Mortality from Isolated Civilian Penetrating Extremity Injury

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Background: **Although studies have ascertained that ten percent of soldiers killed in battle bleed to death from extremity wounds, little data exists on exsanguination and mortality from extremity injuries in civilian trauma. This study examined the treatment course and outcomes of civilian patients who appear to have exsanguinated from isolated penetrating extremity injuries.**

Methods: **Five and 1/2 years' data (Aug 1994 to Dec 1999) were reviewed from two Level I trauma centers that receive 95% of trauma patients in metropolitan Houston, TX. Records (hospital trauma registries, emergency medical system (EMS) and medical examiner data) were reviewed on all patients with isolated extremity injuries who arrived dead at the trauma center or underwent cardiopulmonary resuscitation (CPR) or emergency center thoracotomy (ECT).**

Results: **Fourteen patients meeting inclusion criteria were identified from over 75,000 trauma emergency center (EC) visits. Average age was 31 years and 93% were males. Gunshot wounds accounted for 50% of the injuries. The exsanguinating wound was in the lower extremity in 10/14 (71%) patients and proximal to the elbow or knee in 12/14 (86%). Ten (71%) had both a major artery and vein injured; one had only a venous injury. Prehospital hemorrhage control was primarily by gauze dressings. Twelve (86%) had "signs of life" in the field, but none had a discernable blood pressure or pulse upon arrival at the EC. Prehospital intravenous access was not obtained in 10 patients (71%). Nine patients underwent ECT, and nine were initially resuscitated (eight with ECT and one with CPR). Those undergoing operative repair received an average of 26 ± 14 units of packed red blood cells. All patients died, 93% succumbing within 12 hours.**

Conclusion: **Although rare, death from isolated extremity injuries does occur in the civilian population. The majority of injuries that lead to immediate death are proximal injuries of the lower extremities. The cause of death in this series appears to have been exsanguination, although definitive etiology cannot be discerned. Intravenous access was not obtainable in the majority of patients. Eight patients (57%) had bleeding from a site that anatomically might have been amenable to tourniquet control. Patients presenting to the EC without any detectable blood pressure and who received either CPR or EC thoracotomy all died.**

Keywords: **trauma exsanguination extremity EMS, extremity injury tourniquet emergency thoracotomy**

J Trauma. 2005;59:217–222.

Control of hemorrhage, treatment of co-morbid factors, fluid resuscitation, and urgent operation are critical to the survival of trauma patients. Eighty percent of early mortality in civilian trauma and half of all combat deaths are from uncontrolled bleeding, largely due to truncal injuries.[1,2] According to an analysis of the largest compilation of wartime mortality data, up to one third of the deaths from exsanguinations during the Vietnam War might have been prevented by the use of effective field hemorrhage control methods.[2] Utilizing a research model of wartime data, it was postulated that 10% of combat deaths in Vietnam were due to uncontrolled extremity hemorrhage.[2] Although civilian trauma mortality statistics do not provide exact numbers for prehospital deaths from extremity hemorrhage, case and anecdotal reports indicate that a small percentage of people die each year from isolated extremity trauma.[3]

Submitted for publication May 16, 2005.
Accepted for publication June 3, 2005.
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DOI: 10.1097/01.TA.0000173699.71652.BA

Although extremity injuries are common in both civilian and military trauma, they are apparently a much greater source of exsanguination on the battlefield than in the peacetime urban setting. The difference in mortality from military versus civilian extremity injury may be due to wounding mechanism, scene security or the speed of evacuation. Fortunately, most of these issues do not apply to the urban civilian setting.

Few published reports document the mechanism, treatment and outcome from isolated civilian extremity hemorrhage. Therefore, we examined the injury patterns, treatment course and outcomes of civilian patients who appear to have exsanguinated from these injuries. These data may prove useful in guiding future research in hemorrhage control.

