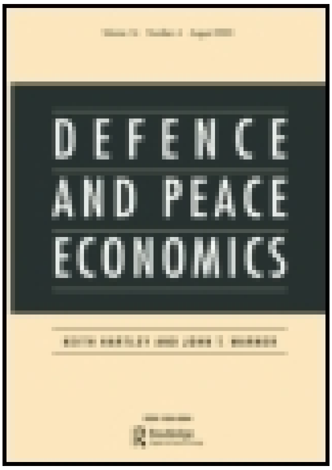

Defence and Peace Economics
Publication details, including instructions for authors and subscription information:
http://www.tandfonline.com/loi/gdpe20

Using Combat Losses of Medical Personnel to Estimate the Impact of Trauma Care in Battle: Evidence from World War II, Korea, Vietnam, Iraq and Afghanistan

Chris Rohlfs[a], Ryan Sullivan[b], Jeffrey Treistman[c] & Ying Deng[d]
[a] Morgan Stanley, New York, NY, USA
[b] Defense Resources Management Institute, Naval Postgraduate School, Monterey, CA, USA
[c] Department of Political Science, Syracuse University, Syracuse, NY, USA
[d] Department of Quantitative Economics, University of International Business and Economics, Beijing, China

To cite this article: Chris Rohlfs, Ryan Sullivan, Jeffrey Treistman & Ying Deng (2015): Using Combat Losses of Medical Personnel to Estimate the Impact of Trauma Care in Battle: Evidence from World War II, Korea, Vietnam, Iraq and Afghanistan, Defence and Peace Economics, DOI: 10.1080/10242694.2015.1005897

To link to this article: http://dx.doi.org/10.1080/10242694.2015.1005897

Defence and Peace Economics, 2015
http://dx.doi.org/10.1080/10242694.2015.1005897

Routledge
Taylor & Francis Group

USING COMBAT LOSSES OF MEDICAL PERSONNEL TO ESTIMATE THE IMPACT OF TRAUMA CARE IN BATTLE: EVIDENCE FROM WORLD WAR II, KOREA, VIETNAM, IRAQ AND AFGHANISTAN

CHRIS ROHLFS[a], RYAN SULLIVAN[b]*, JEFFREY TREISTMAN[c] AND YING DENG[d]

[a]*Morgan Stanley, New York, NY, USA;* [b]*Defense Resources Management Institute, Naval Postgraduate School, Monterey, CA, USA;* [c]*Department of Political Science, Syracuse University, Syracuse, NY, USA;* [d]*Department of Quantitative Economics, University of International Business and Economics, Beijing, China*

(*Received 28 April 2014; in final form 30 December 2014*)

This study investigates the effect that US medical personnel deaths in combat have on other unit deaths and 'military success,' which we measure using commendation medals as a proxy. We use a difference-in-differences identification strategy, measuring the changes over time in these outcomes following the combat loss of a medic or doctor and comparing it to the changes following the combat loss of a soldier who is not a medic or doctor. We find that overall unit deaths decrease in the five or ten days following the deaths of medical personnel in Vietnam, Korea, and the Pacific theater in World War II (WWII). In contrast, the WWII European and North African results indicate that overall unit deaths rise following medical personnel deaths. We find no relationship between medical personnel deaths and other unit deaths in Iraq and Afghanistan. For Korea and the Pacific theater of WWII, our estimates suggest unit commendation medals decrease following the deaths of medical personnel. This pattern of evidence is consistent with a model in which units often halted aggressive tactical maneuvers and reduced pursuit of their military objectives until deceased medical personnel were replaced. The results for the other conflicts are mixed and show little connection between medical personnel deaths and commendation medals.

Keywords: Trauma care; Medic; Medical personnel; Military; Fatalities; Military success

JEL Codes: I12, I18, H43

1. INTRODUCTION

Since the inception of the Global War on Terrorism there have been over 60,000 US casualties (i.e., combined number of deaths and wounded). Many of these casualties have been surviving at higher rates than in past conflicts. The number of wounded-to-deaths ratio for US soldiers in major conflicts has steadily risen over the years, from a low of 1.65 in WWII, to a high of 9.19 in Iraq and Afghanistan (Congressional Research Service 2010;

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*Corresponding author: Defense Resources Management Institute, Naval Postgraduate School, 287 Halligan Hall, Monterey, CA 93943, USA. E-mail: rssulliv@nps.edu

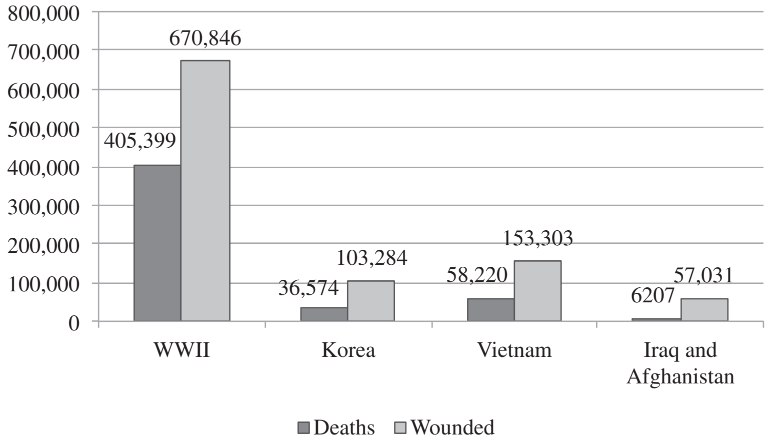

FIGURE 1A Total number of deaths and wounded
Source: Iraq and Afghanistan casualty numbers were obtained from U.S. Defense Manpower Data Center (2011). WWII, Korea, and Vietnam casualty numbers were obtained from Congressional Research Service (2010).

U.S. Defense Manpower Data Center 2011).[1] The medical literature attributes much of this change to increases in the quality of medical care that US troops receive (Holcomb et al. 2006; Kotwal et al. 2011). Providing quality medical care is by no means free and, according to Congressional Budget Office estimates, the Department of Defense (DoD) expects its health care expenditures to reach $59 billion by 2016 (Congressional Budget Office 2011). These expenditures pay for amenities such as treatment centers, pills, medical devices and, of course, medical personnel.

This study examines the extent to which medical personnel deaths in combat affect the losses of other soldiers in their units. We also investigate the relationship between medical personnel deaths and commendation medals earned by military units. We employ a unique natural experiment that is based upon the randomness of events on the battlefield. It is difficult to predict what types of personnel might be lost in a given battle, and units experiencing similar types of combat lose different types of personnel for essentially random reasons. Our difference-in-differences approach compares the change in deaths or commendations that a unit experiences following the combat loss of a medic or doctor to the change in deaths or commendations that a unit experiences following the combat loss of a soldier who is not a medic or doctor. Our detailed data on unit characteristics enable us to ensure that, prior to the exposure of the combat loss, the 'treatment' units that lost medical personnel were similar to the 'control' units that lost non-medical personnel and allow us to control for time-constant variables that differed between the two groups. To our knowledge, this is the first study to use this type of identification strategy to plausibly identify the effect that medical personnel deaths have on other unit deaths and our proxy measure for military success (i.e., commendation medals).

The casualty data in this study originate from multiple sources and include detailed information about unit affiliation, date of death, and medical occupation for personnel serving in

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[1] For the conflicts in Iraq and Afghanistan, there were a total of 4897 hostile deaths, 1310 non-hostile deaths, and 57,031 wounded from 9 October 2001 to 29 August 2011 for US soldiers (U.S. Defense Manpower Data Center 2011). The number of deaths for WWII, Korea, and Vietnam were 405,399, 36,574, and 58,220, respectively. As for their wounded, the numbers for WWII, Korea, and Vietnam were 670,846, 103,284, and 153,303, respectively (Congressional Research Service 2010). These numbers are shown in Figure 1A. Figure 1B shows the total number of wounded to deaths ratio for major US military engagements since WWII.

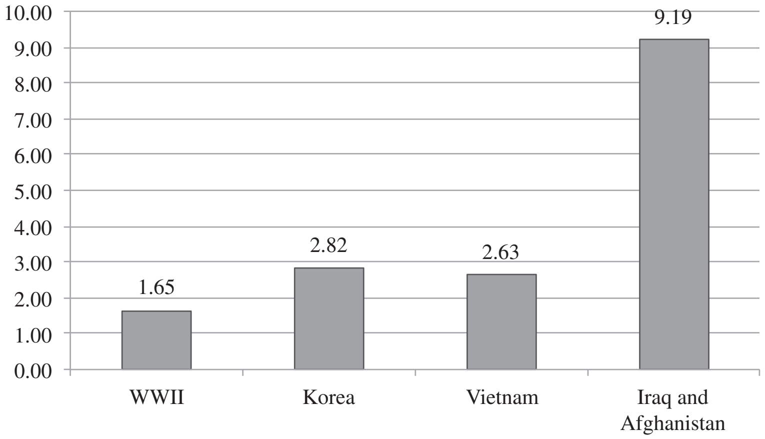

FIGURE 1B Total number of wounded/total deaths
Source: Iraq and Afghanistan casualty numbers were obtained from U.S. Defense Manpower Data Center (2011). WWII, Korea, and Vietnam casualty numbers were obtained from Congressional Research Service (2010).

WWII, Korea, Vietnam, Iraq and Afghanistan.[2] These data provide results related to the 1940s, 1950s, 1960s and 1970s, and the 2000s. Hand-typed paper archival records supply the WWII data; Korea and Vietnam data come from electronic archival records; and the US Defense Manpower Data Center (DMDC) provide the Iraq and Afghanistan data. The Iraq and Afghanistan data are for official use only (FOUO), whereas the casualty data from WWII, Korea, and Vietnam are publicly available. We obtained the commendation medal data from publicly available sources online.

