Life and Limb In-Flight Surgical Intervention

Fifteen Years of Experience by Joint Medical Augmentation Unit Surgical Resuscitation Teams

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ABSTRACT

Background: Expedient resuscitation and emergent damage control interventions remain critical tools of modern combat casualty care. Although fortunately rare, the requirement for life and limb salvaging surgical intervention prior to arrival at traditional deployed medical treatment facilities may be required for the care of select casualties. The optimal employment of a surgical resuscitation team (SRT) may afford life and limb salvage in these unique situations. **Methods:** Fifteen years of after-action reports (AARs) from a highly specialized SRTs were reviewed. Patient demographics, specific details of encounter, team role, advanced emergent life and limb interventions, and outcomes were analyzed. **Results:** Data from 317 casualties (312 human, five canines) over 15 years were reviewed. Among human casualties, 20 had no signs of life at intercept, with only one (5%) surviving to reach a Military Treatment Facility (MTF). Among the 292 casualties with signs of life at intercept, SRTs were employed in a variety of roles, including MTF augmentation (48.6%), as a transport capability from other aeromedical platforms, critical care transport (CCT) between MTFs (27.7%), or as an in-flight damage control capability directly to point of injury (POI) (18.2%). In the context of these roles, the SRT performed in-flight life and limb preserving surgery for nine patients. Procedures performed included resuscitative thoracotomy (7/9; 77.8%), damage control laparotomy (1/9; 11.1%) and extremity fasciotomy for acute lower extremity compartment syndrome (1/11; 11%). Survival following in-flight resuscitative thoracotomy was 33% (1/3) when signs of life (SOL) were absent at intercept and 75% (3/4) among patients who lost SOL during transport. **Conclusion:** In-flight surgery by a specifically trained and experienced SRT can salvage life and limb for casualties of major combat injury. Additional research is required to determine optimal SRT utilization in present and future conflicts.

KEYWORDS: *in-flight; surgical rescusitation team; casualty; limb salvage; military treatment facility; trauma*

Introduction

Recent experiences in modern regions of conflict have demonstrated a continued need to develop and effectively employ strategies to mitigate the risk of hemorrhagic death on the battlefield.[1–5] These include early resuscitation with blood products and the ability to control noncompressible torso hemorrhage (NCTH) early after injury by expedient surgical intervention or other means.[1,5–9] A Secretary of Defense mandate issued in 2009 established a desired "golden hour" standard for the delivery of combat casualties to an environment capable of damage control surgery (DCS).[10,11] However, contemporary experience suggests that medical support for military conflict may face significant challenges to meet this mandate.[12,13] Current evidence also suggests that the "golden hour" is not an accurate timeframe upon which to base improvement in survival after major traumatic injury. Much shorter time intervals are associated with more significant improvements in outcome among those requiring surgery.[14]

Existing forward surgical unit configurations, while a mainstay in recent conflicts, may not be practically designed to support a full range of rapid medical and surgical response contingencies across the range of medical operations (ROMO) and across significant geographical distances. While more mobile resuscitative prehospital capabilities were developed during recent conflicts, such as the UK Medical Response Team (MERT), these units possess inherent limitations and do not afford DCS capabilities.[15,16]

We describe the experience of a surgical resuscitation team (SRT) specifically designed to respond rapidly in support of emerging contingencies in the modern battlefield. This unit effectively bridges the gaps between Tactical Combat Casualty Care (TCCC), further damage control, and definitive surgical care in a variety of settings and platforms. More specifically, the SRT is uniquely capable of expediently and effectively providing delivery of both resuscitation and DCS in austere environments on multiple platforms.

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Methods

After institutional review board approval, comprehensive review of AARs from casualty episodes of care by a multidisciplinary SRT was conducted over a 15-year time frame (September 2004–May 2019). All AARs were reviewed by a board-certified trauma/vascular surgeon and an experienced team-certified physician assistant (PA). Data were abstracted as part of ongoing quality improvement efforts for the Joint Medical Augmentation Unit designed to inform and improve training and readiness efforts.

