



COMBAT-ASSOCIATED DROWNING

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ABSTRACT

Objective: Describe the clinical course and outcome of drowning cases in association with combat operations in Iraq and Afghanistan.

Design: Retrospective case series over a 6-year period (Dec 2002 to Jan 2009).

Setting: Echelon IV military trauma center in Europe.

Measurements: Patient demographics and description of the situational and the clinical findings at the initial drowning scene were abstracted from the medical record. A comprehensive account of patient care describing each subject as they transitioned through the combat theater to the final destination of an Echelon IV trauma center in Europe was created.

Results: The overall mortality rate was 37.5% (3 of 8 drowning patients). Glasgow Coma Scale (GCS) scores and the need for cardiopulmonary resuscitation at the scene of injury were predictive of eventual patient mortality (100% mortality in patients with a GCS score of 3 and 75% mortality with history of CPR). Advanced modes of mechanical ventilation and respiratory support such as airway pressure release ventilation and extracorporeal membrane oxygenation were essential to sustaining clinically acceptable oxygen tensions in a majority of the cohort (6 of 8 cases). Vasopressors (7 of 8 cases) were required to ensure adequate end-organ perfusion. Long term morbidity was related to the sequelae of acute respiratory distress syndrome and hypoxic encephalopathy.

Conclusion: Drowning in the context of a combat deployment was frequently associated with severe acute respiratory distress syndrome and shock. Patient survival appeared most consistently linked to initial GCS score and CPR requirements at the scene of injury.

INTRODUCTION

Drowning is defined as respiratory compromise, be it eventually fatal or nonfatal, sustained as a result of submersion in a liquid medium. Pneumonia, hypotension, anoxic brain injury, hypothermia and multiple organ dysfunction syndrome (MODS) are some of the consequences of prolonged fresh or salt water submersion and fluid aspiration. Studies of drowning victims in the United States suggest that these events typically occur among young male adults, are frequently associated with alcohol use, and take place in proximity to recreational pools or lakes. However, this information may have a limited correlation to other populations. There have been no publications discussing the challenges of caring for drowning victims in the context of a combat operations.

Landstuhl Regional Medical Center (LRMC) is an American College of Surgeons verified Level II military medical facility which serves as the central receiving and stabilization point for all wounded coalition members originating from the Iraq and the Afghanistan combat theaters. As such, LRMC has the unique perspective of managing all drowning victims that required aeromedical evacuation from the conflicts. Using a digital repository of trauma patients who transitioned through LRMC, we extracted all cases involving drowning for the purposes of a descriptive analysis.

Our anecdotal experience suggests that, with the exception of patient demographics (young male soldiers), drowning events among military members serving in Iraq and Afghanistan are dissimilar from prior reports in the literature. Drowning in association with combat may involve roadside improvised explosive devices (IED) with the concussive magnitude to collapse river-spanning bridges and launch armored vehicles into sewage or rainwater-filled ravines. Both restrained and unrestrained passengers confined within flooding vehicles may undergo temporary submersion and aspirate polluted water. IED detonation is also anticipated to inflict elements of both blunt and penetrating trauma.

MATERIALS AND METHODS

The LRMC Trauma Service instituted a database in 2002 which functioned as the digital repository for all trauma-related admissions. The database was queried for the interval between December 2002 to January 2009 and all patient files which involved drowning, water aspiration, or temporary submersion were extracted. We collected and tabulated all information pertaining to the descriptive incident report, the initial medical evaluation at the scene of injury, the node-to-node transfer of the patient from Iraq and Afghanistan to LRMC, and then final transfer to a medical center destination in the United States. Every effort was made to adhere to the terminology and publication stipulations of the **Recommended Guidelines for Uniform Reporting of Data from Drowning**. This manuscript represents a drowning subset analysis of a larger combat-associated acute lung injury study which was approved by the Investigational Review Board at the Institute of Surgical Research, Brooke Army Medical Center (Fort Sam Houston, Texas).

