

Incidence of Pulmonary Embolus in Combat Casualties With Extremity Amputations and Fractures

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Background: The objective of this retrospective study was to determine the incidence of pulmonary embolism (PE) in casualties of wartime extremity wounds and specifically in casualties with a trauma-associated amputation.

Methods: Records of all combat-wounded evacuated and admitted between March 1, 2003, and December 31, 2007, were retrospectively reviewed. Continuous and categorical variables were studied with the Student's *t* test, Fisher's exact test or χ^2 test; multivariate analysis was performed using a stepwise regression logistic model.

Results: A total of 1,213 records were reviewed; 263 casualties met the inclusion criteria. One hundred three (41.5%) had amputations and 145 (58.5%) had long-bone fractures not requiring amputation. The observed rate

of PE in these 263 casualties was 5.7%. More casualties with amputations, 10 (3.7%), developed PE than those with long-bone fractures in the absence of amputation, 5 (1.9%) ($p = 0.045$). Casualties with bilateral lower extremity trauma-associated amputations had a significantly higher incidence of PE compared with those sustaining a single amputation ($p = 0.023$), and the presence of bilateral lower extremity amputations was an independent risk factor for development of a PE ($p = 0.007$, odds ratio 5.9) (univariate and multivariate analysis, respectively).

Conclusion: The cumulative incidence of PE was 5.7%. The incidence of PE is significantly higher with trauma-associated amputation than with extremity long-bone fracture without amputation. Bilateral amputations, multiple long-bone fractures, and pelvic fractures are independent risk factors for the development of PE. The use of aggressive prophylaxis, deep venous thrombosis screening with ultrasound, and use of prophylactic inferior vena cava filters should be considered in this patient population.

Key Words: Wounds, Combat, Pulmonary embolus, War.

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This study was approved by the National Naval Medical Center Institutional Review Board in compliance with all Federal regulations governing the protection of human subjects. The NNMCI IRB-approved protocol number is NNMCI.2005.0027 and the protocol title is "Caring for the casualties from Operation Iraqi Freedom and Enduring Freedom in the continental United States: the Bethesda experience."

We certify that all individuals who qualify as authors have been listed; each has participated in the conception and design of this work, the analysis of data (when applicable), the writing of the document, and the approval of the submission of this version; that the document represents valid work; that if we used information derived from another source, we obtained all necessary approvals to use it and made appropriate acknowledgements in the document; and that each takes public responsibility for it.

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Pulmonary embolism (PE) is a cause of significant morbidity and mortality in trauma casualties with the incidence of PE reported as ranging from <1% to 58% in this population.^{1–8} In 2004, Knudson et al. analyzed the National Trauma Data Base, consisting of >450,000 trauma patients treated at 131 trauma centers, and reported the incidence of PE to be 0.14%.³ Several recent studies have found similarly low rates of clinically significant PE in the trauma population.^{5,8}

Identifying subgroups of casualties who are at increased risk of developing a PE is important for appropriate risk stratification and hence screening and prophylaxis management. The EAST Practice Management Group performed a meta-analysis and determined the following: patients with spinal cord injuries and spinal fractures are at an increased risk of developing venous thromboembolism (VTE) (level I evidence); and increased age, increasing Injury Severity Score (ISS), and greater numbers of blood transfusions are associated with an increased risk of VTE in trauma patients (level II evidence). Although the presence of long-bone fractures, pelvic fractures, and head injuries has been identified as significant risk factors for PE in single-institution studies, they were not identified as significant risk factors in the EAST Practice Management Group meta-analysis.⁹ Subsequently, Knudson et al.³ analyzed the National Trauma Data Base and determined lower extremity fracture to be an independent risk factor for PE by multivariate analysis.