Data abstracted from AARs included team utilization, patient demographics, mechanism of injury, and interventions prior to team intercept. Interventions conducted by the SRT and outcomes were also recorded and analyzed. As a subset of the examination, patients undergoing attempts at in-flight life and limb preserving surgical intervention were abstracted for further review. All data abstracted and the composition for reporting were reviewed and approved by appropriate Joint Special Operations Command Operational Security Review and Public Affairs Officers prior to publication.

Team Construct and Capabilities

The multidisciplinary SRT described consists of an appropriately trained surgeon, emergency medicine physician, a certified registered nurse anesthetist (CRNA), a PA, a medical team seargant, and a communications expert (RTO). Members of this team undergo specialized recruitment, assessment, and selection. New members participate in an initial skills pipeline, including team-centric advanced austere and far-forward medical/surgical training. Every team member performs advanced training on a continual basis to maintain readiness and proficiency.

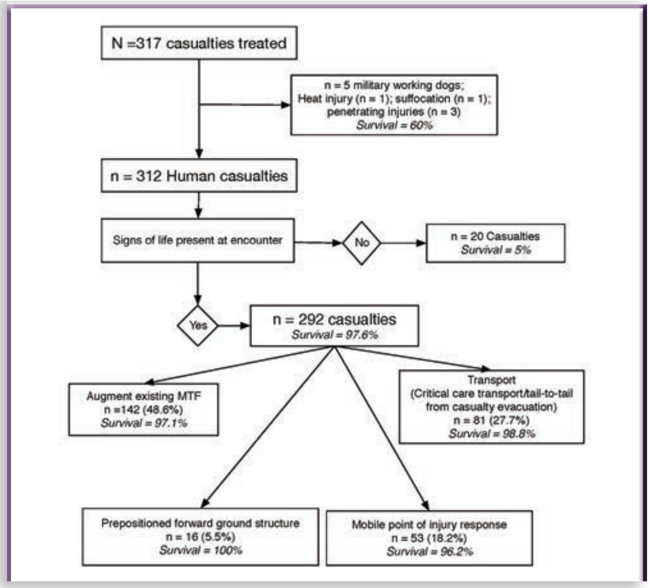
The primary role of the SRT is to provide damage control resuscitation and surgery in the austere, prehospital setting, as close to point of injury (POI) as tactically feasible, and to facilitate subsequent transfer to definitive care. This mission requires flexibility of team response to contingencies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

Results

SRT Employment

Over the review period, SRTs were used in a variety of roles and settings, treating 312 human casualties and five working canines (Figure 1). Among the 292 casualties with signs of life present at initial encounter, the SRT was used predominantly in strategic augmentation of an existing MTF (142/292; 48.6%) during anticipated potential mass casualty events. Other roles for the SRT included transfer of casualties to a higher echelon of care via either tail-to-tail aeromedical transfer from another aeromedical evacuation platform or in prescribed CCT roles from an existing MTF to a higher echelon of care (81/292, 27.7%). In a smaller number of instances, SRTs were used as an independently deployed expedient surgical capability in a ground structure or hardstand (16/292, 5.5%) or in mobile response to point of casualty injury (53/292, 18.2%).

FIGURE 1 *Casualty flow diagram of a 15-year surgical resuscitation team (SRT) experience.*



Overall After-Action Casualty Review – Management and Outcomes

Canine Casualties

Among the five working 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 following care. Two canines were evacuated to a higher echelon of care. Two were without signs of life at intercept and were unable to be resuscitated and expired.

Human Casualties

Casualties were predominantly male (302/312; 96.8%) and had sustained penetrating injuries from gunshot or fragmentation mechanisms (261/312; 83.7%). TCCC interventions provided prior to surgical team intercept included tourniquet placement (65/312; 20.8%), peripheral intravenous (IV) access (72/312; 23.1%), intraosseous (IO) access (13/312; 4.5%), airway establishment (24/312; 7.7%), and chest seal or thoracostomy decompression (26/312; 8.3%). Blood products had been administered prior to SRT intercept for only 13 patients (13/312; 4.2%) with either whole blood (6/312; 1.9%), packed red blood cells (PRBCs) (8/312; 2.6%), thawed plasma (3/312; 1.0%), or freeze-dried plasma (1/312; 0.3%).