PATIENTS AND METHODS

Patients in prehospital arrest with isolated extremity injuries admitted to Ben Taub General Hospital and Hermann Memorial Hospital between August 1994 and December 1999 were identified from a retrospective review of medical records. These two Level I trauma centers receive over 95% of the critical trauma patients within the greater Houston area. Admission criteria for the study and descriptors utilized in the review were apparent hemorrhage from an isolated extremity injury resulting in cardiopulmonary resuscitation (CPR),

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1. REPORT DATE	2. REPORT TYPE	3. DATES COVERED
01 JUL 2005	**N/A**	**-**

4. TITLE AND SUBTITLE	5a. CONTRACT NUMBER
Mortality from isolated civilian penetrating extremity injury	5b. GRANT NUMBER
	5c. PROGRAM ELEMENT NUMBER
6. AUTHOR(S)	5d. PROJECT NUMBER
Dorlac W. C., DeBakey M. E., Holcomb J. B., Fagan S. P., Kwong K. L., Dorlac G. R., Schreiber M. A., Persse D. E., Moore F. A., Mattox K. L.,	5e. TASK NUMBER
	5f. WORK UNIT NUMBER
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)	8. PERFORMING ORGANIZATION REPORT NUMBER
United States Army Institute of Surgical Research, JBSA Fort Sam Houston, TX 78234	
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)	10. SPONSOR/MONITOR'S ACRONYM(S)
	11. SPONSOR/MONITOR'S REPORT NUMBER(S)

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

13. SUPPLEMENTARY NOTES

14. ABSTRACT

15. SUBJECT TERMS

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a REPORT	b ABSTRACT	c THIS PAGE			
unclassified	**unclassified**	**unclassified**	**SAR**	**6**	

emergency center thoracotomy (ECT) and/or death in the emergency center (EC). The trauma registry, EC logs, and the weekly surgery department records that include all operative procedures, deaths, and complications were reviewed. Patients were identified by the description of their injuries and procedures performed. To standardize anatomic location of injuries, the upper extremity was defined as distal to the axillary crease and the lower extremity defined as distal to the inguinal crease.

Once patients were identified as meeting study criteria, their hospital records were reviewed. Emergency Medical System (EMS) unit response records were obtained on all patients and medical examiner post-mortem reports were obtained on all patients undergoing autopsy. Patients were excluded if any significant non-extremity injury had been discovered at the time of operation or autopsy. Patients who might have arrived in prehospital arrest but who went on to survive without receiving either CPR or ECT were not evaluated. Patient demographics, mechanism and location of injury, prehospital treatment, transport times, vital signs and signs of life, procedures performed and clinical outcomes were noted for each patient. Only 50% of patients had desired laboratory data on substance abuse, time from wounding to EMS notification, pre-morbid medical conditions, and patient temperature; therefore these data were considered unreliable and were not used.

RESULTS

Fourteen patients were identified from over 75,000 trauma EC visits at the two trauma centers (0.02% of trauma visits). Autopsy results (13 patients) and an operative report (1 patient) confirmed that these patients had isolated extremity injuries and had not suffered other major wounds. Mean age of the patients was 31 ± 12 years and only one was female (Table 1). Gunshot wounds accounted for seven (50%) of the injuries, the balance were stab wounds and lacerations (50%). No patients meeting the entry criteria were identified with blunt trauma isolated to an extremity. The apparent site of exsanguination was the lower extremity in 10 patients (71%) and the upper in 4 (29%). The injury site was proximal to the elbow in 2 cases (14%) and the knee in 12 (86%). One patient bled from a distal radial artery injury and another from an injury to his dorsalis pedis vessels. Ten patients (71%) had both a major artery and vein injured, three patients (21%) had only an arterial injury and one (7%) had only a venous injury. Average EMS scene time was 10.1 ± 6.6 minutes (range 5 -31 minutes), and mean transport time was 13.7 ± 7.8 minutes (range 5 - 30 minutes). The majority of patients (86%) had "signs of life" in the field, i.e. detectable blood pressure, pupillary activity, respiratory effort, or cardiac electrical activity.[4,5] No patient had a discernable blood pressure or pulse upon arrival to the EC. An accurate assessment of initial cardiac electrical activity was difficult to obtain from records. Twelve of fourteen patients (86%) underwent CPR either en route or at the hospital, while two (14%) had no documented CPR despite absence of a pulse (Table 2). There was no documented hemorrhage control 29% of the time. Only one patient had some form of hemorrhage control documented before the arrival of EMS. This consisted of wrapping the patient's foot in duct tape in an attempt to stop dorsalis pedis artery and vein bleeding. Hemorrhage control by EMS consisted of gauze dressings 64% of the time. Prehospital Military Anti-Shock Trousers (MAST) trousers were used once in an attempt to control a common femoral artery and vein injury (this patient arrived to the trauma center via helicopter). Prehospital intravenous access was not obtained in 10 (71%) patients (Table 3). Eleven patients (79%) were intubated before their arrival to the trauma center. Nine patients (63%) underwent immediate ECT, one patient had CPR only, while four patients were

Table 1 Demographic and Injury Data in Patients that Exsanguinated from Extremity Injuries