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Military medical facilities are uniquely exposed to casualties of combat. The extreme high-energy nature of wartime mechanisms contrasts markedly to the common mechanisms of civilian trauma and often results in devastating extremity injuries that include a high incidence of complex long-bone fractures and trauma associated amputations. Medical advancements, improvements in body armor, and more efficient aeromedical evacuation have resulted in increased survival from severe combat injuries. Given the severity and increased survival of present day combat casualties and foreknowledge that lower extremity fractures place patients at increased risk for developing PE,^{3,9} we hypothesized that casualties suffering a trauma-associated amputation (to include amputations above knee, below knee, above elbow and below elbow but not to include amputations of hands/digits/ankles/feet) are at increased risk of developing a PE than those suffering long-bone fracture without an associated amputation.

MATERIALS AND METHODS

Study Methodology

The institutional review board at the National Naval Medical Center approved this study. The medical records of all combat casualties admitted to the National Naval Medical Center, between March 1, 2003, and December 31, 2007, were retrospectively reviewed. Casualties were included in the study if they underwent at least one orthopedic procedure performed at our institution or had an amputation before arrival. An orthopedic procedure was defined as an open reduction-internal fixation, definitive external fixation, amputation, or amputation revision. Amputations and extremity fractures limited in level to or distal to the wrist or ankle were excluded from analysis. The primary outcome measured was documentation of a pulmonary embolus. The diagnosis of PE was determined by spiral computed tomographic scans as defined by a filling defect in a pulmonary subsegmental or larger artery, clinical symptoms that led a clinician to start therapeutic anticoagulation, or autopsy results. Variables recorded for each study subject included age, gender, and mechanism of injury. The location and type of injury (fracture or amputation) was documented. A casualty's injuries were defined as primary and secondary injuries based on Abbreviated Injury Scale severity.

The casualties' associated injuries were also documented and categorized as abdominal, spinal (both cord injuries and fractures), pelvic fractures, and traumatic brain injury. The ISS and APACHE II scores were recorded. The length of hospital stay, number of surgeries, number and type of blood transfusions, and number of days on the ventilator and days spent in the intensive care unit, if applicable, were also recorded. In addition, the diagnosis of deep venous thrombosis (DVT) was documented if and when it occurred. In addition, the type, if any, of DVT prophylaxis given was recorded as well as if that prophylaxis was stopped the morning of surgery, the night before surgery, or not at all. Finally, placement of inferior vena cava (IVC) filter was documented, including the timing of placement.

Statistical Analysis

Statistical differences between mean continuous variables were analyzed by the Student's *t* test. Associations between categorical variables were analyzed by Fisher's exact test or χ^2 test as appropriate. The clinical outcome studied was the presence of a pulmonary embolus. To assess the independent predictive effect of a covariate for a nominal response (development of pulmonary embolus), a logistic regression model was constructed and parameters were estimated using maximum likelihood. Only those factors identified to be potentially significant ($p < 0.05$) on categorical contingency analysis were entered into the multivariate model to determine the independent prognostic effect of these variables for the development of pulmonary embolus. Odds ratios were calculated for the maximum likelihood parameter estimates. Statistical analyses were performed using JMP v7.0 and SAS software (JMP and SAS, Cary, NC). A p value < 0.05 was considered significant.

RESULTS

During the study period, 1,213 combat casualties were admitted to the National Naval Medical Center; 263 casualties met inclusion criteria and were included in the study and analysis. Fifteen (5.7%) casualties were diagnosed with a PE and 15 (5.7%) were diagnosed with a DVT during their hospitalization. Three (20%) of the 15 casualties diagnosed with PE were also diagnosed with a DVT. There was one death from PE in the study cohort (0.38%), equating to a 6.7% mortality of PE. The average time from injury to diagnosis of PE was 18 ± 15.7 days (range, 2–54 days), and the mean time from arrival to this institution to diagnosis of PE was 11 ± 11.9 days (range, 0–36 days).