We find that unit deaths decrease in the five or ten days following the deaths of medical personnel in Vietnam, Korea, and the Pacific theater in WWII. In contrast, the WWII European and North African results indicate that unit deaths rise following medical personnel deaths. We find no relationship between medical personnel deaths and other unit deaths in Iraq and Afghanistan. As for the commendation medal results, our estimates suggest that unit commendation medals decrease following the deaths of medical personnel in Korea and the Pacific theater of WWII. This pattern of evidence is consistent with a model in which units often halted aggressive tactical maneuvers and reduced pursuit of their military objectives until deceased medical personnel were replaced. The commendation medal results for the other conflicts are mixed and show little evidence of a connection between medical personnel deaths and commendation medals.

The remainder of this study proceeds as follows. Section 2 provides key institutional details about the equipment and modern day training of medical personnel in the US military. Section 3 outlines the conceptual framework. Section 4 describes the data. Section 5 presents the results and Section 6 concludes.

2. INSTITUTIONAL DETAILS

Prospective combat medics begin their careers by undergoing the same initial military training as all other army recruits. Known as basic combat training (BCT), it serves as a soldier's initial foray into military life, which the army designs to acclimate them to the

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[2] Iraq and Afghanistan casualty numbers were obtained from U.S. Defense Manpower Data Center (2011). WWII, Korea, and Vietnam casualty numbers were obtained from Congressional Research Service (2010).

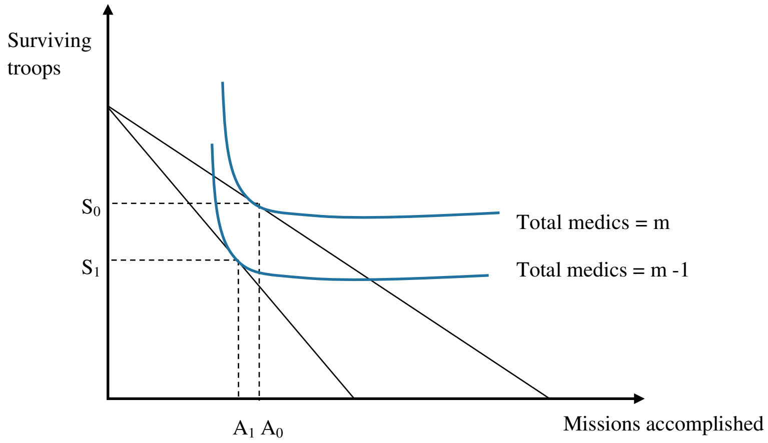

FIGURE 2A Medic loss reduces troop survival

physical stress of actual combat. Recruits learn the army's core values and military heritage and receive an introduction to fundamental combat skills, ranging from basic rifle marksmanship to advanced weapons training.

Upon successfully completing combat training, recruits then move on to advanced individual training where they acquire specialized skills related to their military occupation. For health care specialists, this entails medical training at Fort Sam Houston in San Antonio, Texas. In fact, since WWII, the army has conducted nearly all army medical training at this site. Under the auspices of the Army Medical Department, soldiers receive the skills necessary to deliver emergency medical care. As discussed in Butler and Hagmann (1996, 3), 'Prehospital phase of caring for combat casualties is critically important, since up to 90% of combat deaths occur on the battlefield before the casualty ever reaches a medical treatment facility.' Although training may emphasize traumatic medical treatment and battlefield triage, health care specialists also learn a myriad of non-combat skills. For example, soldiers are instructed on preventative medicine, field sanitation, preparation of blood samples for laboratory analysis, outpatient and inpatient care and treatment, recording patients' medical histories, and maintaining clinical records.

The army conducts training for combat medics in accordance with the National Registry of Emergency Medical Technicians, making soldiers eligible for certification. In fact, warzone trauma care shares many characteristics with civilian emergency care. Combat medics, for example, deliver pre-hospital care that is identical to that of emergency medical technicians (EMTs); this includes patient diagnostics and triage, stabilization of patient breathing and cardiovascular circulation, responsibility for patient transfer to hospitals, and operating emergency medical equipment, such as electrocardiograms and external defibrillators. Communication with treatment centers, decontamination of medical facilities, and providing patients with comfort amidst trauma are other tasks that combat medics share with civilian EMTs. Moreover, the techniques that military trauma care employs have been influential in the civilian realm, particularly in the context of disaster relief (Grathwohl and Venticinque 2008; Grathwohl et al. 2008; Haley and De Lorenzo 2009; Malish et al. 2009).

Combat lifesavers (CLS) are another type of army personnel able to deliver emergency medical assistance to battlefield units. They are a byproduct of AirLand Battle doctrine that emphasized aggressive maneuvers in conjunction with air forces. The rapid mobilization

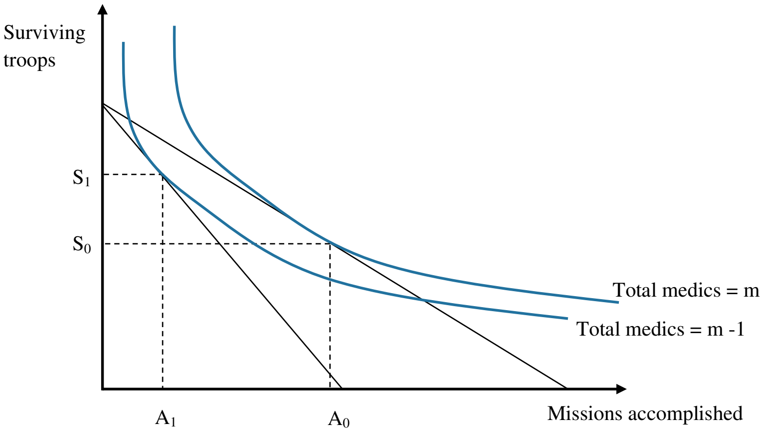

FIGURE 2B Medic loss increases troop survival

inherent in AirLand Battle, however, limited the number of available health care specialists to reach forward deployed forces. As a result, the army designed CLS to merely provide temporary care to wounded soldiers and serve as a bridge between the rudimentary emergency medical skills of the average infantry solider and the more comprehensive capabilities of health care specialists. Indeed, the army does not regard lifesavers as medical personnel and the 40 h of training CLS receive pales in comparison with the rigorous four-month course reserved for combat medics. Additionally, health care specialists also plan and provide instructions for unit combat lifesaver programs.

In contrast, medical doctors that comprise the Army medical corps have undergone the most rigorous amount of training by virtue of obtaining a doctorate of medicine.[3] Whereas medics and CLS are required to attend BCT, medical doctors are permitted to skip such training and instead proceed directly to Officer Basic Leadership Course. Medical officers are responsible for not only providing treatment to soldiers and their families at home, but ‘many officers are selected to command units, such as medical brigades, combat support hospitals, clinics and hospitals’ (U.S. Army Recruiting Command 2014). During deployment medical doctors can fulfill a wide variety of missions including humanitarian relief or combat support.[4]

3. CONCEPTUAL FRAMEWORK

3.1. Surviving Troops and Missions Accomplished

The death of a medic could affect a military unit’s rate of casualties in one of two ways.[5] First, following the death of a medic, we would expect the numbers of personnel who are killed in action (KIA) or died of wounds (DOW) to rise as a direct result of the unit’s reduced ability to treat critically injured soldiers. A second possible result of the death of a medic is that the unit might pull back and become less aggressive in its pursuit of military

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[3] Osteopathic physicians were permitted into the medical corps in 1966 due to a shortage of available physicians.

[4] For a more thorough history of the medical corps, see Ginn (1997).

[5] Notably, combat medics and medical doctors are both categorized as medics in our data-set which we describe in Section 6. Therefore, the term ‘medic’ in this context refers to both of these types of medical personnel. We use the terms medic and medical personnel interchangeably throughout much of the paper for this reason.

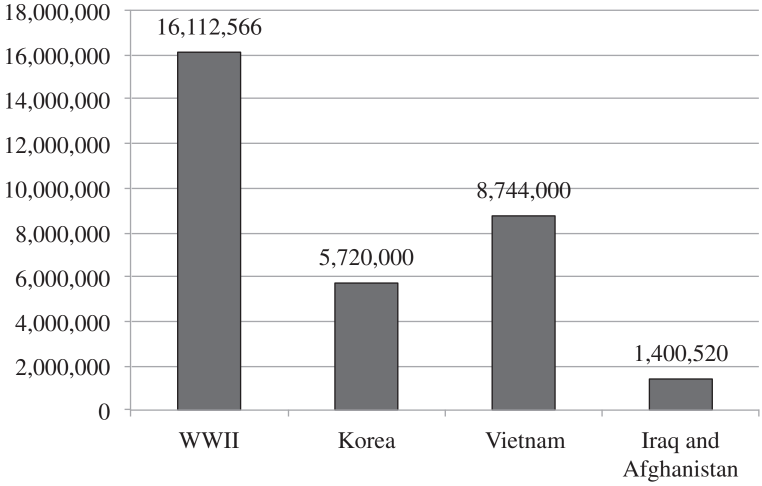

FIGURE 3A Overall number of personnel serving
Source: WWII, Korea, and Vietnam personnel numbers were obtained from Congressional Research Service (2010), whereas Iraq and Afghanistan personnel numbers are from Baiocchi (2013). Totals for Medal of Honor and Distinguished Service Cross award recipients were obtained from U.S. Department of Defense (2014). Totals for Silver Star award recipients were obtained from U.S. Army (2014). Notably, some of the numbers presented in this figure may not reflect all recipients of the awards (and likewise on the Home of Heroes website) due to operational security, privacy, and administrative reasons.

objectives. Hence, the death of a medic could potentially reduce a unit's overall casualties by causing the unit to pull out of combat.