Initial interventions delivered by the SRT included the establishment of IV access (120; 38.5%), airway placement (67; 21.5%) and thoracostomy tube (28; 9.0%) (Table 1). Resuscitation was undertaken with whole blood (6.4%, mean = 3.3 units), PRBCs (15.4%, mean = 10.0 units), and thawed plasma (7.7%, mean = 8.0 units). Medications administered included fentanyl (18.9%), midazolam (Versed) (10.0%), ketamine (13.1%), morphine (9.3%), and tranexamic acid (3.8%) (Table 1).

The SRT provided damage control surgical intervention for 87 casualties (87/312; 27.9%). A variety of surgical interventions were performed, to include complex wounds debridement/washout (22/87; 25.2%), exploratory or damage control

TABLE 1 *Documented SRT Resuscitation Interventions During Entire Period of Care Interaction – All Environments (September 2004–May 2019)*

	N = 312 casualties
Resuscitation Interventions	
Any intravenous access	120 (38.5%)
Central venous access	20 (6.4%)
Intraosseous access	11 (13.5%)
Any airway intervention	67 (21.5%)
Endotracheal intubation	63 (20.2%)
Crichothyrotomy	4 (1.3%)
Thoracostomy tube	28 (9.0%)
Whole blood administration	20 (6.4%)
Mean whole blood units used	3.3 units
Packed red blood cell administration	48 (15.4%)
Mean packed red blood cell units used	10.0 units
Thawed plasma administration	24 (7.7%)
Mean thawed plasma units used	8.0 units
Drug Administration	
Fentanyl	59 (18.9%)
Versed	32 (10.03%)
Ketamine	41 (13.1%)
Morphine	29 (9.3%)
Tranexamic acid	12 (3.8%)
Other medication (antibiotics, paryalytics, antiemetics, or NOS)	113 (36.2%)

laparotomy (18/87; 20.7%), thoracotomy (13/87; 14.9%), and arterial injury shunting or repair (12/87; 13.8%) (Table 2).

Of the 312 human casualties, 20 presented to the SRT without signs of life (SOLs; no pulse, Glasgow Coma Scale score of 3, no respirations or detected cardiac activity). All had sustained penetrating injuries due to gunshot or fragmentation mechanisms. Only one survivor was observed from this group, despite maximal attempts at salvage. The remainder of the casualties treated demonstrated SOLs at intercept and resulted in an overall survival of 97.6% (285/292) (Figure 1). Seven patients expired during SRT care. Mortalities occurred during augmentation of an existing Role 2 MTF (4/7; 57.1%) or during transport from location of injury to an established MTF (3/7; 42.9%).

Among the entire cohort of 312 human casualties, time from injury to intercept was adequately documented for 174, with the median time to intercept being 60 minutes (range of 5 minutes to 24 hours; interquartile range of 80 minutes). Mortality among those intercepted within an hour of injury was 10.1% (8/79); if less than 30 minutes, it was 12.8% (5/39).

In-Flight Life and Limb Surgery Results

In-flight surgery was performed on both rotary wing and fixed wing evacuation platforms by the SRT for a total of nine patients, in roles including POI response (6/9; 66.7%), tail-to-tail transfer from other aeromedical evacuation platform (1/9; 11.1%) and CCT between MTF echelons (2/9; 22.2%).