Demographic Data and Risk Factors

Analyses of demographic-dependent variables are summarized in Table 1. Univariate and multivariate analyses are summarized in Tables 2 and 3. The study population consisted of 99.2% men with a mean age of 25.2 years. The majority of the injuries were caused by blasts (78.7%) with no statistical difference between those with PE and those without PE ($p = 0.41$). The mean amount of time from day of injury to arrival at this institution was 6.5 days, and the mean length of stay was 27.17 days, with no statistical difference between the two groups. However, on univariate analysis, it was determined that casualties with PE had significantly more days on the ventilator ($p = 0.024$) and more days spent in the intensive care unit ($p = 0.032$). The number of ventilator days was also found to be an independent risk factor for development of PE on multivariate analysis ($p < 0.001$). Additionally, casualties diagnosed with a PE underwent more surgical procedures, as defined by a procedure performed in the operating room with anesthesia support, compared with casualties who were not diagnosed with a PE (9.0 ± 7.2 vs. 5.0 ± 4 ; $p = 0.005$).

Both the ISS and APACHE II score were significantly higher in the PE group ($p = 0.042$ and $p = 0.043$, respectively). Casualties with a PE had a mean ISS of 22.93 and a mean APACHE II score of 10.87, and casualties without a PE

TABLE 1. Univariate Analysis of Patient Demographics and the Occurrence of PE

Patient Characteristics	Total Population (N = 263), N (%) Total	No PE (N = 248), N (%) Total	PE (n = 15), N (%) Total	p
Demographics				
Sex				0.727
Male	261 (99.2%)	246 (99.2%)	15 (100%)	
Female	2 (0.8%)	2 (0.8%)	0 (0%)	
Age (mo)	25.23 ± 17.7	25.38 ± 18.2	22.87 ± 4.6	0.595
Mechanism of injury				0.410
Blast	207 (78.7%)	194 (78.2%)	14 (86.7%)	
GSW	30 (11.4%)	30 (12.1%)	0 (0%)	
MVA	17 (6.5%)	16 (6.5%)	1 (6.7%)	
Other	8 (3.0%)	7 (2.8%)	1 (6.7%)	
Hospital course				
Days from injury to arrival at NMMC	6.47 ± 7.8	6.71 ± 9.1	7.33 ± 6.2	0.793
LOS	27.17 ± 20.5	26.33 ± 19.4	40.91 ± 31.37	0.096
Ventilator days	2.18 ± 5.8	1.59 ± 3.9	11.93 ± 15.8	0.024
ICU days	3.43 ± 8.8	2.62 ± 6.3	16.73 ± 23.0	0.032
Blood transfusions				
Whole blood	0.37 ± 2.49	0.39 ± 2.56	0.13 ± 0.52	0.699
Cryoprecipitate	0.15 ± 0.95	0.16 ± 0.98	0 ± 0	0.542
FFP	2.26 ± 13.7	2.36 ± 14.1	0.67 ± 1.23	0.642
Platelets	0.69 ± 2.67	0.71 ± 2.75	0.40 ± .83	0.665
Factor 7	0.06 ± 0.65	0.06 ± 0.66	0 ± 0	0.730
PRBC	11.22 ± 18.8	11.59 ± 19.3	3.67 ± 3.82	0.109
Associated injuries				
Spinal injury	25 (9.5%)	20 (8.1%)	5 (33.3%)	0.001
Abdominal injury	52 (20.2%)	45 (18.1%)	8 (53.3%)	0.001
Pelvic fracture	18 (6.8%)	13 (5.2%)	5 (33.3%)	0.002
ISS	17.29 ± 11.1	16.95 ± 11.2	22.93 ± 7.9	0.042
APACHE II	6.71 ± 5.0	6.46 ± 4.7	10.87 ± 7.6	0.043
Perioperative care				
Number of surgeries	5 ± 4.3	5 ± 4.0	9 ± 7.2	0.005
DVT prophylaxis				0.428
None	17 (6.5%)	16 (6.5%)	1 (6.7%)	
Lovenox 30 BID	216 (82.1%)	205 (82.7%)	11 (73.3%)	
Lovenox 40 QD	21 (8.0%)	20 (8.1%)	1 (6.7%)	
Heparin 5,000 TID	5 (1.9%)	4 (1.6%)	1 (6.7%)	
Heparin 5,000 BID	4 (1.5%)	2 (1.2%)	1 (6.7%)	
Perioperative prophylaxis				0.476
Not stopped	22 (8.4%)	20 (8.1%)	2 (13.4%)	
Held morning of surgery	224 (85.2%)	211 (85.1%)	13 (86.7%)	
Held evening and morning prior	17 (6.5%)	17 (6.9%)	0 (0%)	
Placement of IVC filter	23 (8.7%)	12 (4.8%)	11 (73.3%)	<0.0001