These two possibilities are illustrated in the two panels of Figures 2A and 2B. The axes plot the quantities of two goods that the unit values: the number of troops that survive and the number of missions that the unit successfully completes. In the graphs shown here, the unit has convex preferences over these two sets of goods, as illustrated by the convex isoquants from the unit's objective function. In each panel, the higher, flatter diagonal budget line depicts the combinations of numbers of surviving troops and completed missions that fall within the unit's feasibility set when it has m medics in the unit. After a medic in the unit dies, so that the total number of medics in the unit is $m - 1$, the curve rotates inward to the lower, steeper budget line. The budget line rotates inward because, with one fewer medic, troops are more susceptible to critical injuries, and the number of troops who can survive a given mission declines. The pair (S_0, A_0) indicates the number of surviving troops and the number of missions accomplished in the 'pre' period, when the unit has m medics, and the pair (S_1, A_1) depicts these same quantities in the 'post' period, when the unit has $m - 1$ medics.

The two panels illustrate the effects of losing a medic for two different units. In Figure 2A, the unit's isoquants are tangent to the budget lines at points where the isoquants are relatively steep, meaning that the unit's valuation of the marginal mission accomplished is high relative to its valuation of saving the marginal troop's life. In this context, when a medic dies and the budget line rotates inward, the number of surviving troops declines by a relatively large amount, and the level of mission accomplishment is essentially unchanged. The unit depicted in Figure 2B has isoquants that are tangent to its budget lines at points where the isoquants are relatively flat. Hence, the unit in panel B places a relatively high value on saving the marginal troop's life relative to accomplishing the marginal mission. In this context, when a medic dies, the unit withdraws from combat substantially, and its level of mission accomplishment declines accordingly. At the new, lower isoquant, the number of surviving troops has risen substantially.

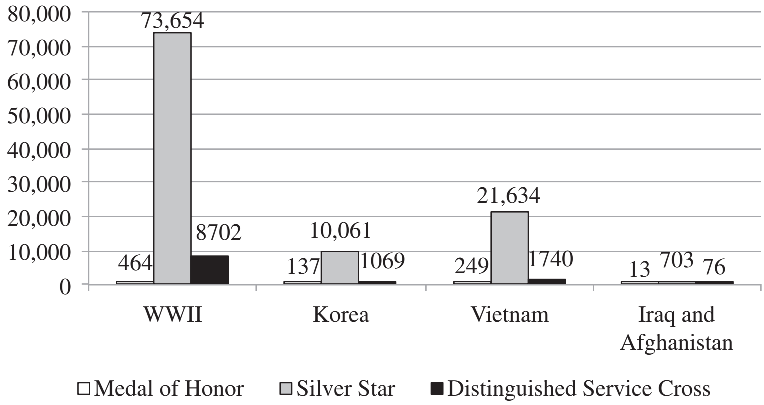

FIGURE 3B Total number of award recipients
Source: WWII, Korea, and Vietnam personnel numbers were obtained from Congressional Research Service (2010), whereas Iraq and Afghanistan personnel numbers are from Baiocchi (2013). Totals for Medal of Honor and Distinguished Service Cross award recipients were obtained from U.S. Department of Defense (2014). Totals for Silver Star award recipients were obtained from U.S. Army (2014). Notably, some of the numbers presented in this figure may not reflect all recipients of the awards (and likewise on the Home of Heroes website) due to operational security, privacy, and administrative reasons.

The costs, benefits, and types of missions fought vary substantially across the different wars examined in this study. Consequently, we should expect the shapes of the isoquants and the effects of medical losses on the slopes of the budget lines to vary widely across wars as well. Next, we consider how to estimate the differences $S_1 - S_0$ and $A_1 - A_0$ and how these effects vary across contexts.

3.2. Estimation Equations

In order to formally evaluate the effects of medical personnel, we initially use a first-differencing approach to analyze the impact that the variation of medical personnel by unit had on fatalities across time. The following structural model shows this relationship:

$$\Delta Fatalities_{ut} = \alpha^{Fatal} * \Delta Medic_{ut} + \boldsymbol{\beta}^{\mathbf{Fatal}\prime}\mathbf{x_{ut}} + Unit_u + Time_t + \Delta\varepsilon_{ut}^{Fatal}, \tag{1}$$

where $\Delta Fatalities_{ut}$ measures the total number of deaths in combat unit u over the five or ten days after date t minus total deaths in unit u over the five or ten days before date t; $\Delta Medics_{ut}$ is the change in the number of medical personnel (i.e., combat medics and medical doctors) in unit u over the same time period; $\mathbf{x_{ut}}$ is a vector of control variables that includes personnel traits and previous unit deaths; $Unit_u$ is the individual unit effects, $Time_t$ is the time effects from daily dummy variables; and $\Delta\varepsilon_{ut}^{Fatal}$ is a random error term. The coefficient of interest is α^{Fatal}, which we can interpret as the marginal effect that the addition of a medic in unit u on day t has on fatalities over the five or ten days after date t.

One important difficulty that arises in estimating α^{Fatal} is that the military does not randomly assign medical personnel across combat units. The military, for example, may assign higher numbers of medical personnel to units that are especially large, or that serve in particularly intensive combat operations; as a result, units that have already experienced severe losses and have not yet received replacements may have unusually few numbers of medical personnel. Therefore, the predicted sign for α^{Fatal} is likely biased. For these reasons, an ordinary least squares (OLS) regression of $\Delta Fatalities_{ut}$ on $\Delta Medics_{ut}$ and $\mathbf{x_{ut}}$ might produce biased estimates.

To address this problem, we use an instrumental variables[6] approach that is related to combat losses. Given a sample of engagements with the same level of combat intensity and the same number of American losses, the types of personnel that similar units lose will vary due to essentially random events. We use the exogenous variation of medical personnel deaths in theater as a way to remedy the endogeneity problem that we described previously.

Our instrumental variables strategy uses military fatalities, where we index each individual who died in the war by $i = 1, \ldots, N$. Let $u(i)$ denote soldier i's assigned unit, let $t(i)$ represent soldier i's date of death. Soldier i's occupation, signified by $Medical\,Occupation_i$, is a dummy variable equal to one for being a medic or medical doctor and zero for being in the infantry. For the ten days before and the ten days after soldier i's death, we express the effect of medical losses on the total number of medics in that soldier's unit in day t as:

$$\Delta Medics_{u(i)t(i)} = -Medical\,Occupation_i + \boldsymbol{\delta}'\mathbf{x_{u(i)t(i)}} + Unit_{u(i)} + Time_{t(i)} + \Delta v_{u(i)t(i)} \qquad (2)$$

Hence, we express the change in the number of medics serving in unit u on date t endogenously as a function of the values of the personnel traits and previous unit deaths included in $\mathbf{x_{ut}}$, and unit and time fixed effects. Of note, the personnel trait controls are comprised of a dummy for whether the person was drafted, a dummy for whether the person was KIA, and fixed for the different ranks. Also, for the WWII results, a continuous variable measuring the accuracy of the death date observation (based upon consistency across multiple reports) is included. The previous unit death controls include total KIA in the unit and a dummy for whether unit deaths were ≥3. In addition to including the contemporaneous values for these three variables, we also include 10 daily lags for each of these 3. In the days immediately following the death of a soldier, if that soldier was a medic, then we can expect the unit to have exactly one fewer medic in the overall composition of their forces.

For each military fatality, we construct twenty observations in the data-set, one for each of the ten days preceding that soldier's death and one for each of the ten days afterward. Due to data limitations, we do not know the exact number of medics in a unit at a given point in time.[7] Nevertheless, given that we know the coefficient on $Medical\,Occupation_i$ in Equation (2) is negative one, our identification strategy will still enable us to obtain consistent estimates of α^{Fatal}. Plugging Equation (2) into Equation (1), our parameters of interest appear in the reduced-form equation for unit-level fatalities:

$$\begin{aligned}\Delta Fatalities_{u(i)t(i)} = {} & -\alpha^{Fatal} * Medical\,Occupation_i + \boldsymbol{\pi}'\mathbf{x_{u(i)t(i)}} + Unit_{u(i)} + Time_{t(i)} \\ & + \Delta e^{Fatal}_{u(i)t(i)}. \end{aligned} \qquad (3)$$

Our final estimation procedure estimates a version of Equation (3) in which the number of observations is twenty times the total number of deaths in the war. The coefficient of interest is α^{Fatal}, and we can still interpret it as the marginal effect on fatalities over the five or ten days after date t, which the addition of a medic in unit u on day t caused.

As a key identifying assumption, we require that the occupation of the individual who dies in combat is essentially randomly determined by the uncertainty of war. Hence, we require that any systematic differences between units that lose medics and those that do not

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[6] The identification strategy we use is somewhat different than a standard IV approach, and thus, it is based upon a different set of assumptions and estimation techniques.

[7] Likewise, we do not have any information on the percentage of medics relative to infantrymen.

are persistent differences that we were able to observe prior to that soldier's death. Therefore, any additional changes in fatalities that we observe after $t(i)$, for cases in which we attribute $Medical\,Occupation_i = 1$, identifies the effect that medical personnel have in reducing fatality rates.