TABLE 1: DEMOGRAPHICS, PRESENTATION AND INITIAL CARE

Pt	Age	Incident	Duration of Submersion	CPR	Hypothermia	Initial GCS Score	Surgery	Blood Products	Coagulopathy	Acidosis	Circulatory Shock
1	23 Y M	Vehicle rollover into retention pond	Unknown	No	No	14	Ex lap, bilateral chest tubes	4 FFP	Yes	Yes	Yes, norepinephrine
2	20 Y M	IED w/ bridge collapse	< 1 minute	No	No	15	No	No	No	Yes	Yes, NE and vasopressin
3	29 Y M	Vehicle rollover into pool of standing water	Unknown	No	No	15	No	No	Yes	No	Yes, norepinephrine
4	33 Y M	Vehicle rollover into canal	45 minutes	Yes, 20 minutes	No	3	No	6 FFP	Yes	Yes	Yes, epinephrine
5	23 Y M	Vehicle drove off bridge into roadside ditch	Unknown	Yes, 10 minutes	Yes, 86.9 F	3	No	4 FFP	Yes	Yes	Yes, epi and dobutamine
6	23 Y M	Vehicle rollover into canal	1 minute	No	No	15	No	No	No	No	No
7	23 Y M	Vehicle submerged in pool of standing water	2 minutes	Yes, <1 minute	No	15	No	No	No	Yes	No
8	32 Y M	Vehicle drove off bridge into roadside ditch	> 5 minutes	Yes, unknown duration	Yes, 94.0 F	3	No	4 PRBCs	Yes	Yes	Yes, NE, norepinephrine and dopamine

TABLE 2: SEVERITY OF ILLNESS AND CONTINUED CARE

Pt	Apache II Score	MODS	ISS Score	Chest Radiograph	ARDS PaO2/FiO2 Nadir	Vent Days	Rescue Modes	Respiratory Culture Results	Antibiotics	Outcome and Morbidity
1	25	7	24	Diffuse bilateral patchy infiltrates	Yes, 65	8	APRV, HFPV	Protocus mirabilis, Pseudomonas aeruginosa, Spingomonas paucimobilis, E coli, Klebsiella pneumoniae	meropenem, amikacin, vancomycin -> Zosyn, tobramycin	Survived, bronchiectasis
2	14	9	16	Left: near opacification, Right: perihilar infiltrate	Yes, 111	7	APRV, HFPV	None	Zosyn -> meropenem and amikacin	Survived, vocal cord dysfunction
3	15	9	16	Bilateral perihilar infiltrates	Yes, 79	18	APRV	E coli, Aspergillus species	Zosyn -> meropenem, vancomycin, and metronidazole, later voriconazole	Survived, hypoxic encephalopathy
4	27	10	50	Diffuse bilateral patchy infiltrates	Yes, 82	3	APRV	E coli, Pseudomonas aeruginosa, and Klebsiella pneumoniae (E coli bacteremia)	tigecycline-> Timentin, vancomycin	Died
5	31	8	50	Bilateral airspace disease	Yes, 102	10	APRV	Haemophilus influenzae, Achromobacter xylosoxidans, Alcaligenes denitrificans, Pseudomonas and Vibrio fluvialis	imipenem, amikacin, ciprofloxacin -> Zosyn and gentamicin	Died
6	2	NG	9	Diffuse infiltrates	No, 335	<1	None	None	clindamycin, cefuroxime -> aztreonam and levofloxacin	Survived
7	26	5	36	Left: severe consolidation, Right: patchy infiltrates	Yes, 50	17	APRV, HFOV, ECMO	Enterobacter aerogenes, Pseudomonas aeruginosa	Unasyn -> meropenem, levofloxacin, vancomycin	Survived, restrictive lung disease
8	35	12	50	Bilateral right > left infiltrates	Yes, 52	2	None	None	None	Died (on LRMC arrival)

RESULTS PART 1: DEMOGRAPHICS/EARLY MOVEMENT

For the study period, eight admissions to LRMC resulted from drowning. All eight were young men (mean age 25.8 years) without pre-existent co-morbid diseases. Only one patient was an active smoker. Three events were associated with improvised explosive devices (IED). The five remaining submersion events were due to temporary loss of vehicle control with no reported history of, or positive urine/blood testing for, alcohol or illicit substance use. When reported, the submersion time spanned from < 1 to 45 minutes in length. Submersion time was an estimate of the actual time the individual was underwater. Roadside ditches, canals, or retention ponds were the predominant water sources with all exposures anecdotally reported to contain sewage of uncertain origin. Water salinity and sewage content was not quantified.

Four subjects were initially comatose (pt# 4, 5, 6 and 8); one of which was also cyanotic (pt #8). Two of the low GCS Score cases (pt# 4 and 5) demonstrated fixed and dilated pupils in combination with a diffuse flaccid paralysis. Overall GCS Score averaged of 10.4, but this belies the association of all three eventual deaths with an initial GCS Score 3. All survivors demonstrated a GCS Score ≥14 and were spontaneously breathing except for one subject who required < 1 minute of cardiopulmonary resuscitation.

