Experience With Prehospital Damage Control Capability in Modern Conflict

Results From Surgical Resuscitation Team Use

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ABSTRACT

Background: Early resuscitation and damage control surgery (DCS) are critical components of modern combat casualty care. Early and effective DCS capabilities can be delivered in a variety of settings through the use of a mobile surgical resuscitation team (SRT). **Methods:** Twelve years of after-action reports from SRTs were reviewed. Demographics, interventions, and outcomes were analyzed. **Results:** Data from 190 casualties (185 human, five canine) were reviewed. Among human casualties, 12 had no signs of life at intercept and did not survive. Of the remaining 173 human casualties, 96.0% were male and 90.8% sustained penetrating injuries. Interventions by the SRT included intravascular access (50.9%) and advanced airway establishment (29.5%). Resuscitation included whole blood (3.5%), packed red blood cells (20.8%), and thawed plasma (11.0%). Surgery was provided for 63 of the 173 human casualties (36.4%), including damage control laparotomy (23.8%) and arterial injury shunting or repair (19.0%). SRTs were effectively used to augment an existing medical treatment facility (70.5%), to facilitate casualty transport (13.3%), as an independent surgical entity at a forward ground structure (9.2%), and in mobile response directly to the point of injury (6.9%). Overall survival was 97.1%. **Conclusion:** An SRT provides a unique DCS capability that can be successfully used in a variety of flexible roles.

KEYWORDS: *resuscitation; damage control surgery; combat casualty care; mobile surgical resuscitation team*

Introduction

Recent experiences in modern regions of conflict have demonstrated a continued need to develop and effectively use strategies to mitigate the risk for hemorrhagic death on the battlefield.[1–10] Contemporary experience, however, suggests that medical support in present and future theatres of military conflict may be faced with significant challenges to meet this requirement.[11–13]

We describe the experience of a mobile surgical resuscitation team (SRT) designed specifically for its flexibility and ability to rapidly respond to support emerging contingencies of the modern battlefield. This unit effectively bridges the gap between tactical combat casualty care (TCCC) and further damage control or definitive surgical care in various settings. The SRT is capable of expediently and effectively facilitating delivery of both resuscitation and damage control surgery (DCS) within 1 hour from point of injury (POI) in austere environments.

Methods

A comprehensive review was conducted of deidentified data collected from 12 years of after action reports (AARs) from casualty episodes of care by a multidisciplinary surgical team. All AAR reviews were performed by an experienced team-certified physician assistant and a board-certified trauma/vascular surgeon.

Data abstracted from AARs included how the team was used, patient demographics, mechanism of injury, and interventions before team intercept. Interventions conducted by the multidisciplinary team and the outcomes were also recorded and analyzed.

Team and Capabilities

The multidisciplinary SRT consists of an appropriately trained surgeon, an emergency medicine physician, a certified registered nurse anesthetist, and a physician assistant. Members of this team undergo specialized recruitment, assessment, and selection, with new members participating in an initial skills pipeline including team-centric, advanced, austere and far-forward medical and surgical training. Every team member performs advanced training continually to maintain readiness and proficiency.

The primary role of the SRT is to provide damage control resuscitation and surgery as close to the POI as tactically feasible and to facilitate subsequent transfer to definitive care. This mission requires flexibility of team response to contingencies ranging from POI casualty collection to critical care transport of casualties. Team composition and equipment are designed to facilitate bridging the treatment gap between unit medic TCCC interventions and an established medical treatment facility (MTF) while maintaining the ability to effectively augment the entire care spectrum based on mission and casualty needs.

SRT Uses

Over the study period, the SRTs were used in various roles and settings (Figure 1). They were predominantly used in strategic

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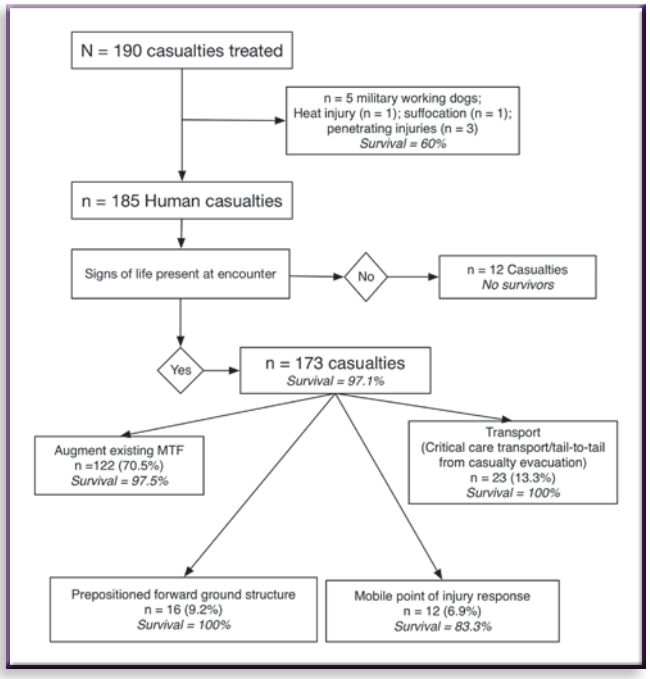
Figure 1 *Casualty flow diagram for 12-year SRT experience.*