Patient #	Age	Sex	Mechanism	Extremity	Extremity Location	Named Artery	Named Vein
1	33	M	GSW	lower	proximal	CFA	CFV
2	42	F	laceration	upper	proximal	BA	BV
3	38	M	SW	lower	proximal	CFA	none
4	44	M	GSW	upper	proximal	BA	none
5	24	M	GSW	upper	proximal	BA	BV
6	44	M	laceration	lower	distal	DPA	DPV
7	23	M	GSW	lower	proximal	CFA	CFV
8	29	M	SW	lower	proximal	CFA	CFV
9	30	M	laceration	upper	distal	RA	none
10	34	M	GSW	lower	proximal	CFA	CFV
11	52	M	GSW	lower	proximal	SFA	SFV
12	20	M	SW	lower	proximal	none	PV
13	11	M	SW	lower	proximal	CFA	CFV
14	14	M	GSW	lower	proximal	SFA	SFV

M, male; F, female; GSW, gunshot wound; SW, stab wound; BA, brachial artery; CFA, common femoral artery; DPA, dorsalis pedis artery; RA, radial artery; SFA, superficial femoral artery; BV, brachial vein; DPV, dorsalis pedis vein; CFV common femoral vein; SFV, superficial femoral vein; PV, popliteal vein.

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Table 2 Prehospital Times and Treatment in Patients that Exsanguinated from Extremity Injuries

Patient #	Treatment Pre EMS	EMS Scene Time (min)	Transport Time (min)	Pre-Hosp CPR	Vital Signs in the Field HR = bpm SBP = mm Hg
1	none	10	14	yes	Yes but not recorded
2	none	8	23	no	HR = 73 SBP = none
3	none	5	9	yes	HR = 140 SBP = none
4	none	6	23	yes	HR = none SBP = none
5	none	10	3	yes	HR = 120 SBP = >80
6	duct tape	31	10	yes	HR = 30 SBP = none
7	none	6	5	yes	HR = 100 SBP = >70
8	none	13	30	yes	HR = 36 SBP = none
9	none	5	13	no	HR = 50 SBP = >80
10	none	8	11	yes	HR = 48 SBP = 80
11	none	10	24	yes	HR = EMD SBP = none
12	none	5	11	yes	HR = 70 SBP = none
13	none	16	6	yes	weak pulse
14	none	8	10	yes	HR = none SBP = none

EMS, emergency medical system; Min, minutes; HR, heart rate; bpm, beats per minute; SBP, systolic blood pressure; EMD, electrical mechanical dissociation; CPR, cardiopulmonary resuscitation.

declared dead on arrival (DOA). The decision to proceed to a thoracotomy was made by the senior resident or surgical attending based on clinical judgment. Nine patients were initially resuscitated (eight with an ECT and one with CPR) and were transported to the operating room and underwent surgical control of the bleeding. Arterial procedures included primary repairs, interposition of synthetic grafts, shunting or ligation. Temporary intravascular shunts were not used in any patients. Patients undergoing repairs had a mean initial pH of 6.95 ± 0.28 and received an average of 26 ± 14 units of packed red blood cells. All patients died, 93% within 12 hours. The one longer-term survivor died at 25 days from complications of severe anoxic encephalopathy.

Table 3 Interventions in Patients that Exsanguinated from Extremity Injuries

Patient #	Hemorrhage Control by EMS	IV Access Successful	Intubated By EMS	Time in EC	ECT	EC CPR
1	dressing	no	no	49 min	yes	no
2	dressing and pressure	no	no	23 min	yes	no
3	dressing	yes	yes	24 min	*yes	no
4	dressing and pressure	no	yes	DOA	no	no
5	dressing and pressure	no	no	15 min	yes	no
6	duct tape in place	yes	yes	DOA	no	no
7	dressing and pressure	no	no	30 min	yes	no
8	dressing	no	yes	DOA	no	no
9	dressing and pressure	no	yes	20 min	yes	no
10	dressing	no	yes	20 min	#yes	no
11	none	no	yes	24 min	yes	no
12	none	yes (TKO)	yes	DOA	no	no
13	MAST	no	yes	70 min	no	yes
14	none	yes	yes	28 min	yes	no

EC, emergency center; ECT, emergency center thoracotomy; CPR, cardiopulmonary resuscitation; TKO, to keep open; min, minutes; DOA, Dead on Arrival; MAST, Military Anti-Shock Trousers; * lived 25 days before dying; # died in EC after thoracotomy.