Procedures performed included resuscitative thoracotomy (7/9; 77.8%), damage control laparotomy with control of pelvic hemorrhage (1/9; 11.1%), and extremity fasciotomy for acute lower extremity compartment syndrome (1/9; 11%)

TABLE 2 *Documented Team Surgical Interventions Performed in All Environments of Care (September 2004–May 2019)*

	N = 312 casualties
Any surgical intervention	87 (27.9%)
Cranial decompression	1/87 (1.1%)
Extremity amputation	1/87 (1.1%)
Thoracotomy	13/87 (14.9%)
Pericardial window	1/87 (1.1%)
Exploratory/damage control laparotomy	18/87 (20.7%)
Splenectomy	1/87 (1.1%)
Intestinal resection or repair	7/87 (8.0%)
Arterial shunting, ligation, or repair	12/87 (13.8%)
External fixator extremity	7/87 (8.0%)
Burn debridement	1/87 (1.1%)
Extremity fasciotomy	13/87 (15.0%)
Neck exploration	4/87 (4.6%)
Complex wound debridement/washout	22/87 (25.2%)

(Table 3). Resuscitative thoracotomy was attempted for three patients without SOL at initial encounter, with one survivor (1/3; 33.0%) Resuscitative thoracotomy was also performed for four patients who lost vital signs while in SRT care, with three surviving after achieving return of spontaneous circulation with aortic cross-clamping and blood product resuscitation while en route to an established MTF. Among these three patients, all survived to achieve discharge in stable condition from a Role 4 or 5 MTF. In total, the survival for resuscitative thoracotomy with SOL present at initial encounter was 75% (3/4). Additional in-flight surgical procedures all resulted in life and limb salvage, including an exploratory laparotomy with packing for control of exsanguinating pelvic hemorrhage and an in-flight fasciotomy for emergent compartment syndrome of the lower extremity.

TABLE 3 *Documented SRT Life and Limb Surgical Interventions During In-Flight Care Only (September 2004–May 2019)*

	N = 9 casualties
Resuscitative thoracotomy	7 (77.8%)
Exploratory/damage control laparotomy	1 (11.1%)
Extremity fasciotomy	1 (11.1%)

Resuscitative thoracotomies were conducted by six different SRT surgeons. Three were fellowship-trained trauma surgeons stationed at high volume trauma centers, with prior experience as deployed trauma chiefs at Role 2 or 3 facilities and multiple subsequent deployments with SRTs (ranging from one to four). The remaining three surgeons were MTF based at their home duty stations, but had a minimum of four deployments prior to the described episodes. All interventions were conducted as part of a team approach to care. Interventions were surrounded by experienced, multidisciplinary teams who were intensively trained on a recurring basis in the unique capabilities inherent to the SRT mission set.

Discussion

A review of modern military conflict publications has demonstrated a continued need to optimize effective strategies to mitigate the risk of early death due to hemorrhage prior to delivery to an MTF.[1–5] In particular, an emerging appreciation of NCTH as a cause of potentially preventable death has fueled critical examination of combat casualty care practices.[1]

Optimal strategies to combat NCTH on the battlefield have included pre-hospital resuscitation with blood products and the ability to control NCTH in the earliest phases by expedient surgical intervention or other means.[1,5–9]

A Secretary of Defense directive issued in 2009 established a "golden hour" as the time standard for the delivery of combat casualties to an environment capable of DCS intervention. A subsequent review reported by Kotwal and colleagues retrospectively examined the effects of this time-sensitive intervention on subsequent combat casualty outcomes from military action in Afghanistan.[10,11] The investigators examined outcomes from 21,089 military casualties occurring from September 2001 to March 2014 and 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 wounds. This group of 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.[10,11]

The data from this important effort by Kotwal and colleagues were, however, largely collected during a period of robust military activity in a mature combat theater. Accordingly, the time period of examination was associated with the availability of a relatively developed casualty evacuation system and a medical "footprint" designed to optimally position DCS capabilities with the establishment of Role 2 and Role 3 MTFs. More contemporary experience suggests that future military medical care may be required in less mature environments, in which distances to an established Role 2 or Role 3 DCS capability may prove more challenging. In addition, there is emerging civilian evidence that the timeframes required to optimize outcomes of those that require surgery after major trauma are much shorter in interval than those prescribed by traditional "golden hour" principles.[12]