GSW, gunshot wound; MVA, motor vehicle accident; NMMC, National Naval Medical Center; LOS, length of stay; ICU, intensive care unit; FFP, fresh frozen platelets; PRBC, packed red blood cells; BID, twice a day; QD, each day; TID, three times a day.

Values are presented as mean ± SD or n (%).

had mean scores of 16.95 and 6.46, respectively. ISS score was significantly higher in those with PE than in those without by multivariate analysis ($p = 0.028$). The number and type of different blood products transfused was not found to be of statistical significance in the diagnosis of PE. Casualties who had an associated spinal injury (25, 9.5%), abdominal injury (52, 20.2%), or pelvic fracture (18, 6.8%) were found to have a significantly higher incidence of PE ($p = 0.001$, $p = 0.001$, $p = 0.002$, respectively). The presence of

a pelvic fracture was also found to be an independent risk factor for the development of PE on multivariate analysis ($p = 0.025$, odds ratio [OR] 6.3). There was no statistical difference found in this study population in the number of head-injured casualties with and without a PE.

Amputation and Pulmonary Embolus

The most common site of extremity injury was the lower extremity, accounting for 68% of the primary injuries

TABLE 2. Univariate Analysis of Extremity Injuries and the Occurrence of PE

Patient Characteristics	Total Population (N = 263), N (% Total)	No PE (N = 248), N (% Total)	PE (N = 15), N (% Total)	<i>p</i>
Multiple limbs injured	137 (52.1%)	124 (50.0%)	13 (86.75%)	0.007
Fractures	167 (63.5%)	160 (64.5%)	7 (46.6%)	0.090
Long bone fractures	158 (60.0%)	151 (60.1%)	7 (46.6%)	0.082
Lower extremity fractures	101 (38.4%)	94 (37.9%)	7 (46.6%)	0.146
Amputation present	110 (41.8%)	100 (40.3%)	10 (66.7%)	0.045
Long bone amputations	84 (31.9%)	74 (29.8%)	10 (66.6%)	0.040
Lower extremity amputations	73 (27.8%)	64 (25.8%)	9 (60.0%)	0.148
Bilateral lower extremity amputations	28 (10.6%)	22 (8.9%)	6 (40.0%)	0.002

TABLE 3. Independent Risk Factors for Development of PE on Multivariate Analysis

	<i>p</i>	χ^2	Odds Ratio
Bilateral lower extremity amputation	0.007	7.4	5.9
ISS	0.028	4.8	N/A
Multiple limbs injured	0.026	5.0	12.9
Ventilator days	<0.001	12.6	N/A
Pelvic fracture	0.025	5.0	6.3

in this patient population. Casualties with injuries, including fracture or amputation, to multiple limbs had a statistically significant increased rate of PE on univariate analysis ($p = 0.007$) compared with casualties without a diagnosis of PE (Table 2). The presence of multiple injured limbs was found to be an independent risk factor for the development of PE on multivariate analysis ($p = 0.026$, OR 12.9) (Table 3). There were 167 (63.5%) casualties with at least one fracture as their primary or secondary injury, and 158 (60.0%) casualties had long-bone fractures: 101 (38.4%) with lower extremity and 57 (21.7%) with long-bone fractures. Casualties with ≥ 1 trauma-associated amputation had a significantly higher incidence of PE ($p = 0.040$) compared with those without an amputation. There were 28 (10.6%) casualties in the study population with bilateral lower extremity amputations, and 5 (17.9%) of those 28 suffered a PE. This was statistically significant on univariate analysis ($p = 0.002$) and multivariate analysis ($p = 0.007$, OR 5.9).