The effect on fatalities is only one outcome variable in determining the effectiveness of medical personnel. The military may experience other possible benefits when increasing the number of medical personnel in military units. It is possible, for example, that troop morale increases when soldiers know they will quickly receive medical care in the event of an enemy attack. It might also be the case that troops simply do not want to take additional territory without the ability to care for their wounded. Thus, for those units with low numbers of medics, the military slows tactical advances until it can provide further medical personnel to units. These are just a couple examples of how the number of medics can affect 'military success.'[8]

One proxy measure for military success is the number of commendation medals that individuals and units receive from combat. The military normally awards high-level commendation medals, such as the Medal of Honor (MOH), the Distinguished Service Cross (DSC), and the Silver Star (SS), for heroism and gallantry in action. The number of commendation medals that individuals and units receive should correlate highly with 'military success' variables, such as taking enemy ground, capturing soldiers, and enemy KIA. In addition to estimating the effect of medical personnel on fatalities, we include the following model to estimate military success, which we measure using commendation medals as a proxy:

$$\begin{aligned}\Delta Medals_{u(i)t(i)} = -\alpha^{Medal} * Medical\,Occupation_i + \boldsymbol{\pi}^{\mathbf{Medal}'}\mathbf{x}_{\mathbf{u(i)t(i)}} + Unit_{u(i)} + Time_{t(i)} \\ + \Delta e^{Medal}_{u(i)t(i)}.\end{aligned} \tag{4}$$

where $\Delta Medals_{u(i)t(i)}$ is the number of commendation medals (i.e., total number of MOH, SS, and DSC medals) personnel earn in combat unit u for actions that occurred over the five or ten days after date t minus the total number of commendation medals among unit u's personnel for actions that occurred over the five or ten days before date t.[9] The outcome variable of choice is the primary difference between Equations (3) and (4). The coefficient of interest in Equation (4) is α^{Medal}, which we interpret in the same regard as α^{Fatal} from Equation (3); we must caveat, however, that it now measures the effect of medical personnel on 'military success' rather than fatalities.

4. DATA

4.1. Description

We construct the primary data for this study from casualty rosters in different wars. In each case, the sample consists of individuals who were attached to US Army ground units and

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[8] Military success variables are of course subjective in nature. This study uses commendation medals as a proxy for military success. Other studies such as Rohlfs, Sullivan, and Kniesner (2014) have used geographical progress as proxy for this measure. Rohlfs and Sullivan (2013a, 2013b) and Kniesner, Leeth, and Sullivan (2015) discuss the difficulty in measuring 'military success' in cost-benefit analysis.

[9] We measure the number of medals as the sum of the number of Medal of Honor, Silver Star, and Distinguished Service Crosses received by unit i for their action on day t. Some medals were awarded for unit action over multiple days of fighting. For these observations, we allocate the medals equally across dates. For instance if unit i received one Medal of Honor for action during the dates 6 and 7 June 1944, then each of those dates would receive 0.5 medals.

died in combat. The key variables of interest are unit affiliation, occupation, and date of death. For each war, using the unit affiliation and date of death variables, we first construct a panel data-set that describes the number of deaths incurred by each unit per day. For each person *i* who died in the war, we then use the panel data-set to measure the number of deaths that *i*'s unit experienced on the day ten days before *i*'s death, the day nine days before *i*'s death, and so on through the day ten days after *i*'s death. Our research design examines the extent to which *i*'s death affected the fatality rate of *i*'s unit and how that effect varies depending upon whether *i* was a medic or an infantry soldier. After computing total death rates for each unit (summed across all occupations), we restrict the casualty rosters (used to measure the effect of an individual's death) to individuals who were medical or infantry personnel.

Tables IA and IB show summary statistics for WWII, Korean War, Vietnam War, and the Iraq and Afghanistan Wars. For each war, the means of the different variables are shown separately for units that lost medical personnel and for units that lost infantrymen. Below each sample mean is a standard error that is calculated under the assumption of arbitrary autocorrelation among observations from the same unit (clustering in Stata based upon 'unit name' from the data). For WWII, our casualty roster comes from data collected in Rohlfs, Sullivan, and Kniesner (2014). This data-set includes name, rank, profession, and unit, and for 67% of observations, the date of death. These data only include US Army ground division deaths. We drop the observations without date of death. Additionally, to adjust for missing dates, we divide the unit-level deaths by the unit-specific fractions of observations with dates. For the Korean War, our casualty roster comes from the Korean War Extract Data File from the U.S. National Archives and Records Administration (2011). For the Vietnam data, we use the Coffelt Database of casualties (2011). In both cases, we include only army units, and drop all units with aviation-related or seafaring-related names, so that we only include units engaged in ground warfare.[10]

Per our request, DMDC provided data on Iraq and Afghanistan. DMDC classifies these data as FOUO, which restricts us from sharing the data with individuals outside of DoD. The World War II, Korea, and Vietnam unit data are measured at the regiment-level (roughly 3000 people) or at the battalion level (roughly 800 people), depending on how the army organized units across divisions (roughly 15,000 people) and the level of detail that the casualty records provided. For the Iraq and Afghanistan data, unit is measured according to the three-digit Unit Identification Code, which is roughly equivalent to the regiment-level.

We find large variations in the frequencies of death across different combat environments as shown in Tables IA and IB. This is particularly prominent in row one in these tables which displays descriptive statistics for 'Unit deaths over 10 days after death minus unit deaths over 10 days before.' Columns (3) and (6) in these tables shows the difference between medical and infantry deaths across conflicts over this time period. These numbers display a low of −8.520 in Korea to a high of 3.034 in WWII, Europe, and North Africa. The five-day results show similar trends in row three in Tables IA and IB. Also of note are the large differences in 'Unit deaths on day of death' as shown in row five. These values range from a high of around 20–25 in the Korean and WWII, European and North African

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[10] We believe the overall quality of the casualty data in this paper is quite reliable. However, some of the wars have better data than others. For instance, the data from DMDC on the Iraq and Afghanistan casualties are likely spot on for accuracy and include detailed information on all deaths in those wars. However, some of the other wars (e.g., WWII) had hand-typed data from historical documents as discussed previously. Those data have some limitations – mainly the fact that we had to discard 33% of the observations due to lack of information. This would only be an issue if these observations were correlated with both the outcome and explanatory variables – causing a standard omitted variable bias in the regressions. We believe this to not be the case, however, if this were true then readers should understand the estimates from WWII might be biased.

TABLE IA Descriptive Statistics on Units of Infantry and Medical Personnel who Died by War

	(1)	(2)	(3)	(4)	(5)	(6)
	WWII, Europe and North Africa			WWII, Pacific		
Variable	Medical	Infantry	Infantry	Medical	Infantry	(4)–(5)
Unit deaths over 10 days after death minus unit deaths over 10 days before death	2.966 (1.676)	−0.068 (0.040)	3.034 (1.714)*	−5.959 (2.579)	0.200 (0.075)	−6.159 (2.648)**
Unit awards for gallantry over 10 days after death minus unit awards for gallantry over 10 days before death	−0.114 (0.122)	−0.158 (0.047)	0.044 (0.112)	−0.300 (0.191)	−0.043 (0.114)	−0.257 (0.193)
Unit deaths over 5 days after death minus unit deaths over 5 days before death	3.554 (1.197)	−0.422 (0.088)	3.976 (1.234)**	−4.498 (2.094)	−0.477 (0.235)	−4.021 (1.999)**
Unit awards for gallantry over 5 days after death minus unit awards for gallantry over 5 days before death	0.027 (0.101)	−0.127 (0.035)	0.154 (0.097)	−0.236 (0.150)	−0.098 (0.089)	−0.137 (0.148)
Unit deaths on day of death	25.22 (7.053)	23.66 (4.658)	1.56 (2.488)	14.06 (1.531)	14.55 (1.897)	−0.490 (1.293)
Unit awards for gallantry on day of death	1.065 (0.262)	0.840 (0.127)	0.225 (0.150)	0.703 (0.122)	0.603 (0.056)	0.101 (0.100)
Unit deaths over 10 days before death	44.64 (2.542)	49.24 (2.358)	−4.60 (1.445)**	43.54 (4.604)	42.20 (4.480)	1.339 (1.714)
Unit awards for gallantry over 10 days before death	1.898 (0.176)	1.920 (0.120)	−0.021 (0.112)	2.049 (0.206)	2.163 (0.255)	−0.114 (0.172)
Unit deaths over 5 days before death	30.87 (1.890)	35.28 (1.590)	−4.41 (1.085)**	30.54 (3.900)	30.55 (3.747)	−0.004 (1.306)
Unit awards for gallantry over 5 days before death	1.313 (0.124)	1.406 (0.089)	−0.093 (0.079)	1.392 (0.158)	1.553 (0.184)	−0.161 (0.147)
Individual was killed in action	0.849 (0.009)	0.869 (0.003)	−0.020 (0.009)**	0.824 (0.013)	0.823 (0.006)	0.001 (0.015)
Unit was an infantry regiment	0.872 (0.019)	0.911 (0.015)	−0.039 (0.011)**	0.960 (0.015)	0.996 (0.001)	−0.036 (0.015)**
Division was armored	0.121 (0.022)	0.104 (0.019)	0.017 (0.011)	0.000 (0.000)	0.000 (0.000)	0.000 (0.000)
Division was airborne	0.054 (0.016)	0.598 (0.017)	−0.006 (0.009)	0.000 (0.000)	0.000 (0.000)	0.000 (0.000)
Drafted	0.846 (0.011)	0.807 (0.006)	0.040 (0.010)**	0.836 (0.021)	0.784 (0.010)	0.052 (0.021)**
Officer	0.029 (0.005)	0.060 (0.001)	−0.031 (0.005)**	0.028 (0.009)	0.062 (0.003)	−0.034 (0.008)**

(*Continued*)

TABLE IA (*Continued*)

	(1)	(2)	(3)	(4)	(5)	(6)
	WWII, Europe and North Africa			WWII, Pacific		
Variable	Medical	Infantry	Infantry	Medical	Infantry	(4)–(5)
Private	0.666	0.701	−0.035	0.640	0.689	−0.049
	(0.014)	(0.004)	(0.013)**	(0.027)	(0.007)	(0.026)*
Observations (deaths)	1634	71,818	73,452	397	13,361	13,758
Units	243	323	359	64	83	90

Notes: Standard errors for means and differences assume clustering by unit. For the WWII results, a variable not shown is estimated accuracy of date of death, which is determined based upon agreement of death date across multiple sources. This value ranges across individuals from 0.722 to 1.00; the mean values were 0.978 for units losing infantry and medical personnel in Europe and North Africa, and the mean values were 0.973 and 0.977 for units losing infantry and medical personnel in the Pacific. For Vietnam results, infantry results for 'drafted' are missing two observations.