augmentation of an existing MTF (*n* = 122; 70.5%) during anticipated potential mass casualty events. In this context, the mean number of casualties treated per specific event was 4.4 (range, 1–10). Other roles for which the SRT was used included the transfer of casualties in a tail-to-tail transfer from a casualty evacuation airframe (three episodes; 1.7%) to facilitate critical care transport from an established MTF to the next higher echelon of care (*n* = 20; 11.6%) as an independently deployed surgical capability in a ground structure/hardstand (16 episodes; 9.2%) or in mobile response to a POI casualty (*n* = 12; 6.9%).

Case Series and Results

From the reviewed AARs, data on 190 total casualties (*n* = 185 humans; *n* = 5 working military canines) treated were abstracted.

Among the five canines, injuries included heat injury (*n* = 1), suffocation (*n* = 1), and penetrating injuries due to gunshot or explosive fragmentation (*n* = 3). One military working dog was returned to duty after care. Two canines were evacuated to a higher echelon of care. Two were without signs of life at intercept, were unable to be resuscitated, and died.

Among the 185 human casualties, 12 presented to the SRT without signs of life (no pulse, Glasgow Coma Scale [GCS] score of 3, no respirations or detected cardiac activity). All had sustained penetrating injuries due to gunshot or fragmentation. Specific time of injury for these casualties was discernable in six instances, with a mean time of delivery to the mobile surgical capability of 61 minutes. Ten of the casualties presenting without discernable signs of life were encountered in the context of MTF augmentation, with seven encounters occurring during casualty events involving four or more patients. The other two were encountered during response directly to the POI (50 and 102 minutes from injury to intercept, respectively). The SRT response to these casualties included cardiopulmonary resuscitative efforts, including four endotracheal intubations, one cricothyrotomy, and four tube thoracostomies. Resuscitative thoracotomy was attempted in six casualties. Despite these exhaustive efforts, none of the 12 patients who presented without signs of life survived their injuries.

The remaining 173 human casualties (Figure 1) were predominantly male (*n* = 166; 96.0%) and most had sustained penetrating injuries (*n* = 157; 90.8%) from gunshot or fragmentation mechanisms. TCCC interventions provided before surgical team intercept included tourniquet placement (36 of 173; 20.8%), peripheral intravenous access (24 of 173;13.9%), Intraosseous access (one of 173; 0.6%), airway establishment (seven of 173; 4.0%), chest seal or thoracostomy decompression (13 of 173; 7.5%), extremity splinting (three of 173; 1.7%), and a variety of wound packings and dressings. Blood products had been administered before intercept by the SRT in 4.6% of the patients (eight of 173): whole blood (*n* = 3), packed red blood cells (PRBCs; *n* = 3), thawed plasma (*n* = 1), or freeze dried plasma (*n* = 1). Documented medication administration before intercept included fentanyl (21 of 173: 12.1%), versed (four of 173; 2.3%), ketamine (six of 173; 3.5%), tranexamic acid (five of 173; 2.9%), and other resuscitative adjuncts, including antibiotics and antiemetics (13 of 173; 7.5%).

Time from injury to SRT intercept was recorded in 62 of the 173 patients, with 33 (19.1%) evaluated and treated within 1 hour after injury. Seventeen of these patients (9.8%) were described as unstable, with variable documentation of specific vitals elements in reviewed AARs. From available specific data, mean heart rate was noted at 102/minute (46 casualties), mean systolic blood pressure was 108mmHg (32 casualties), mean oxygen saturation was 95% (29 casualties), mean GCS score was 14.6 (66 casualties), and mean temperature was 36.1°C (97°F; seven casualties).