Furthermore, the future construct of military resuscitation and DCS capabilities may be evolving.[4] Traditional forward surgical elements depend largely on the establishment of a robust supply chain, and are relatively large in size.[13–15] Additionally, the traditional forward surgical teams of various military services are less mobile, due to larger footprints and ancillary requirements, within the very short timeframes potentially required to effectively respond to distant emergent contingencies.[4] While more mobile resuscitative prehospital capabilities, such as the UK MERT, were developed during recent conflicts, these unique platforms offer primarily nonsurgical resuscitative capabilities and require the optimal placement of DCS capabilities relative to mission locations.[16] These specific units are also not designed to be used in a flexible manner to support contingency situations in various environments outside their tightly defined roles.

Earlier intervention during transport from POI to an MTF warrants consideration but requires an appreciation that rotary wing transport of combat casualties represents a unique environment requiring specialized training and capabilities. In one review of 149 combat platform helicopter transports conducted by Lehmann and colleagues, 30% of casualties transported by this modality had in-flight clinical deterioration and 9% required urgent intervention after delivery to a receiving facility.[17] This work focused on interfacility transfers, with comparatively less having been reported about the occurrence of adverse events during rotary wing transport from the POI itself. For select casualties, the benefit of an experienced team capable of responding to these decompensations is apparent. Improved data are required, however, to optimize selection of the need for DCS following combat injury by this unique capability. The judicious utse of this resource is paramount to success, as it is clear that not every casualty will require the DCS capabilities afforded.

It is also important to note that the successes achieved in our report were achieved only in the setting of effective TCCC care prior to SRT intercept and a robust and mature MTF to receive the casualties after SRT management. In an era of increasingly burdened military medical resources, it would almost certainly prove counterproductive to convert a large number of surgical teams to the kind of in-flight capabilities described. Without appropriate investment of these capabilities in the receiving MTFs, the in-flight capabilities become the proverbial "bridge to nowhere." In this regard, additional study and consideration are required to determine the appropriate balance along the chain of care.

Resuscitative thoracotomy remains a heroic effort of trauma care, reserved for those patients who are not responding to resuscitation with blood products – regardless of the environment in which it is used. The addition of advanced invasive resuscitative interventions in the prehospital setting by well-trained teams is not novel and has been described in a variety of both military and civilian environments.[18–25] In-flight use of damage control surgery, however, represents specific challenges. The performance of DCS interventions on an aircraft require an experienced provider who is well trained to conduct procedures in a chaotic environment characterized by active movement, noise, and lighting challenges. They must be able to intervene with only a limited toolset relative to more robust civilian environments. Despite these challenges, our described results compare favorably to those of mature civilian trauma environments. In the largest reported experience with resuscitative thoracotomy to date, DuBose et al. documented outcomes from 310 procedures conducted at American College of Surgeons Level I trauma centers.[26] They found that injuries resulting from penetrating mechanisms among civilian casualties presenting with SOL resulted in survival in 13.9% (11/79), and only 1.7% (2/118) when SOL were not present on arrival. In our more limited combat environment experience, we observed corresponding survival rates of 75% (3/4) and 33% (1/3), respectively.

We have previously described the SRT as designed specifically for rapid and flexible response to emerging contingencies in various roles.[27] This unit is capable of effectively bridging the gap between TCCC and definitive surgical care in a variety of settings. A unique selection and training regimen is required for the development of this capability. Our data demonstrates the wide range of skills implemented effectively by an SRT team must be capable of providing appropriate TCCC interventions, the benefit of which has been demonstrated in several large reports.[3,28-30] In addition, the multidisciplinary SRT maintains currency in the effective utilization 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.[9] Finally, the SRT can transition rapidly to providing surgical intervention in the pre-Role 2 setting for a variety of emergent indications, including cranial decompression, emergent orthopaedic interventions, control of NCTH, and shunting or repair of arterial injuries to restore distal perfusion.