**Indicates significant at the 5% level.

*Indicates significant at the 10% level.

data to a low of around 1.6 in the Iraq and Afghanistan data. This shows that variations in the rate of death can vary by as much as 15 times other estimates across separate conflicts.

In addition to data on deaths, following Birchenall and Koch (2013), we use data on awards for gallantry from the Home of Heroes (2012) website. We focus on SS, DSC, and MOH award recipients. The SS is the third highest combat award, which the army presents to soldiers who demonstrate gallantry in action while engaged in military operations involving enemy forces. The DSC is the second highest military commendation, which the army awards for extraordinary heroism in combat. Lastly, the MOH is the highest military decoration reserved for those who demonstrate gallantry and courage in combat, which only the President of the United States can present to recipients (Schading 2011; U.S. Department of Defense 2014).

Figure 3A shows the overall number of US personnel which served in WWII, Korea, Vietnam, and Iraq and Afghanistan and Figure 3B shows the number of MOH, SS, and DSC award recipients.[11] The incredibly small number of MOH award recipients immediately becomes prominent in the figure with only 863 being awarded in the conflicts being investigated. This constitutes only 0.0027% of the total number of military personnel (31,977,086 individuals) having served in these conflicts. The numbers of SS and DSC recipients are still relatively rare with only 0.3316 and 0.0362% of military personnel receiving the awards, respectively.

The DSC and MOH data include information on unit affiliation and date of action; we use these data to construct a unit-by-day panel of gallantry awards. Unfortunately, the DSC data for the Vietnam War do not include unit; therefore, we must exclude the DSC from our analysis of that war. The SS data for World War II have division and name, but not detailed unit (regiment or battalion) or date. The SS data for Korea and Vietnam contain only recipient names. For the SS cases in which the individual died, we use the recipient's date of death to estimate dates of action for these posthumous awards; we then add these posthumous SS awards to the total number of awards by unit and day. Consequently, our estimates of the award totals include DSC and MOH in addition to posthumous SS awards. The Iraq and Afghanistan

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[11] Data sources for Figures 3A and 3B: WWII, Korea, and Vietnam personnel numbers were obtained from Congressional Research Service (2010), whereas Iraq and Afghanistan personnel numbers are from Baiocchi (2013). Totals for MOH and DSC award recipients were obtained from U.S. Department of Defense (2014). Totals for Silver Star award recipients were obtained from U.S. Army (2014). Notably, some of the numbers presented in this figure may not reflect all recipients of the awards (and likewise on the Home of Heroes website) due to operational security, privacy, and administrative reasons.

TABLE IB Descriptive Statistics on Units of Infantry and Medical personnel who Died by War

	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)
		Korean War			Vietnam War			Iraq & Afghanistan Wars	
Variable	Medical	Infantry	(7)–(8)	Medical	Infantry	(10)–(11)	Medical	Infantry	(13)–(14)
Unit deaths over 10 days after death minus unit deaths over 10 days before death	−7.772	0.748	−8.520	−0.772	0.010	−0.782	−0.099	0.037	−0.136
	(2.551)	(0.322)	(2.727)**	(0.344)	(0.033)	(0.351)**	(0.058)	(0.034)	(0.080)*
Unit awards for gallantry over 10 days after death minus unit awards for gallantry over 10 days before death	−0.348	0.125	−0.474	−0.009	−0.008	−0.001			
	(0.188)	(0.094)	(0.217)**	(0.017)	(0.009)	(0.012)			
Unit deaths over 5 days after death minus unit deaths over 5 days before death	−6.938	0.628	−7.566	−0.702	0.040	−0.742	−0.057	0.069	−0.126
	(1.992)	(0.462)	(2.150)**	(0.296)	(0.037)	(0.308)**	(0.089)	(0.025)	(0.084)
Unit awards for gallantry over 5 days after death minus unit awards for gallantry over 5 days before death	−0.272	0.153	−0.426	−0.012	−0.008	−0.003			
	(0.122)	(0.098)	(0.184)**	(0.017)	(0.005)	(0.012)			
Unit deaths on day of death	20.49	24.26	−3.77	6.29	6.31	−0.017	1.61	1.69	−0.082
	(4.407)	(4.084)	(2.291)	(0.809)	(0.635)	(0.404)	(0.164)	(0.125)	(0.203)
Unit awards for gallantry on day of death	0.833	0.890	−0.058	0.057	0.034	0.023			
	(0.141)	(0.119)	(0.069)	(0.012)	(0.007)	(0.008)**			
Unit deaths over 10 days before death	33.65	30.97	2.68	4.65	6.52	−1.87	0.461	1.69	−1.23
	(3.952)	(2.669)	(2.132)	(0.523)	(0.882)	(0.904)**	(0.160)	(0.802)	(0.760)
Unit awards for gallantry over 10 days before death	1.674	1.481	0.193	0.049	0.032	0.017			
	(0.359)	(0.251)	(0.154)	(0.015)	(0.009)	(0.010)*			
Unit deaths over 5 days before death	25.06	23.05	2.00	3.31	4.39	−1.083	0.305	0.971	−0.666
	(3.197)	(2.128)	(1.985)	(0.439)	(0.595)	(0.606)*	(0.152)	(0.480)	(0.486)
Unit awards for gallantry over 5 days before death	1.241	1.081	0.161	0.039	0.025	0.013			
	(0.286)	(0.180)	(0.135)	(0.014)	(0.008)	(0.010)			
Individual was killed in action	0.897	0.918	−0.022	0.881	0.884	−0.003	0.787	0.753	0.034
	(0.014)	(0.005)	(0.015)	(0.011)	(0.004)	(0.011)	(0.033)	(0.152)	(0.035)
Unit was an infantry regiment	0.772	0.781	−0.008	0.723	0.551	0.171			
	(0.078)	(0.087)	(0.026)	(0.723)	(0.077)	(0.060)**			
Division was armored	0.000	0.000	0.000						
	(0.000)	(0.000)	(0.000)						

(*Continued*)

TABLE IB (*Continued*)

	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)
	Korean War			Vietnam War			Iraq & Afghanistan Wars		
Variable	Medical	Infantry	(7)–(8)	Medical	Infantry	(10)–(11)	Medical	Infantry	(13)–(14)
Division was airborne	0.005	0.004	0.001	0.202	0.156	0.046			
	(0.004)	(0.002)	(0.003)	(0.063)	(0.052)	(0.024)*			
Drafted	0.374	0.311	0.063	0.539	0.439	0.101	0.000	0.000	0.000
	(0.039)	(0.027)	(0.024)**	(0.026)	(0.044)	(0.043)**	(0.000)	(0.000)	(0.000)
Officer	0.009	0.032	−0.023	0.007	0.039	−0.032	0.064	0.044	0.020
	(0.003)	(0.002)	(0.004)**	(0.002)	(0.005)	(0.005)**	(0.021)	(0.016)	(0.025)
Private	0.638	0.668	−0.030	0.281	0.364	−0.083	0.121	0.251	−0.130
	(0.019)	(0.008)	(0.021)	(0.020)	(0.016)	(0.023)**	(0.033)	(0.101)	(0.108)
Observations (deaths)	580	15,948	16,528	955	27,551	28,506	141	1188	1329
Units	48	82	90	101	235	245	95	117	172

Notes: Standard errors for means and differences assume clustering by unit. For the WWII results, a variable not shown is estimated accuracy of date of death, which is determined based upon agreement of death date across multiple sources. This value ranges across individuals from 0.722 to 1.00; the mean values were 0.978 for units losing infantry and medical personnel in Europe and North Africa, and the mean values were 0.973 and 0.977 for units losing infantry and medical personnel in the Pacific. For Vietnam results, infantry results for ‘drafted’ are missing two observations.

**Indicates significant at the 5% level.

*Indicates significant at the 10% level.

data do not include names for confidentiality reasons; as a result, we cannot merge the SS data for these wars. In only three cases were DSC and MOH awards granted for actions within ten days of an infantry or medical casualty to a ground unit. For this reason, we do not estimate the effects of medical deaths on awards for gallantry in Iraq and Afghanistan.

In addition to unit-level deaths and awards, date of death, unit, and occupation, the army casualty rosters all include type of death (KIA or DOWs), rank, and unit type. Additionally, in each case, whether the individual was drafted or enlisted voluntarily was either provided in the data-set or could be imputed from the serial number.

4.2. Descriptive Results

4.2.1. Validity of the Identification Strategy

An important assumption underlying our identification strategy is that, given that a death occurs in combat, the identity of the person killed is essentially randomly determined. This assumption implies that units in the 'treatment' group – who experienced a loss of a medic or doctor – should be generally similar to units in the 'control' group – who lost an infantryman – prior to the exposure of the treatment of the combat loss. Using our difference-in-differences strategy, we are able to identify the effect of a medical loss even if the treatment was not randomly assigned and the treatment and control groups were different prior to the combat loss, provided that these pre-treatment differences remained constant over time or moved in parallel for the two groups. One method for testing the validity of this assumption is to compare the magnitudes of the means between the treatment and control groups prior to the combat loss for the unit characteristic variables shown in Tables IA and IB. While we cannot observe all of the unit characteristics that might be correlated with medical personnel losses, measuring the differences for a handful of variables that we do observe provides evidence as to whether the treatment and control groups are generally similar. If the identity of the person killed was truly random, as in a controlled experiment, then it would not be necessary to take pre-post differences, and the effect of the treatment could be identified by simply comparing post-treatment death and award levels between the treatment and control groups.