DVT Prophylaxis

The majority (216, 82.1%) of casualties received low-molecular weight heparin (LMWH) 30 mg subcutaneously twice a day for DVT prophylaxis during their hospitalization. In addition, 17 (6.5%) received no prophylaxis, 21 (8.0%) received enoxaparin 40 mg daily, 5 (1.9%) received unfractionated heparin 5,000 U three times a day, and 4 (1.5%) casualties received unfractionated heparin 5,000 U twice a day. There was no significant difference between the PE and non-PE group in regard to the type of prophylaxis given. The majority of casualties treated with LMWH (85.2%) had their prophylaxis stopped the morning of surgery; this was not found to be significantly associated with PE. Those casualties diagnosed with PE had a significantly higher number of IVC

filters placed ($p < 0.0001$), eight of which were placed after diagnosis of PE and three before diagnosis of PE. Of those patients with IVC filters in place before diagnosis of PE, one patient had a PE that occurred in the perioperative period following a ventral hernia repair 12 months after placement of the IVC filter and two patients had PE that occurred during the same hospitalization as placement of the filter (3 and 4 weeks after filter placement), both of whom had jugular vein thrombosis diagnosed by ultrasound at the time of PE diagnosis. All 23 IVC filters were placed by vascular surgery.

DISCUSSION

The incidence of PE in the study population was 5.7%. This incidence is greater than that encountered in the civilian trauma population^{3,5,10–12} in general, and specifically for patients with at least one risk factor for PE. On univariate analysis, there was a significant difference in the number of PEs between the casualties who experienced an amputation, and even more specifically a long-bone amputation than those who suffered fractures alone. In addition, bilateral lower extremity amputation, pelvic fractures, and multiply injured limbs were determined to be independent risk factors for development of PE on multivariate analysis. However, there are many potential reasons beyond amputation alone for the increased rate of PE in casualties with trauma-associated amputations evaluated in this study.

The casualties with trauma-associated amputations suffered high-energy, devastating injuries, often to multiple limbs. These injuries frequently require multiple visits to the operating room to undergo surgical debridement, definitive fracture fixation, amputation revisions, and care for other associated injuries. The reason for the multitude of surgeries is to effectively treat the injuries in a manner that will provide the greatest rehabilitation ability. It is well documented that surgery alone is a risk factor for development of a VTE.¹³ This was seen in our study population as the casualties who sustained a PE underwent a greater number of surgeries compared with those without a PE (9.0 ± 7.2 vs. 5.0 ± 4 ; $p = 0.005$). Repetitive operative trauma in conjunction with the prolonged immobility secondary to these operations were potentially contributing factors influencing PE incidence in this population. Additionally, when these casualties undergo surgery, DVT prophylaxis is often held perioperatively. Although perioperative LMWH stoppage was not significantly

associated with PE in this study, the size of the study cohort cannot rule out the possibility that the interruption of LMWH associated with increased number of surgeries may be contributory to the higher incidence of PE.

Another likely contributing factor to the increased rate of PE in the amputee population is that these casualties endure prolonged periods of immobility before beginning vigorous physical therapy and rehab. Immobility has been shown to be a risk factor for the development of PE, especially in the trauma setting.^{13,14} In our population, we observed a mean time from injury to diagnosis of PE of 18 days, which is significantly longer than previous reports which document the majority of PEs are diagnosed within the first week after injury.^{5,15–20} This longer time to diagnosis of PE may be due to the extended period of immobilization that these casualties, and particularly those with bilateral lower extremity amputations, typically endure.