Our reported experience demonstrates that an SRT can effectively employ a unique capability in a variety of roles – from augmentation of a Role 2 facility during mass casualty events, to independent action, or even in 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 a wide variety of contingency operations that require speed and mobility of medical support. In this context, the SRT is capable of rapidly and effectively supporting both resuscitation and DCS within one hour of POI in the austere military environments, with the goal of delivering optimal casualty care in closest feasible proximity to POI.

Our present 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. It is also important to note the context of conflict in which these results were obtained. In future "near peer" conflict, aeriel denial of active battlespaces may represent a different challenge to the utilization of inflight interventions. As such, caution should be taken when attempting to extrapolate the results outlined in our report with other care settings or capability configurations.

Conclusion

An SRT provides a unique resuscitative and damage control surgery capability that can be effectively employed in a variety of roles, including in-flight DCS delivery, with good outcomes. Additional research is required to determine optimal SRT utilization in present and future conflicts.

Disclaimer

The viewpoints expressed in this manuscript are those of the authors and do not represent official positions of the United States Air Force, the United States Army, or the Department of Defense. All data contained herein has been reviewed and approved by appropriate Joint Special Operations Command Operational Security and Public Affairs processes for publication.

Disclosure

The authors have no financial or other conflicts of interest to disclose.

Author Contributions

All authors contributed to the design, writing, editing, and approval of the manuscript.

References

1. **Eastbridge BJ, Mabry RL, Seguin P, et al.** Death on the battlefield (2001–2011): implications for the future of combat casualty care. *J Trauma Acute Care Surg*. 2012;73(6 suppl 5):S431–S437.
2. **Sauer SW, Robinson JB, Smith MP, et al.** Saving Lives on the Battlefield (Part II) ? One year later A Joint Theater Trauma System and Joint Trauma System review of prehospital trauma care in combined joint operations area?Afghanistan (CJOA-A) final report, 30 May 2014. *J Spec Oper Med*. 2015;15(2):25–41.
3. **Lairet JR, Bebarta VS, Burns CJ, et al.** Pre-hospital interventions performed in a combat zone: a prospective multicenter study of 1,003 combat wounded. *J Trauma Acute Care Surg*. 2012;73(2 suppl 1):S38–S42.
4. **Freel D, Warr BJ.** Surgical and resuscitation capabilities for the "next war" based on lessons learned from "this war." *US Army Med Dep J*. 2016;(2–16):188–191.
5. **Kotwal RS, Mazuchowski EL, Stern CA, et al.** A descriptive study of US Special Operations Command fatalities, 2001–2018. *J Trauma Acute Care Surg*. 2019;87(3):645–657.
6. **Nessen SC, Eastridge BJ, Cronk D, et al.** Fresh whole blood use by forward surgical teams in Afghanistan is associated with improved survival compared to component therapy without platelets. *Transfusion*. 2013;53(suppl 1):107S–113S.
7. **Cap AP, Pidcoke HF, DePasquale M, et al.** Blood far forward: time to get moving! *J Trauma Acute Care Surg*. 2015;78(6 suppl 1):S2–S6.
8. **Hooper TJ, Nadler R, Badloe J, et al.** Implementation and execution of military forward resuscitation programs. *Shock*. 2014; 41(suppl 1):90–97.
9. **Russo RM, Williams TK, Grayson JK, et al.** Extending the golden hour: partial resuscitative endovascular balloon occlusion of the aorta in a highly lethal swine injury model. *J Trauma Acute Care Surg*. 2016;80(3):372–380.
10. **Welch A.** "Golden hour" policy saved hundreds of U.S. troops. *CBS News*. http://www.cbsnews.com/news/golden-hour-policy-decreased-combat-deaths-among-u-s-troops/. Accessed September 10, 2020.
11. **Kotwal RS, Howard JT, Orman JA, et al.** The effect of a Golden Hour Policy on the morbidity and mortality of combat casualties. *JAMA Surg*. 2016;151(1):15–24.
12. **Remmick, KN, Schwab CW, Smith BP, et al.** Defining the optimal time to operating room may salvage early trauma deaths. *J Trauma Acute Care Surg*. 2014;76(5):1251–1258.
13. **Childers R, Parker P.** The cost of deploying a Role 2 medical asset to Afghanistan. *Mil Med*. 2015;180(11):1132–1134.
14. **Malgras B, Barbier O, Petit L, et al.** Surgical challenges in a new theater of modern warfare: the French Role 2 in Gao, Mali. *Injury*. 2016;47(1):99–103.
15. **Malgras B, Barbier O, Pasquier P, et al.** Initial deployment of the 14th Parachutist Forward Surgical Team at the beginning of the operation Sangaris in Central African Republic. *Mil Med*. 2015; 180(5):533–538.
16. **Apodoca AN, Morrison JJ, Spott MA, et al.** Improvements in the hemodynamic stability of combat casualties during en route care. *Shock*. 2013;40(1):5–10.
17. **Lehmann R, Oh J, Killius S, et al.** Interhospital transport by rotary wing aircraft in a combat environment: risks, adverse events and process improvement. *J Trauma*. 2009;66(4 suppl):S31–S36.
18. **Garner A, Rashford S, Lee A, et al.** Addition of physicians to paramedic helicopter services decreases blunt trauma mortality. *Aust N Z Surg*. 1999;69(10):697–701.
19. **Darocha T, Kosinski S, Serednicki W, et al.** Prehospital emergency thoracotomy performed by helicopter emergency medical team: a case report. *Ulus Travma Acil Cerrahi Derg*. 2019;25(3):303–306.
20. **Pieper MA, Vonderharr MJ, Knutson TL, et al.** Versatility with far forward damage control surgery: successful resuscitative thoracotomy in an HH-60 Black Hawk. *J Spec Oper Med*. 2019;19 (1):20–22.
21. **Ter Avest E, Griggs J, Prentice C, et al.** Out-of-hospital cardiac arrest following trauma: what does a helicopter emergency service offer? *Resuscitation*. 2019;135:73–79.
22. **Van Vledder MG, Van Waes OJF, Kooij FO, et al.** Out of hospital thoracotomy for cardiac arrest after penetrating thoracic trauma. *Injury*. 2017;48(9):1865–1869.
23. **Coats TJ, Koegh S, Clark H, et al.** Prehospital resuscitative thoracotomy for cardiac arrest after penetrating trauma: rationale and case series. *J Trauma*. 2001;50(4):670–673.