Overall, the differences between the treatment and control groups tend to deviate somewhat from zero, indicating that the difference-in-differences comparison is necessary for identification. We do not, however, observe large pre-treatment differences that are consistently in one direction. Hence, whether a medic or doctor was lost or an infantryman was lost does not appear to be proxying for some important omitted variable describing combat conditions or underlying unit characteristics. The control variables that we can compare between the treatment and control groups are the eight variables from 'unit deaths over 10 days before death' to 'division was airborne,' shown in the 7–14 rows in the tables. We do not observe a clear pattern in which the units experiencing medical losses had systematically more or fewer losses than those who lost infantrymen in the 5 or 10 days before the death. The difference is negative, moderate-sized, and mostly significant for the WWII Europe and North Africa and Vietnam samples, indicating that, in those cases, the units losing medical personnel may have experienced lighter combat than those losing infantrymen. For Iraq and Afghanistan, the differences in these same variables are smaller (reflecting the overall lower casualty rates for those wars) and statistically insignificant. For WWII Pacific and Korea, the differences in these variables tend to be positive, around the same magnitudes, and statistically insignificant. The units losing medical personnel appear to have received the same numbers of awards for gallantry as the units losing infantrymen over the 10 or 5 days prior to the death. Similar fractions of the medical personnel and infantrymen were KIA (rather than dying of wounds), indicating a dimension of the treatment that was similar between the two groups. Surprisingly, we do not observe a consistent pattern in the differences in the fraction of units that were infantry regiments, with the medical deaths being significantly less likely to come from infantry regiments in WWII, about the same in Korea, and significantly more likely to come from infantry regiments in the Vietnam War.

In addition to examining potential sources of bias, comparing the characteristics of the individuals who died helps to better understand the nature of the treatment. As the last few rows of Tables IA and IB show, the medics and doctors who died were significantly more likely than the infantrymen to have been drafted, and they were significantly less likely to be officers or privates. The medics who died tended to hold professions such as technician or specialist, while the doctors were officers.

4.2.2. Mean Differences in Outcomes

The first four rows of Tables IA and IB provide a preview of the results from this study. Because the variables shown in these rows represent changes over time, each of the differences between units losing medical and those losing infantry personnel represents a differences-in-differences estimate.

Overall, we find that the case described in Figure 2A, where medical losses decrease troop survival, appears in WWII Europe and North Africa, whereas the results for the other wars are consistent with the case described in Figure 2B, where medical losses increase troop survival due to a reduction in aggressiveness – with the exception of Iraq and Afghanistan, where the effects tend to be negative but fairly small, due to the relatively low numbers of deaths in those wars. Relative to infantry losses, medical losses are associated with a moderate-sized and statistically significant increase in deaths and a small and statistically insignificant increase in awards for gallantry for WWII Europe and North Africa. This rise is slightly smaller than the negative difference observed between the two categories of units prior to the death. For WWII Pacific, Korea, and Vietnam, we observe significant negative drops in deaths following the loss of a medic or doctor relative to the loss of an infantryman, and in Iraq and Afghanistan, we observe small and insignificant negative effects. The large effects in WWII Pacific and Korea are substantially larger than the positive differences in deaths 10 days prior between the two categories of units, and the measured effects in Vietnam and Iraq and Afghanistan tend to be smaller than the pre-treatment differences. In WWII Pacific and in Korea, we observe similar drops in the numbers of awards for gallantry given to those units for action in the days following the death; no such drop is observed for Vietnam, when awards for gallantry were very low overall. Next, we explore the formal estimates obtained from multivariate regressions.

5. RESULTS

5.1. Effect of Medical Personnel on Fatalities

Panels A and B in Tables IIA and IIB present OLS and fixed effects results from Equation (3) for WWII (split into the Pacific and European/North African theaters of war), Korea, Vietnam, and Iraq and Afghanistan. Columns (1) through (4) present the WWII, European and North African campaign results; columns (5) through (8) show the WWII Pacific results; columns (9) through (12) depict the Korean results; columns (13) through (16) supply the Vietnamese results; and columns (17) through (20) offer the Iraq and Afghanistan results.

TABLE IIA OLS Estimates of Effect of Medic Death on Later Unit Deaths

	WWII, Europe and North Africa				WWII Pacific			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Panel A: Unit deaths over 5 days after death minus unit deaths over 5 days before death								
Medical	3.976	4.371	0.143	1.466	−4.021	−3.903	−4.516	−0.936
	(1.234)**	(1.303)**	(1.001)	(0.766)*	(1.999)**	(2.206)*	(1.897)**	(1.202)
Unit × quarter effects?		Yes		Yes		Yes		Yes
Year × month?		Yes		Yes		Yes		Yes
Personnel traits?		Yes		Yes		Yes		Yes
Previous unit deaths?			Yes	Yes			Yes	Yes
R^2	0.000	0.029	0.502	0.736	0.000	0.042	0.505	0.764
Panel B: Unit deaths over 10 days after death minus unit deaths over 10 days before death								
Medical	3.034	3.408	−0.750	1.011	−6.159	−6.010	−5.084	0.102
	(1.714)*	(1.782)*	(1.339)	(0.748)	(2.648)**	(2.958)**	(2.432)**	(1.244)
Unit × quarter effects?		Yes		Yes		Yes		Yes
Year × month?		Yes		Yes		Yes		Yes
Personnel traits?		Yes		Yes		Yes		Yes
Previous unit deaths?			Yes	Yes			Yes	Yes
R^2	0.000	0.058	0.452	0.748	0.000	0.125	0.436	0.782
Observations	73,452				13,758			
Clusters (Unit × qtr)	1109				337			

Notes: Unit × quarter effects are fixed effects for each interaction of unit (typically regiment-level), year, and quarter. Year × month includes dummies for year × month interactions together with a daily time trend. Personnel traits include dummies for whether the individual who died was killed in action or was drafted, fixed effects for grade (i.e. rank), and estimated accuracy of date of death. Previous unit deaths include 11 variables for unit deaths in the day that the individual died and in the 10 previous days, variables for unit Killed in Action on each of those 11 days, and 11 variables for whether unit deaths were ≥3 on each of those 11 days. Standard errors adjusted for clustering by unit × year × quarter interaction.

*indicates significant at the 10% level.

**indicates significant at the 5% level.

TABLE IIB OLS Estimates of Effect of Medic Death on Later Unit Deaths

	Korean War				Vietnam War				Iraq and Afghanistan Wars			
	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)	(19)	(20)
Panel A: Unit deaths over 5 days after death minus unit deaths over 5 days before death												
Medical	−7.628	−8.594	−4.633	−1.750	−0.840	−0.460	−1.620	−0.305	−0.126	0.103	−0.330	0.560
	(2.394)**	(2.517)**	(1.432)**	(1.344)	(0.367)**	(0.323)	(0.274)**	(0.174)*	(0.125)	(1.131)	(0.109)**	(0.551)
Unit × quarter effects?		Yes		Yes		Yes		Yes		Yes		Yes
Year × month?		Yes		Yes		Yes		Yes		Yes		Yes
Personnel traits?		Yes		Yes		Yes		Yes		Yes		Yes
Previous unit deaths?			Yes	Yes			Yes	Yes			Yes	Yes
R^2	0.001	0.047	0.623	0.784	0.000	0.018	0.476	0.709	0.001	0.090	0.374	0.700
Panel B: Unit deaths over 10 days after death minus unit deaths over 10 days before death												
Medical	−8.591	−9.998	−4.862	−1.204	−0.885	−0.514	−2.302	−0.352	−0.136	−0.399	−0.613	0.007
	(2.863)**	(2.918)**	(1.541)**	(1.369)	(0.382)**	(0.367)	(0.349)**	(0.192)*	(0.129)	(1.141)	(0.162)**	(0.517)
Unit × quarter effects?		Yes		Yes		Yes		Yes		Yes		Yes
Year × month?		Yes		Yes		Yes		Yes		Yes		Yes
Personnel traits?		Yes		Yes		Yes		Yes		Yes		Yes
Previous unit deaths?			Yes	Yes			Yes	Yes			Yes	Yes
R^2	0.001	0.058	0.573	0.787	0.000	0.026	0.403	0.691	0.000	0.118	0.280	0.750
Observations	16,472				25,342				1329			
Clusters (Unit × qtr)	345				1746				564			

Notes: Unit × quarter effects are fixed effects for each interaction of unit (typically regiment-level), year, and quarter. Year × month includes dummies for year × month interactions together with a daily time trend. Personnel traits include dummies for whether the individual who died was killed in action or was drafted, fixed effects for grade (i.e. rank), and estimated accuracy of date of death. Previous unit deaths include 11 variables for unit deaths in the day that the individual died and in the 10 previous days, variables for unit Killed in Action on each of those 11 days, and 11 variables for whether unit deaths were ≥3 on each of those 11 days. Standard errors adjusted for clustering by unit × year × quarter interaction.

*indicates significant at the 10% level.

**indicates significant at the 5% level.

We use a variety of control variables across each of the twenty specifications. Columns (1), (5), (9), (13), and (17) include only a constant term. Columns (2), (6), (10), (14), and (18) add in controls for year by month time effects, and unit by quarter fixed effects for each interaction of unit, year and quarter, and personnel trait controls which are comprised of a dummy for whether the person was drafted, a dummy for whether the person was KIA, and fixed for the different ranks. Also, for the WWII results, a continuous variable measuring the accuracy of the death date observation (based upon consistency across multiple reports) is included. Columns (3), (7), (11), (15), and (19) replace the controls in columns (2), (6), (10), (14), and (18) with variables controlling for previous unit deaths. The previous unit death controls include total KIA in the unit and a dummy for whether unit deaths were ≥3. In addition to including the contemporaneous values for these 3 variables, we also include 10 daily lags for each of these 3. Columns (4), (8), (12), (16), and (20) are the most robust specifications in Panels A and B and include all available sets of controls.