In previous conflicts, these high-energy injuries were more commonly fatal. Advancements in body armor, forward-deployed medical care, aeromedical capabilities, and overall trauma care, to include implementation of clinical practice guidelines via the Joint Theater Trauma System, have improved casualty survival. Since the Joint Theater Trauma System initiation, a mortality rate of 5.2% for casualties arriving to a combat hospital has been realized and is comparable to the fatality rate of 4.3% reported in an age-matched cohort from the National Trauma Data Base.²¹ Many of these “newly” surviving casualties are often critically ill and require lengthy intensive care and ventilator support; the number of days for both of these requirements was significantly higher in the PE group of this study, with the number of ventilator days determined to be a significant risk factor on multivariate analysis. The ISS was higher than what is commonly seen with simple or isolated extremity wounds and was found to be an independent risk factor for the development of PE in this population. All of these factors increase the time of immobility; however, the actual duration of immobility was not captured and hence not reviewed in this study. Longer duration on the ventilator, increased number of intensive care unit days, and increased ISS likely contributed to this population with amputations being at an increased risk for the development of PE.

Unfortunately, there are few level I recommendations to guide clinical decision making concerning the use of LMWH, the placement of IVC filters, or the use of screening ultrasounds for DVT in asymptomatic patients.⁹ It has been shown that the use of prophylaxis does significantly decrease the rate of DVT and most likely subsequent PE.^{4,22} There have also been subsequent studies showing LMWH to be superior to compression devices and low-dose unfractionated heparin.^{22,23} Sequential compression devices were used intermittently in our study population, but we were unable to clearly determine how many casualties used them and the duration of treatment because of incomplete documentation. The feasibility of consistent use of mechanical prophylaxis was also problematic given that our population consisted of casualties sustaining extremity injuries often to most or all of their limbs.

Surprisingly, we found no significant difference in the number of PEs in casualties who received chemical prophylaxis and those who did not. In addition, we found no difference in PE rates between the different types of prophylaxis given. There was also no difference in the number of PEs based on whether and when this prophylaxis was held before surgery. This may be due to the small sample size in this study and thus a type II error. One other consideration is the appropriate dose of the enoxaparin in this patient population. Unfortunately, we did not have data available on anti-Xa levels in these casualties. It is possible that body habitus, renal clearance, and severity of injuries; the PE incidence can be higher in casualties because the traditional dose of enoxaparin is not effective. Although we are unable to comment on this currently because of the limited data available, this is something that should be considered in future military and civilian studies.

Options to reduce the incidence of PE in this population focus on screening, anticoagulation, and utilization of IVC filters. The role of screening ultrasound in asymptomatic trauma patients is still controversial. Current EAST Practice Management level III recommendations concerning this issue suggest that the use of duplex ultrasound for high-risk asymptomatic patients may be a cost-effective means to decrease the incidence of PE.⁹ In addition, the Seventh American College of Chest Physicians Conference on antithrombosis and thrombolytic therapy urged the consideration of surveillance duplex ultrasounds in patients who are at high risk and are unable to receive prophylaxis.²⁴ In a recent study, Adams et al.¹² found that 86% of lower extremity DVTs were found in asymptomatic patients on screening duplex performed weekly in nonambulatory or high risk patients. Although duplex ultrasound is limited by its ability to adequately view the vasculature of the pelvis, consideration should be given to performing screening ultrasounds in the high-risk casualties, especially those who have suffered bilateral lower extremity amputations. Within the past 3 years, the military has adopted the practice of performing screening ultrasounds in all casualties with lower extremity injuries.

One other consideration for the prevention of PE in amputee casualties is the use of prophylactic IVC filters. Currently, East Practice Management Guidelines offer only level III recommendations for the use of prophylactic IVC filters in patients who have an injury that renders them immobilized for long periods of time and a contraindication to anticoagulation.⁹ Unfortunately, there are complications associated with the placement of IVC filters, the most common being the development of a DVT.^{25–27} However, in a report looking specifically at the use of retrievable IVC filters in casualties, the rate of development of subsequent DVT was 0% and attributed to the fact that casualties who received prophylactic IVC filters were also able to receive some form of anticoagulation.²⁸ Therefore, at the very least, consideration should be given to the placement of prophylactic IVC filters in these high-risk casualties.