Initial interventions delivered by the SRT are listed in Table 1. These included the establishment of intravenous access (50.9%), airway placement (29.5%), and thoracostomy tube (9.2%). Resuscitation was undertaken with whole blood (3.5%; mean, 3.3 units), PRBCs (20.8%; mean, 5.2 units), and thawed plasma (11.0%; mean, 5.6 units). Medications administered (Table 1) included fentanyl (18.5%), versed (11.0%), ketamine (11.0%), morphine (15.6%), tranexamic acid (2.3%), antibiotics (26.6%), and other drugs (33.5%).

The SRT provided DCS for 63 casualties (36.4%). Various surgical interventions were performed; most common were complex wound debridement/washout (17 of 63 casualties; 27.0%), exploratory or damage control laparotomy (15 of 63; 23.8%), and arterial injury shunting or repair (12 of 63; 19.0%; Table 2).

Of casualties delivered to the next echelon of care by the SRT, 95.4% (*n* = 165) were characterized as stable, and three had ongoing resuscitation in the face of persistent hemodynamic instability. Five patients died during SRT care. Three deaths occurred during augmentation of an existing Role 2 military treatment facility (MTF) and two occurred during transport from the POI to an established MTF. Overall survival among patients intercepted by the SRT while any signs of life were present was 97.1%.

Among the 62 patients for whom time from injury to intercept was adequately documented, there was no statistically

Table 1 *Documented Team Resuscitation Interventions (*N = *173 human casualties)*

Intervention	No. (%)[a]
Any intravenous access	88 (50.9)
Central venous access	15 (8.7)
Intraosseous access	2 (1.2)
Any airway intervention	51 (29.5)
Endotracheal intubation	50 (28.9)
Cricothyrotomy	1 (0.6)
Thoracostomy tube	16 (9.2)
Splinting	12 (6.9)
Whole-blood administration	6 (3.5)
Mean whole blood units, No.	3.3
Packed red blood cell administration	36 (20.8)
Mean packed red blood cell units, No.	5.2
Thawed plasma administration	19 (11.0)
Mean thawed plasma units, No.	5.6
Fluid or blood warming device use	10 (5.8)
Drug administration	
Fentanyl	32 (18.5)
Versed	19 (11.0)
Ketamine	19 (11.0)
Morphine	27 (15.6)
Tranexamic acid	4 (2.3)
Antibiotics	46 (26.6)
Other medication (i.e., paralytics, antiemetics, or not otherwise specified)	58 (33.5)
Patient warming interventions (external or internal)	28 (16.2)

[a]Blood product use reported in No. of units.

Table 2 *Documented Team Surgical Interventions (*N = *173 human casualties;* n = *63 damage control surgeries)*

Intervention	No./Total (%)
Any surgical intervention	63/173 (36.4)
Cranial decompression	1/63 (1.6)
Extremity amputation	1/63 (1.6)
Thoracotomy	3/63 (4.8)
Pericardial window	2/63 (3.2)
Exploratory or damage control laparotomy	15/63 (23.8)
Splenectomy	1/63 (1.6)
Renal repair or resection	1/63 (1.6)
Bladder repair or percutaneous drainage	1/63 (1.6)
Pancreatic drainage, resection, or repair	1/63 (1.6)
Hepatic repair or resection	1/63 (1.6)
Intestinal resection or repair	6/63 (9.5)
Arterial shunting or repair	12/63 (19.0)
External fixator extremity	7/173 (4.0)
Burn debridement	1/63 (1.6)
Extremity fasciotomy	6/63 (9.5)
Neck exploration	3/63 (4.8)
Complex wound debridement/washout	17/63 (27.0)

significant difference in survival between patients intercepted in less than 1 hour (31 of 33; 93.9%) or more than 1 hour from injury (28 of 29; 96.6%; 1.81 [95% CI, 0.16–21.02]; P = .632). Patients intercepted in less than 1 hour ultimately did require fewer total mean units of PRBCs (3.9 versus 5.9 units; 1.83 [95% CI, –1.79 to 5.83]; P = .283), and mean units of thawed plasma (1.5 versus 5.3 units; 1.82 [95% CI, –0.62 to 8.29]; P = .08), but these differences were not statistically significant.