Panel A in Tables IIA and IIB show the most immediate effect on fatalities over the five days following a medic's death. These results are mixed and depend largely on the theater of operations. The WWII Pacific, Korean, and Vietnamese estimates in Panel A strongly indicate that a medic's death in the units for these theaters of war has large, negative effects on fatalities in the initial five days following their death. All of the coefficients in columns (5) through (16) are negative with estimates ranging between −0.305 and −8.594. We can interpret this as meaning the death of one medic in unit u at time t causes a decrease of between −0.305 and −8.594 unit deaths over days t though $t + 5$ than otherwise would have occurred had a medic not died. Most of the coefficients show statistical significance; seven out of the twelve estimates are significant at the 5% level, and two of the coefficients are significant at the 10% level. We can largely explain this somewhat counter-intuitive result by a simultaneous decrease in military success resulting from a medic's death, which we will discuss after presenting the results from Tables IIIA and IIIB.

The WWII, European, and North African results starkly contrast those from WWII Pacific, Korea, and Vietnam. Columns (1) through (4) in Panel A in Table IIA show the results from the European and North African theaters. These are the only estimates illustrating that the death of a medic has a positive, statistically significant effect on fatalities. The coefficients range in value from 0.143 to 4.371. Two of the four coefficients of interest α^{Fatal} are significant at the 5% level, and one is significant at the 10% level. Our preferred specification in column (4) has a point estimate of 1.466. We interpret this to mean that the death of one medic in unit u at time t causes an additional 1.466 unit deaths over days t though $t + 5$ than otherwise would have occurred had a medic not died.

The results from Iraq and Afghanistan, as shown in Panel A in Table IIB, largely show no effect on fatalities in the five days following the death of a medic. Two of the coefficients are positive and two are negative, with only one of the negative coefficients significant at the 10% level. The remaining coefficients are statistically insignificant. Our preferred specification, which includes all controls, shows no statistically significant effect on fatalities resulting from the death of a medic in Iraq and Afghanistan.

Panel B in Tables IIA and IIB show the effect on fatalities in the 10 days following a medic's death. Most of these estimates show similar results as those from the five-day after effects in Panel A. The point estimates from the ten-day after effects for the Pacific theater of WWII, Korea, and Vietnam in Panel B generally show a slightly larger decrease in the effect on fatalities in comparison with the five-day estimates in Panel A. Eleven of the twelve coefficients in columns (5) through (16) are negative, with eight of the estimates significant at the 5% level and one significant at the 10% level. Similar to the five-day

TABLE IIIA OLS Estimates of Effect of Medic Death on Later Unit Awards for Gallantry

	WWII, Europe and North Africa				WWII Pacific			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Panel A: Unit awards over 5 days after death minus unit awards over 5 days before death								
Medical	0.154	0.176	−0.006	0.048	−0.137	−0.130	−0.155	−0.043
	(0.083)*	(0.085)**	(0.087)	(0.084)	(0.147)	(0.149)	(0.132)	(0.122)
Unit × quarter effects?		Yes		Yes		Yes		Yes
Year × month?		Yes		Yes		Yes		Yes
Personnel traits?		Yes		Yes		Yes		Yes
Previous unit deaths?			Yes	Yes			Yes	Yes
R^2	0.000	0.054	0.188	0.304	0.000	0.164	0.161	0.342
Panel B: Unit awards over 10 days after death minus unit awards over 10 days before death								
Medical	0.044	0.059	−0.101	−0.034	−0.257	−0.267	−0.214	−0.074
	(0.101)	(0.102)	(0.103)	(0.096)	(0.206)	(0.211)	(0.178)	(0.173)
Unit × quarter effects?		Yes		Yes		Yes		Yes
Year × month?		Yes		Yes		Yes		Yes
Personnel traits?		Yes		Yes		Yes		Yes
Previous unit deaths?			Yes	Yes			Yes	Yes
R^2	0.000	0.078	0.191	0.358	0.000	0.239	0.192	0.433
Observations	73,452				13,758			
Clusters	1109				337			

Notes: Specifications are the same as in Tables IIA and IIB.
*indicates significant at the 10% level.
**indicates significant at the 5% level.

TABLE IIIB OLS Estimates of Effect of Medic Death on Later Unit Awards for Gallantry

	Korean War				Vietnam War[a]			
	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)
Panel A: Unit awards over 5 days after death minus unit awards over 5 days before death								
Medical	−0.429	−0.524	−0.342	−0.262	−0.004	0.005	−0.008	0.003
	(0.162)**	(0.191)**	(0.127)**	(0.161)	(0.015)	(0.013)	(0.014)	(0.012)
Unit × quarter effects?		Yes		Yes		Yes		Yes
Year × month?		Yes		Yes		Yes		Yes
Personnel traits?		Yes		Yes		Yes		Yes
Previous unit deaths?			Yes	Yes			Yes	Yes
R^2	0.001	0.139	0.155	0.346	0.000	0.275	0.231	0.367
Panel B: Unit awards over 10 days after death minus unit awards over 10 days before death								
Medical	−0.477	−0.582	−0.349	−0.236	−0.001	0.006	−0.008	0.003
	(0.175)**	(0.197)**	(0.129)**	(0.156)	(0.016)	(0.014)	(0.015)	(0.013)
Unit × quarter effects?		Yes		Yes		Yes		Yes
Year × month?		Yes		Yes		Yes		Yes
Personnel traits?		Yes		Yes		Yes		Yes
Previous unit deaths?			Yes	Yes			Yes	Yes
R^2	0.001	0.134	0.193	0.390	0.000	0.270	0.191	0.346
Observations	16,472				25,342			
Clusters	345				1746			

Notes: Specifications are the same as in Tables IIA and IIB.
[a]Distinguished service cross not included in Vietnam data.
*indicates significant at the 10% level.
**indicates significant at the 5% level.

estimates, these results show a strong negative effect on fatalities from the death of medical personnel in combat units.

The ten-day results for the European and North African theaters of war in Panel B in Table IIA largely reflect the same finding as the five-day results, mostly showing a positive effect on fatalities from the death of a medic. All of the coefficients are positive except for the estimates in column (3), which only control for previous unit deaths. Two of the four coefficients are marginally significant at the 10% level. The coefficients are slightly smaller than the five-day results, suggesting the effects from medics on casualties dissipate over time.

Similar to WWII, Korea, and Vietnam, the Iraq and Afghanistan ten-day results mostly follow the five-day estimates. The ten-day results for Iraq and Afghanistan, as shown in Panel B in Table IIB generally indicate that there is no effect on fatalities following the death of a medic. The preferred specification, which includes all controls, has a coefficient of 0.007 for α^{Fatal} and is statistically insignificant.

5.2. Effect of Medical Personnel on Commendation Medals

Panels A and B in Tables IIIA and IIIB present OLS and fixed effects results from Equation (4) for the European/North African and Pacific theaters of WWII, Korea, and Vietnam. We use the same sets of control variables, which we describe in Tables IIA and IIB, for each of the specifications. Panel A in Tables IIIA and IIIB shows the effect on unit commendation medals in the five days following the death of a medic. The coefficients for WWII Pacific and Korea are all negative with values ranging from −0.043 to −0.524. We can interpret this to mean that the death of one medic in unit u at time t causes a decrease in unit commendation medals over days t though $t+5$ between −0.043 and −0.524 than otherwise would have occurred had a medic not died. None of the coefficients are statistically significant for the WWII Pacific results and three of the four coefficients are significant for the Korean results in Panel A.

The results for Vietnam and the European and North African theaters in WWII tell a somewhat different story about commendation medals in Panel A from Table IIIA in comparison with the WWII Pacific and Korean results. The Vietnam results show essentially no effect on commendation medals from medics in the five days after their death. None of the coefficients are significant for the Vietnam results. The WWII European and North African results are mixed with the coefficients ranging in value from −0.006 to 0.176. Two of the positive coefficients are statistically significant for the European and North African estimates.

Panel B in Tables IIIA and IIIB show the effect on unit commendation medals in the ten days following the death of a medic. The ten-day results generally follow the five-day estimates. The European and North African theaters once again show mixed results. The Vietnamese ten-day results show no relationship between medics and commendation medals. None of the coefficients for the Vietnamese and WWII European/North African results are statistically significant at any level.

The ten-day after effects for the Korean and WWII Pacific results in Panel B in Tables IIIA and IIIB generally show a negative relationship between the death of medics and commendation medals. All of the coefficients are negative with values ranging from −0.074 to −0.582. The coefficients for the Korean results are the only ones with any level of significance; three of the four coefficients are significant at the 5% level. None of the WWII Pacific coefficients for α^{Medal} are significant at any level.

5.3. Discussion

The WWII Pacific, Korean, and Vietnamese results indicate that unit deaths decrease in the five or ten days following a medic's death for these conflicts. Some individuals might find this somewhat counter-intuitive in that they might expect medical personnel to have a positive influence in treating individuals. Therefore, one might expect that a medic's absence would cause an increase in unit fatalities following their death. The death of medical personnel, however, is likely to have a wide range of behavioral effects within military units. For instance, troops might be hesitant to take new ground, given the low level of medical care available from the loss of medical personnel. The loss of a medic, an integral component of a military unit, might diminish morale. It is likely that these types of behavioral effects would decrease the unit's combat capabilities and their drive to fight in the aftermath of a medic's death. Given the decrease in fighting capability, the military unit might simply wait until new medical personnel arrive before they continue aggressive tactical advances. Therefore, the number of unit deaths might decrease until new medical personnel arrive; similarly, any positive benefits from new tactical maneuvers will remain unrealized. The empirical results for WWII Pacific, Korea, and Vietnam lend some support for this theory.[12]

In addition to the fatality results, our point estimates suggest that the death of medical personnel in WWII Pacific and Korea diminishes military success, as measured by commendation medals. Notably, the WWII Pacific and Vietnamese commendation results are not as robust as those from Korea (in fact, all of the coefficients from WWII Pacific and Vietnam are statistically insignificant) and may suggest that commendation medals might not be the best proxy for military success.[13] Nonetheless, overall these results lend support for the hypothesis that a medic's death may have reduced military units' fighting capabilities, tactical advances, and overall combat effectiveness in these conflicts. The greater the number of commendation medals that a military unit receives should positively correlate with how well military units are fighting, or 'military success.' It appears that military units, specifically those in Korea and possibly to a lesser extent, the Pacific theater of WWII, generally did not partake in major operations until new medical personnel arrived, due to a lack of medical care.