On scene cardiopulmonary resuscitation (CPR) was delivered by emergency medical service-equivalent personnel (e.g. medics) for up to 20 minutes. Three patients who received CPR eventually died with the one survivor requiring CPR for < 1 minute before awakening. Indications for tracheal intubation included apnea (in the three victims with a GCS Score 3) or cardiopulmonary instability (4 of 5 remaining patients). Two of three non-survivors had documented hypothermia while the remaining patients were initially normothermic.

RESULTS PART 2: SEVERITY OF INJURY

Seven patients met criteria for acute respiratory distress syndrome (ARDS) within 12 hours of the time of injury. One patient, after a 4 hour period of reportedly unlabored spontaneous respiration, required emergent intubation for the sudden onset of red frothy sputum with acute hypoxemia (pt #6).

Six patients manifested vasopressor-dependent shock by the time they arrived at a fixed medical facility within 12 hours from the event. Three patients required more than one agent to support perfusion. However, all vasopressor agents were discontinued within 24 hours of initiation. Only one patient received a large volume crystalloid fluid resuscitation (pt #8, >11 liters). Coagulopathy was present in five patients and acidosis was present in six. Three of five coagulopathic patients received FFP. One patient was given four units of packed red blood cells for unclear indications. Other than sinus tachycardia, no clinically significant dysrhythmias were observed.

Injury severity scores ranged from 9 to 50 (mean 31.4). The three non-survivors (pt # 4, 5, and 8) all scored as a 50 due to the severity of the central nervous system insult gauged by computed tomography imaging combined with physical examination.

RESULTS PART 3: ARRIVAL TO LRMC/OUTCOME

All drowning events occurred in the Iraqi theater of combat operations. After downrange care, each patient then flew ~6.5 hours from Iraq to Germany. On arrival, APACHE II scores ranged from 2 to 35 (mean 21.9) with Multiple Organ Dysfunction Scores of 5 to 12 (mean 8.5). One patient (pt #8) arrested within minutes after arrival at LRMC. The cause of death was attributed to recalcitrant hypoxia from ARDS. One patient was extubated within 4 hours of arrival (pt #6). Total length of mechanical ventilation for the remaining six patients ranged from 2 to 18 days (mean 9.2 days). All six patients were placed on varying forms of pressure-limited mechanical ventilation to include high frequency oscillatory (HFOV) or percussive (HFPV) ventilation and airway pressure release ventilation (APRV) to sustain clinically acceptable arterial oxygenation. One patient eventually required extracorporeal membrane oxygenation support after failing a trial of HFOV with prone positioning. All but one of the survivors was eventually extubated at LRMC.

MICROBIOLOGY, ANTIBIOTIC USE AND SECONDARY INFECTIONS

Microbiology data from respiratory samples obtained at LRMC was available for 7 patients. Five patients had positive cultures with 13 different bacterial isolates. Water-associated Gram-negative rods predominated with *Pseudomonas* species, *Klebsiella* species, and *E coli* seen most commonly. Four of 5 patients grew multiple organisms, 3 of whom had 3 or more organisms. Two grew *Aspergillus* species while one grew *Candida glabrata*. Only one Gram-positive organism, *S. aureus*, was cultured. One patient was bacteremic.

In theater, seven patients were empirically started on combination beta-lactam w/ beta-lactamase inhibitors, tigecycline, or clindamycin with an added aminoglycoside in one patient. An analogous antibiotic regimen was continued at LRMC frequently with the addition of vancomycin. An antifungal was added when cultures yielded a potential fungal pathogen in the setting of clinical pneumonia or sepsis. The use of empiric antibiotics for pneumonia associated with drowning is generally discouraged with the exception in some reviews when dealing with heavy aspiration of contaminated water. In our patients, the use of antibiotics was typically substantiated for concerns regarding persistent high grade fever (102-103.5°), progressive infiltrates on chest radiography, and/or concurrent sepsis. Two patients developed ventilator associated-pneumonia (VAP). VAP was defined as pneumonia occurring more than 48 hours after the drowning event with a microbiological isolate that differed from isolates obtained on LRMC admission. However, definitive differentiation between VAP and aspiration pneumonia was difficult.

CONCLUSIONS

The initial GCS Score and the need for CPR appeared to be highly predictive of eventual mortality, but this conclusion is limited by the few observations included in the series. Drowning in the context of a combat environment was associated with ARDS and circulatory shock more frequently and of more severe nature than noted in prior civilian studies. Reassuringly, the severity of ARDS and shock did not appear to consistently predict eventual outcome. Larger adult case series are required to develop a better understanding of the course and outcome of drowning in combat.



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