recent historical cases to explore the relationships between rescuability and time. Marginal changes in incident response times, given a baseline of 6 or 12 hours, do not correlate with dramatically different rescuability rates in the historical cases. Enhancements of the initial medical care provided can improve rescuability rates; however, providing even modestly improved care in an operational context may prove difficult. Future analyses can use the baseline results outlined here to assess the likely rescuability rates associated with alternative rescue options. The cost and effectiveness of options can then be determined and compared. The policy question revolves around balancing the benefits of speed and improved care with the operational, clinical, and financial costs.

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