We find dramatic differences in the estimates across conflicts. Our results vary from finding little effect on fatalities from the loss of medics in Iraq and Afghanistan to finding positive effects in the WWII European theater of operations and negative effects in other conflicts (e.g., WWII Pacific, Korea, and Vietnam). The variation across wars and even within different theaters of certain wars (e.g., WWII) can partially be explained by the changing combat environments.

For instance, within the different combat theaters of WWII, historians have documented that the Pacific theater of operations was much more navy centric in comparison with the European theater. Commanders such as General MacArthur and Admiral Nimitz decided to proceed with a leapfrogging or 'island hopping' strategy for taking ground (Morison 1998; Crabb 2009). The basic idea behind this type of military strategy was

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[12] We thank retired Lieutenant Colonel Stephen Hurst (Vietnam Veteran), Lieutenant Colonel Michael Nixon (Iraq Veteran), and Sergeant Erik Hamilton (Iraq Veteran) for this insight.

[13] It would be ideal if other outcome variables such as troop morale and changes in missions or objectives were available across all of the different conflicts. Other studies such as Rohlfs, Sullivan, and Kniesner (2014) have used data on geographical progress or an index for mission success. However, that data is only available for the WWII conflict. Likewise another variable to consider in this analysis is severity of injuries. That data is available from DMDC for the wars in Iraq and Afghanistan. A future extension of this study using those data would be useful. Thus, further research in this area and using different outcome and control variables across multiple conflicts is warranted.

for commanders to bypass heavily fortified positions and concentrate their attacks on strategically important islands that were not well defended, but still essential in the final pursuit of defeating Japan.

This type of strategy was pursued for a number of reasons, for one, the leaders of the Allies had decided that most of the military resources available to them should be dedicated to defeating the Nazis first and then after their defeat, the Allies would turn to the Japanese. This led to there generally being less resources available to Allied commanders in the Pacific in comparison with the European theater of operations. Thus, it was crucial for commanders to try to avoid large personnel and material losses where possible. Second, the island hopping strategy provided choke points on Japanese resources. Why have frontal assaults on an enemy when you can simply starve them out or make them incapable of pursuing their military objectives? It could be argued that the island hopping strategy worked very well at limiting counter offenses by Japanese forces using these choke points. Lastly, the island hopping strategy allowed Allied forces to advance more speedily toward mainland Japan than otherwise would have been the case. If the Allies had decided to take every single Japanese held island along the way to Tokyo, the operations would have been more meticulous, but expending those kinds of resources would have slowed down their advances. For these reasons, we believe commanders in the Pacific took a very careful approach to expending resources (which would include medical personnel) in taking new ground and often avoided large frontal assaults when the option was available.

In contrast, the commanders in the European theater of war generally had much more resources available to them in their combat operations. Vast amounts of military resources (and reserve supplies) were available for commanders in combat operations such as ‘Operation Overlord’ and the subsequent drive into Germany proper. Commanders such as General Patton were well known to take calculated risks in pursuit of their objectives. These commanders could often sustain substantial losses with the ability to bring in reserve troops where need be. The priority was on gaining new ground, ‘freeing’ occupied civilians, destroying Nazi war fighting capabilities, and ending the war in Europe as soon as possible. These types of tactical risks would often put troops (including medical personnel) and war fighting materials at risk (e.g., Normandy) in the short run. It is likely, however, that medical personnel could have been replenished much more easily in this combat theater due to the closeness of Allied nations (e.g., Great Britain) and the resources dedicated to these operations by the Allied leaders.

As discussed previously, the modern day estimates in Iraq and Afghanistan show little impact on unit fatalities from the loss of medics in combat operations, particularly in comparison with the other conflicts studied here. In previous conflicts, such as in the Pacific theater of WWII, new supplies and personnel were not as readily replaceable as they are in modern day Iraq and Afghanistan. In Iraq and Afghanistan, the military located many of their troops throughout the war relatively near heavily supplied and protected Forward Operating Bases (FOBs). If the opposing side was able to kill or wound a medic, then the army could easily replace them from nearby forces in a short period of time.

Therefore, a medic’s effect on casualties was not as severe as it was in past wars. This was not always the case in prior conflicts. In many cases, such as the Battle of the Guadalcanal in WWII, the military limited troops in their resupply of materials as well as replacement soldiers. It often took weeks to resupply ammunition, bandages, etc. – let alone bring in new medical personnel. This was typically not the case throughout Iraq and Afghanistan; in the very least, Iraq and Afghanistan’s resupply issues did not appear to be as extreme as those in the Pacific theater of WWII and other conflicts such as Korea.[14] Therefore, the estimates showing no change in the behavioral effects from medical personnel losses in Iraq and Afghanistan support the theory that modern day military units generally keep fighting with the same level of intensity as before a medic's death.

There are some potential threats to the internal validity of this study that cannot be discarded easily. For instance, even though there is some merit in the assumption that the identity of the person killed in combat is randomly determined, the day-to-day war operations is a dynamic event itself with time-varying unobserved dimensions that might be correlated with the outcomes of interest. Likewise, the lack of information on the number of combat medics per unit does not allow fully controlling for this important dimension.[15] Moreover, there are a limited number of covariates and sensitivity tests used to validate (indirectly) the identifying assumption. Thus, readers should be aware that some of these issues could potentially impact the accuracy of the estimates.[16]

6. CONCLUSION

This study combines multiple datasets from various government organizations as well as personally collected archival data to analyze the extent that medical personnel deaths in combat affect the losses of other soldiers in their units. We also investigate the relationship between medical personnel deaths and 'military success' as measured by commendation medals earned by military units. A difference-in-differences identification strategy is used to provide estimates for WWII, Korea, Vietnam, Iraq and Afghanistan.

We find that unit deaths decrease in the five or ten days following the death of a medic in Vietnam, Korea, and the Pacific theater in WWII. In contrast, the WWII European and

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[14] Once again, we thank retired Lieutenant Colonel Stephen Hurst (Vietnam Veteran) and Sergeant Erik Hamilton (Iraq Veteran) for their insights in regards to conditions during past and current conflicts.

[15] Also of note is that some of the alternative econometric techniques used in our analysis (not shown) were not as precise when analyzing the WWII data. For instance, we attempted to run alternative regressions by (1) excluding those observations with multiple combat deaths that occurred on the same day and (2) replacing the dummy 'medical' with the total number of medical personnel who died in the unit on that day. We found that the results for these alternative regressions were largely unchanged for the wars in Korea, Vietnam, Iraq and Afghanistan. However, some of the alternative regressions for the WWII results showed that while the sign of the coefficients remained the same (as shown in the tables in this paper), some of the estimates were much more imprecise and became statistically insignificant. This should provide some caution when interpreting the WWII results in this paper. These regression results are available upon request from the authors.

[16] Given that we include both fixed effects and lagged dependent variables in our specifications, it is possible that our estimates might be biased due to some of the issues related to using panel data as discussed in Angrist and Piskchke (2008). Angirst and Pischke in *Mostly Harmless Econometrics* (243–247) argue that the Arellano and Bond estimator suffers from the same possible bias and should also be avoided. Instead, they propose using the following heuristic: (1) If fixed effects is the correct model and you instead use lagged dependents, then your estimated treatment effects will probably be too small (i.e. you will obtain an attenuated estimate). (2) If lagged dependents is the correct model and you instead use fixed effects, then your estimated treatment effects will probably be too large (i.e. you will obtain an extenuated estimate). Angrist and Pischke propose estimating both the lagged dependents and the fixed effects models separately and then using this heuristic to get a basic idea of what the true coefficient probably is. Another related point, however, is that, as the number of observations per unit increases, the fraction of the variance in the residual that is correlated with the lagged dependent shrinks as well. Hence, the original Nickell (1981) critique about the bias when using lagged dependents and fixed effects together applies most when $T = 2$, and the problem quickly becomes less severe as T increases (when $T = 3$, the bias is 1/2 as large as when $T = 2$, and when $T = 4$, the problem is 1/3 as large as when $T = 2$, and so on). For this reason, we believe that it is best to take the Angrist–Pischke heuristic one step further and include all three specifications – and that the one with both lagged dependents and fixed effects is probably the closest to the truth. Notably, the number of observations we use in the regressions are in the thousands or tens of thousands, and thus, these numbers are a far cry from the small sample issues discussed in Nickell (1981) and Angrist and Pischke (2008).

North African results indicate unit deaths rise following the death of a medic and we find no relationship between medical personnel deaths and other unit deaths in Iraq and Afghanistan.

The estimates for the relationship between medical personnel deaths and commendation medals are not as precise as the fatality results. However, in general, our point estimates suggest a decrease in the number of commendation medals earned by units in Korea and the Pacific theater in WWII in the five or ten days following the death of a medic. In contrast, the results show little connection between medic deaths and commendation medals in Vietnam and the European and North African theaters in WWII.

ACKNOWLEDGMENTS

The views expressed in this document are those of the authors and do not reflect the official policy or position of the Department of Defense or the U.S. Government. Distribution for this article is unlimited. We thank Kathleen Bailey for editing assistance.

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