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DISCUSSION

Extremity injuries are common in both civilian and military trauma, but are fatal far more often in military settings.[2,6–8] In both populations, however, a percentage of these deaths may be preventable. During Vietnam, Desert Storm and Somalia hemorrhage from extremity injuries was determined to be a significant cause of preventable death.[2,8,9] Casualties surviving to reach surgical treatment in the field often had ongoing bleeding from extremity injuries that might have been controlled earlier by first aid maneuvers or improved methods of hemorrhage control. Rocko, Tischler, and Swan described the preventable nature of extremity exsanguination and documented eight civilian patients that might have been salvaged had someone initially applied direct pressure to their bleeding wound.[3] More recently, Tarlowe and Swan published the details of the extremity exsanguination of the Confederate General Albert S. Johnson.[10] The general's unused tourniquet was found in his pocket. In an extensive review of exsanguination, Asensio detailed the incidence of apparent exsanguination from various injuries and organ systems.[11] However, no papers have focused on the events surrounding apparent extremity exsanguination in a consecutive series of patients.

In the retrospective search method used in this study, only 14 patients (from over 75,000 patients) that met inclusion criteria were identified from a five-year period. All had penetrating injuries. Blunt trauma was not specifically excluded from the search, but those patients with major extremity injuries from blunt trauma also had other major injuries that may have contributed to their death. The majority of injuries were proximal to the knee or elbow joint and in the lower extremity. In keeping with the nature of civilian urban trauma, average EMS scene times and transport times were short.

The majority of patients in this study had signs of life in the field, yet all but one were dead within 12 hours of admission. Although a recordable blood pressure may have been restored with either CPR or ECT, the response was short lived. Review of the autopsy and operative reports found injuries in 8 of 14 patients in a location that might have been amenable to hemorrhage control by a field tourniquet (Table 1). However, hemorrhage control by bystanders or the injured patient themselves were not recorded on the EMS ambulance run records except in the one noted case (Table 2, patient # 6). Prehospital hemorrhage control by EMS consisted of gauze bandages and pressure, the effectiveness of which was not quantified. No tourniquets were recorded as having been used. With no discussion of the relative risks and benefits of ischemic times and hemorrhage control in an urban environment, national standards for EMTs and paramedics strongly discourage the use of tourniquets. As such, Houston EMS policy (like most EMS programs in the United States) emphasizes direct pressure, use of pressure points, and requires prehospital personnel to obtain physician approval before the use of tourniquets in the field. It is highly likely that upon arrival of EMS for each of these patients, the noted injuries were no longer bleeding significantly, as all were very hypotensive.

Due to current research and proposed changes in doctrine, the military is advocating a more liberal use of tourniquets as an initial hemorrhage control device for severe uncontrollable hemorrhage on the battlefield.[8,12–16] In the military combat casualty care environment delayed evacuation is common, resulting in prolonged tourniquet use which may result in amputation. However, even in this environment tourniquets might not universally result in amputation, as documented by the Korean War experience of LTC CW Hughes.[17] Wolff et al. reported that in 200 random cases of tourniquet application during WWII, no complication involving nerve injury or vascular thrombosis was observed.[18] These authors further wrote, ". . .in our experience, a tourniquet may be left on from two to six hours, depending on the temperature of the atmosphere and of the extremity, without clinically detectible damage."

In an urban scenario where short transport times are typical, (usually 15 minutes), this should not be an issue. Discussing damage control maneuvers for vascular injuries, Aucar and Hirshberg state, ". . .tourniquets should be avoided because they interrupt collateral circulation to the limb. However, in selected circumstances, when focal pressure fails and personnel resources are limited, a properly managed tourniquet may be a life-saving device."[19] Lakstein et al. reported that in 110 cases of tourniquet use by Israeli Defense Forces, neurologic complications occurred in only five patients, all associated with extended ischemic times (109–187 minutes).[15] Tourniquets are used routinely for orthopedic surgery with little complication providing ischemic times are minimized (< 1.5 hour) and tourniquet pressure is not excessive, i.e. <200 mm Hg and <250 mm Hg in the upper extremity the lower extremity, respectively.[20] This ischemic time is well within any expected during an urban trauma scenario. Mechanical injury due to excessive tourniquet pressure can easily be avoided by the use of pneumatic tourniquets, similar to those used for orthopedic surgery. Pneumatic trauma tourniquets are commercially available, e.g. Delfi EMT Tourniquet (Delfi Medical Innovations, Inc.).