There are several limitations to this study, the most significant being that this is a retrospective review from a single institution with a relatively limited sample size. The uniqueness

of this patient population must also be taken into account; not only do all of these casualties have wounds sustained via mechanisms distinct from the civilian population but additionally unique geographical/travel circumstances endured before arrival at this medical institution are different from what is typically encountered in civilian trauma.

CONCLUSION

We found the rate of PE (5.7%) to be greater in this casualty population than cited in the recent literature from civilian trauma centers. We also found that there seems to be an increased rate of PE in casualties with amputations compared with patients suffering long-bone extremity fractures. In addition, bilateral lower extremity amputations, multiple injured limbs, and pelvic fractures were independent risk factors for development of PE. On the basis of these findings, we recommend that clinicians maintain a low threshold of suspicion for VTE in casualties with multiple extremity injuries, amputations, and especially bilateral lower extremity amputations. In addition, appropriate anticoagulation perioperatively, and consideration of screening ultrasound and prophylactic IVC filter placement in these casualties and especially those sustaining bilateral lower extremity amputations are warranted.

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EDITORIAL COMMENT

The devastating dismantled improvised explosive device injuries sustained by the current combat casualties, particularly among Marines during Operation Enduring Freedom in Afghanistan, have resulted in an increased amputation rate from 6% to 18% in recent months (J. B. Holcomb, MD and J. A. Johannigman, MD, personal communication). Thus the above article by Gillern et al. emphasizing the association between pulmonary embolism (PE) and extremity amputations in those injured in battle is particularly timely. The overall observed rate of PE among 263 casualties with amputation or long bone fractures was 5.7%, an incidence far higher than the overall 0.4% seen in the general trauma population.¹ However, in addition to amputations, injured warriors often have coexisting risk factors for the development of thromboembolic complications including the presence of shock on admission, the need for multiple transfusions, associated pulmonary complications requiring prolonged mechanical ventilation, the frequent coexistence of traumatic brain injury or spinal cord injury, and prolonged immobilization during trans-

port from the theater of war to the continental United States, all of which likely contribute to this alarmingly high PE rate.

The other very important finding in this current study is the *lack* of association between deep vein thrombosis (DVT) and PE; only 20% of these injured troops who had documented PE also had a DVT. These data are identical to a recent study from the National Trauma Data Bank, raising the important issue of the uncoupling of DVT and PE after injury.¹ Further, if DVT and PE are not, in fact, the same disease, then methods aimed at preventing DVT (such as mechanical compression and even inferior vena cava filters) may be ineffective in preventing PE. Indeed, in the study by Gillern et al., 3 of the 11 patients with inferior vena cava filters and PE had them placed before the diagnosis of PE was made. The potential source of upper extremity DVT (including those clots found on the filter itself) is recognized by the authors and is deserving of further investigation in both military and civilian settings. Although not designed to address this issue, the authors of the above study could find no significant association between the type of prophylaxis used (Lovenox or heparin in various doses; no prophylaxis) and the rate of PE. Given that the Joint Theater Trauma System has put in place venous thromboembolism prophylaxis guidelines, this area is also ripe for a prospective study conducted by military medical personnel. Recent data from civilian studies suggest that anticoagulants administered as prophylaxis should be dosed appropriately if they are to be effective.^{2,3}

Because mechanical compression devices cannot be used for amputated lower extremities and are impractical during flight, proper doses of effective anticoagulants will likely offer the best protection against potentially fatal PE in those wounded in conflict.

Most importantly, combat casualties with these devastating injuries are surviving their damage control resuscitations, massive transfusions, multiple surgeries, intensive care therapies, prolonged air transports, and in and outpatient treatments to live long enough to develop venous thromboembolic complications. For these enormous advancements in the care of the injured worldwide, we are indebted to our military medical personnel for their dedication and personal sacrifices which have made such survival possible.

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