Discussion

Recent experience in modern armed conflict has demonstrated a continued need to optimize effective strategies to mitigate the risk for death due to bleeding on the battlefield.[1–4] In particular, an emerging appreciation of noncompressible torso hemorrhage (NCTH) as a cause of potentially preventable death[1] has driven critical examination of combat casualty care practices. Proposed strategies to combat NCTH on the battlefield have included optimization of prehospital resuscitation with blood products[5–7] and the ability to control NCTH in the earliest phases after by expedient surgical intervention or other means.[1,8]

A 2009 Secretary of Defense mandate established a desired golden hour standard for the delivery of combat casualties to an environment capable of DCS intervention. A subsequent review reported by Kotwal and colleagues[9,10] retrospectively examined the effects of this time-sensitive intervention on subsequent combat casualty outcomes from military action in Afghanistan. The investigators examined data from 21,089 military casualties injured from September 2001 to March 2014. They noted that, after adjustment for injury severity, casualties who received a transfusion or were transferred to DCS capability within an hour of injury were less likely to die of combat-sustained wounds. The investigators estimated that the practice of delivering casualties to a DCS-capable environment in this time frame resulted in 359 lives saved over the study period.[9,10]

However, most of the data from the Kotwal et al. study were collected during a period of robust military activity in a mature combat theatre. As such, there existed a relatively developed casualty evacuation capability and a medical "footprint" designed to optimally position Role 2 and Role 3 MTFs to achieve delivery of a casualty to resuscitative and DCS capabilities. More contemporary experience suggests that future military medical care may be required in less mature environments, where distances to an established Role 2 DCS capability may prove a greater challenge.

Additionally, the future construct of military resuscitation and DCS capabilities may be evolving.[4] Traditional forward surgical elements are expensive to field,[11] depend largely on the establishment of a robust supply chain, and are relatively large. Additionally, the traditional forward surgical teams of various military services are not capable of movement, due to larger footprints and bulky requirements, within the very short times potentially required to effectively respond to distant emergent contingencies.[4] Although more mobile resuscitative prehospital capabilities, such as the UK Medical Response Team, were developed during recent conflicts,[14,15] these units offer only nonsurgical resuscitative capabilities and require the support of a larger medical evacuation footprint. These specific units are not designed to be used flexibly to support contingency situations in various environments outside their tightly defined roles.

We describe the experience of an SRT designed specifically for rapid and flexible response to emerging contingencies in various roles. This unit can effectively bridge the gap between TCCC and definitive surgical care in various settings.

A unique selection and training regimen is required for the development of this capability. Our data demonstrate the wide range of skills implemented effectively by a SRT. Team members must able to provide appropriate TCCC interventions, the benefit of which has been demonstrated in several large reports.[3,16–18] In addition, the multidisciplinary SRT maintains currency in the effective use of a wide variety of resuscitative adjuncts, including the ability to secure an advanced airway, establish rapid venous access (by central venous cannulation, if necessary), transfusion, and resuscitative endovascular occlusion of the aorta.[8] Finally, the SRT can transition rapidly to providing surgical intervention in the pre-Role 2 setting for emergent indications, including cranial decompression, control of NCTH, and shunting or repair of arterial injuries to restore distal perfusion.

Our experience demonstrates that an SRT can be effective in a variety of roles—from augmentation of a Role 2 facility during mass casualty events, to independent action, or even to facilitating critical care transport of severely injured casualties. The small size and flexible capabilities of the SRT may provide a useful life-saving capability in response to contingency operations that require speed and mobility of medical support execution. In this context, the SRT can rapidly and effectively support both resuscitation and DCS within 1 hour of POI in austere military environments, with the goal of delivering optimal casualty care as close as feasible to the POI.

Our report does have important limitations that must be acknowledged, including those inherent to retrospective review. The AARs from which these data were abstracted do not constitute a formal casualty care database. Although these documents accurately recorded team roles and interventions, the granularity of data available was not consistent with an a priori database designed explicitly for the purpose of comprehensive data collection. Some variables, including specific vital signs at delivery to the next echelon of care, were not consistently available for review. As such, caution should be taken when attempting to extrapolate the results outlined in our report with those in other care settings or capability configurations.

Conclusion

A mobile SRT provides a unique resuscitative and DCS capability that can be effective in various roles. Additional research is required to determine optimal SRT use in conflicts.

Disclaimer

The viewpoints expressed in this manuscript are those of the authors and do not represent official positions of the US Air Force, the US Army, or the Department of Defense.

Disclosure

The authors have nothing to disclose.

Author Contributions

All authors participated in the composition of this manuscript through data collection (J.D., D.M.), analysis (J.D., D.M., C.F., I.H., S.T.), manuscript creation (J.D., D.M., C.F., I.H., S.T., P.B.), and editorial revision (J.D., B.M., P.B.). All authors approved the final revision of the manuscript.

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