Intravenous access in this patient population was apparently very difficult, perhaps related to the difficulty of accessing a collapsed vein after hemorrhage (or other less obvious reasons such as lack of usable veins due to intravenous drug use). Many of these patients had multiple attempts from more than one experienced provider. Additionally, during the study period the principal EMS agency changed its policy and began dispatching the closest ambulance to serious trauma incidents with the intention to shorten the prehospital interval. As a result some patients were transported in EMT-Basic staffed ambulances with paramedic intercept, allowing the paramedics less time to perform interventions such as IV insertion. In one patient where IV access was established, the

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patient's fluid rate was recorded as "TKO" (to keep open). Currently, alternative vascular access techniques in adults (sternal or extremity intraosseous) are not utilized by Houston EMS.[21,22] Hypotensive resuscitation strategies are the standard of care in Houston for patients with penetrating truncal trauma (and recently extended to selected blunt trauma patients) before definitive hemorrhage control. However, severely hypotensive patients with isolated extremity injuries where bleeding could be controlled by an alternative device might benefit from rapid vascular access and fluid resuscitation to a low normal blood pressure. It is clearly beyond the scope of this review to determine the validity of this treatment plan but it would be worthy of further prospective research.

The beneficial use of the emergency center thoracotomy for patients in extremis or for those who have arrested from a penetrating injury is well described.[23–29] However, Shimazu and Shatney demonstrated that in 267 patients arriving with no vital signs following both blunt and penetrating trauma only 1.5% of patients had a functional outcome with ECT.[30] They showed that open cardiac massage did not increase either the success of resuscitation or the long-term survival rate. Although some have reported survival after the use of ECT in patients with an isolated extremity injury, our series documents a different outcome.[25,26] The benefit of ECT in patients with isolated extremity injury must be described as questionable and potentially contraindicated. Ideally, clinical care would involve temporary hemorrhage control, initiation of CPR, and institution of rapid volume resuscitation via multiple means including cut downs, thus avoiding the significant physiologic insult of opening an uninjured body cavity.[31,32] Because the mean pH of patients transported to the OR in this series was 6.95, it is likely that damage control, rather than the decision to proceed directly to emergency department thoracotomy, was indicated. Only a small percentage of trauma patients require damage control, but one of the basic parameters for using damage control include a pH of less than or equal to 7.2.[33]

The principal limitations of this study are its retrospective design and resulting lack of a control group. Additionally, the numbers of patients with an isolated yet an apparent exsanguinating injury were very small, considering the volume of patients seen yearly at the two centers. Patients who did not present in arrest but had similar injuries were not included in this review, nor were those patients who responded to the centers' treatment without either CPR or ECT. The majority of patients with extremity injuries survived, yet this number was difficult to ascertain from the trauma records. However, because of the trauma morbidity review process, information and records on the patients that died were more complete. Additionally, some patients dead at the scene may not have been included, as they were transported directly to the morgue. Unfortunately, the city's medical examiner data could not be accessed by cause of death or body location of injury. Finally, other conditions leading to the patients' death (such as co-morbid disease) could not be determined.

As the incidence of extremity injuries is high and mortality from isolated extremity injuries low, routine application of a tourniquet or other device is not necessary in the overwhelming majority of civilian patients. However, improved hemorrhage control in these 14 patients might have resulted in some survival had it been initiated early. Initial control by a bystander or the patients themselves might have sufficed. Although the numbers presented are small and the exact cause of death cannot definitely be determined, there does appear to be a small group of patients in the civilian population at large who may benefit from earlier hemorrhage control. Rocko et al. stated that after appropriate public education, patients and bystanders should be encouraged to attempt prehospital hemostasis (with pressure).[3] Tourniquets have been available for centuries but no prospective clinical trials have been performed. Information is largely based on anecdotal reports drawn from the military experience. This review does not demonstrate the effectiveness of tourniquets but does present a feasible argument for the small group of patients who might have benefited from their use. Newer experimental methods of hemorrhage control easily utilized by prehospital personnel are also under development.[34,35] Based upon the results of this review, alternative hemorrhage control methods and vascular access techniques warrant prospective clinical trials.

ACKNOWLEDGMENTS

Special thanks are due to Mary Allen from Ben Taub General Hospital and Thomas J. Walters, PhD and Amy Newland from the United States Army Institute of Surgical Research, Fort Sam Houston who graciously provided important advice; Barbara A. Dawson of the Houston Fire Department Fire/EMS Records Section and Judy Robertson and Shavonda Murphy from the Houston Medical Examiners office for their exceptional research assistance.

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