24. **McKenzie MR, Parrish EW, Miles EA, et al.** A case of prehospital traumatic arrest in a US Special Operations Soldier: care from point of injury to full recovery. *J Spec Oper Med.* 2016;16(3): 93–96.
25. **Reva VA, Horer TM, Makhnovskiy AI, et al.** Fied and en-route resuscitative endovascular occlusion of the aorta: a feasible military reality? *J Trauma Acute Care Surg.* 2017;83(1 suppl 1): S170–S176.
26. **DuBose J, Fabian T, Bee T, et al.** Contemporary utilization of resuscitative thoracotomy: results from the AAST Aortic Occlusion for Resuscitation in Trauma and Acute Care Surgery (AORTA) multicenter registry. *Shock*. 2018;50(4):414–420.
27. **DuBose JJ, Martens D, Frament C, et al.** Experience with prehospital damage control capability in modern conflict: results from surgical resuscitation team use. *J Spec Oper Med.* 2017;17(4): 68–71.
28. **Morrison JJ, Oh J, DuBose JJ, et al.** En-route capability from point of injury impacts mortality after severe wartime injury. *Ann Surg.* 2013;257(2):330–334.
29. **Tien HC, Jung V, Rizoli SB, et al.** An evaluation of Tactical Combat Casualty Care interventions in a combat environment. *J Spec Oper Med.* 2009;9(1):65–68.
30. **Morrison JJ, DuBose JJ, Rasmussen TE, et al.** Military Application of Tranexamic acid in Trauma Emergency Resuscitation (MATTERS) Study. *Arch Surg.* 2012;147(2):113–119.

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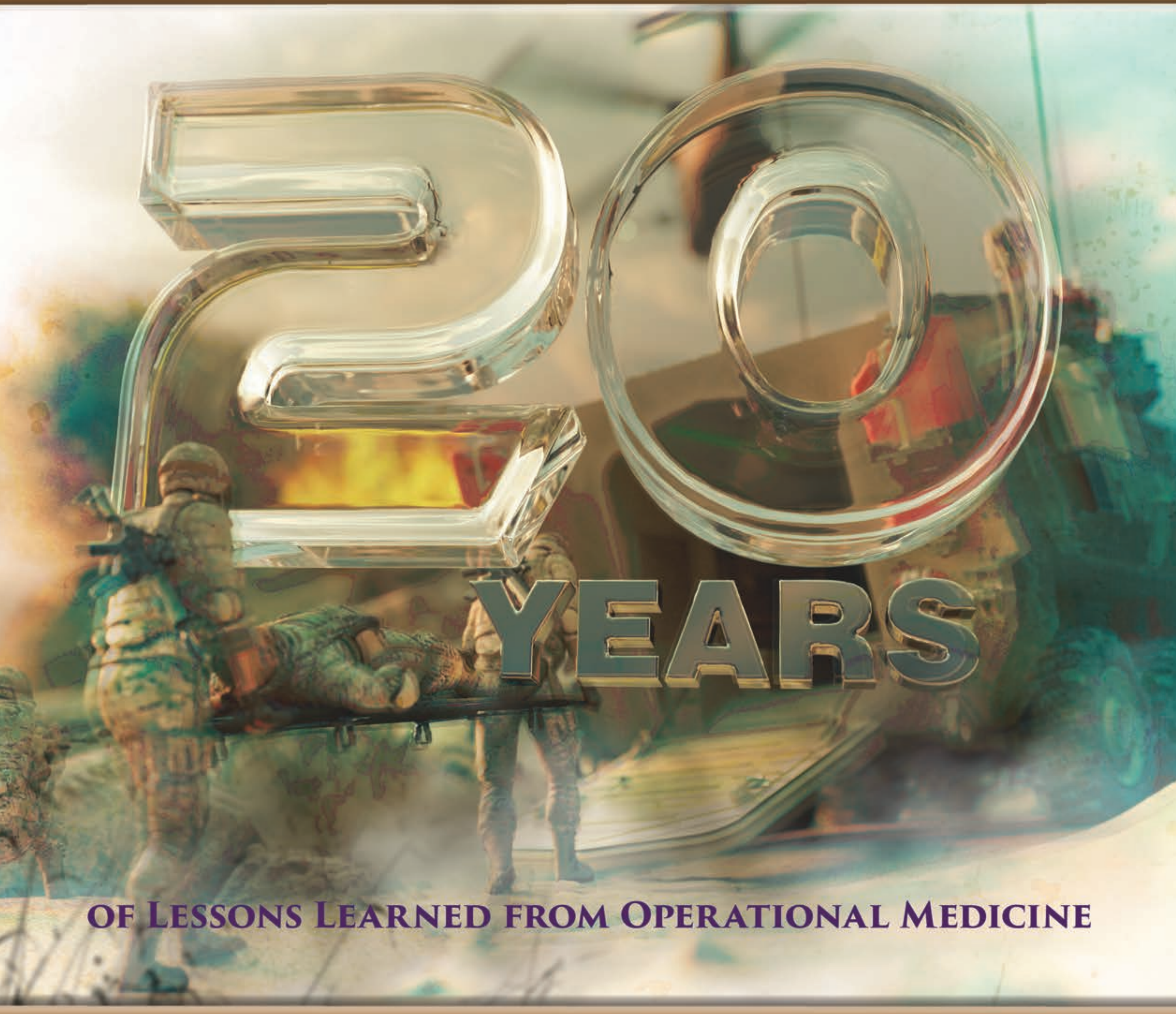

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