Army Combat Trauma Care in 2035:

A Workshop

November 18-20, 2019

DoubleTree San Antonio Downtown
Aztec Ballroom
502 W. Cesar E. Chavez Boulevard
San Antonio, TX

The National Academies of
SCIENCES • ENGINEERING • MEDICINE

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Board on Army Research and Development

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Where: DoubleTree San Antonio Downtown 502
West Cesar E. Chavez Blvd.
San Antonio, TX 78207

The workshop will be live streamed and limited seating is open to the public. Individuals planning to attend in person are strongly encouraged to register for the meeting using the following link: https://combattrauma.eventbrite.com

To view the webcast, a link will be posted to the BOARD webpage the day of the meeting.

Overall Objective: From a medical and physiological perspective, maximize the probability that the warfighter can accomplish the mission and, if injured, can both survive and return to function as soon as possible.

Background: Building on the 2016 National Academies report "A National Trauma Care System: Integrating Military and Civilian Trauma Systems to Achieve Zero Preventable Deaths After Injury", we will explore how to better accelerate the adoption of emerging medical advancements to improve outcomes for Soldiers in 2035 and beyond. The workshop planning committee, led by co-chairs Dr. Jim Bagian and Dr. Joan Bienvenue will host a 3-day workshop with leading medical professionals and researchers from the Army S&T community to focus on three framing topics:

1. What is the state of art and forecast to future the developments in bio- engineering and how can it provide for returning Soldiers to the fight quicker?
2. What areas of Tactical Combat Care in the Army can we improve now?
3. Explore the future of medically related threats, risks, and status of preparedness.

As stated above, space is ***extremely limited***, and registration for this event is expected. You may register for the event here: https://combattrauma.eventbrite.com

If you have any questions regarding the event, please contact NAS Staff members Cameron Malcom (cmalcom@nas.edu) or Aanika Senn (asenn@nas.edu). We welcome your participation and look forward to a truly informative event.

Army Combat Trauma Care in 2035
Workshop Agenda

November 18-20, 2019
San Antonio, TX

Day 1
Monday, November 18, 2019

1030-1200	Planning Committee and Staff Working Breakfast- Prep for day ahead
OPEN SESSION-	Background Overview
1200-1215	Introduction- *Jim Bagian*
1215-1245	Overview of Tactical Combat Casualty Care; Including Point of Wounding- *John Gandy*
1245-1305	Continuum of Care- *Jay Johannigman*
1305-1335	Combat Casualty Mortality- *Brian Eastridge*
1335-1355	Overview of the Joint Trauma System (JTS)- *Mary Ann Spott*
1355-1415	Burns- *Lee Cancio*
1415-1430	BREAK
1430-1500	Fluid Resuscitation for Hemorrhagic Shock- *Don Jenkins*
1500-1520	Military Functional Incapacity Scale- *Harald Scheirich*
1520-1550	Virtual and Autonomous Systems in Remote and Multi Domain Scenarios- *Gary Gilbert*
1550-1630	Future Operational Environments, Gaps, Needs, Opportunities: Operational Environment- *Gerald Leverich*
1630-1800	CLOSED SESSION- Planning Committee and NAS Staff Only
1800-1900	Welcome Reception- Complimentary Reception in the hotel Bar with light appetizers and beverages (All welcome)

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Day 2
Tuesday, November 19, 2019

0900-0930	Keynote Talk: Role of Military Line Leadership and Ensuring Excellence in Combat Casualty Care- *Jim Geracci*
0930-1000	Joint Medical Planning Tools- *Mike Galarneau*
TRAINING	
1000-1030	Initial, Rucurrency, Personalized, Mission Specific Competence Assessment & Team Based Training- *Jay Beaubien*
1030-1130	Integration with Line Tactical Training, Synthetic Training Environment, Med Sim- *Dan Irizarry*
1130-1145	BREAK
1145-1215	How Long Can the Military's Golden Hour Last? Advancing Technology, Training, and Expectations for Multi-Domain Operations- *Todd Rasmussen (remote speaker)*
1215-1245	Ever Adapting for the Warfighter: Combat Casualty Care for the Future Battlespace- Michael *Davis*
1245-1330	LUNCH
ORGANIZATIONAL LEADERSHIP FACTORS	
1330-1400	Overview- *Cord Cunningham*
1400-1430	Performance Improvement and Data Analysis- *Mary Ann Spott*
1430-1500	Resp. Delineation Training & Readiness, DHA vs. OPS- *Ruben Garza & Kazmer Meszaros*
1500-1600	PANEL DISCUSSION- Organizational and Leadership Factors Panel
1600-1800	CLOSED SESSION- Planning Committee and NAS Staff Only

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Day 3
Wednesday, November 20, 2019

HUMAN PERFORMANCE

0800-0815	Introduction- *Russ Kotwal*
0815-0840	Human Performance Optimization (HPO/Total Force Fitness- *Travis Lunasco*
0840-0905	Human Performance Optimization- *Chetan Kharod*
0905-0930	Practical Application of Military Human Performance Program- *Karen Daigle*
0930-0955	Improvements to PPE and Warfighter Survivability Based on Real-Time Combat Trauma Information- *Nick Tsantinis*
0955-1010	BREAK

BIOENGINEERING THE FUTURE FOR IMPROVED FUNC. OUTCOMES

1010-1025	Introduction- *George Christ*
1025-1125	Bioengineered Materials for Improved Wound Healing- *Luke Burnett, Robert Christy, Jennifer Elisseeff*
1125-1225	Future of Tissue Bioengineering- *Chris Dearth, Lisa Larkin, Michael Yaszemski (remote speaker)*
1225-1255	Panel Discussion
1255-1355	LUNCH
1355-1455	Final Thoughts and Wrap Up
1500	ADJOURN

PLANNING COMMITTEE BIOGRAPHIES

Dr. James P. Bagian (co-chair) is a physician and engineer who currently serves as the director of the Center for Healthcare Engineering and Patient Safety at the University of Michigan and focuses on creating solutions that will make healthcare safer, as well as more effective and efficient, for patients. Previously, he served as the first Chief Patient Safety Officer and founding director of the National Center for Patient Safety (NCPS) at the U.S. Department of Veterans Affairs (VA). He has also held positions as a NASA physician and astronaut; U.S. Air Force flight surgeon; and engineer at the U.S. Department of Housing and Urban Development, U.S. Navy, and Environmental Protection Agency. Dr. Bagian was selected in 1998 by the VA to establish NCPS and became its first director. He developed and implemented an innovative national program aimed at protecting patients from hospital-based harm, which the VA has implemented at all 173 VA hospitals. Moreover, this program served as the benchmark for patient safety in hospitals worldwide and earned the Innovations in American Government Award in 2001 from the John F. Kennedy School of Government at Harvard University. During his 15-year tenure with NASA, Dr. Bagian flew on two Space Shuttle missions. He led the development of a high-altitude pressure suit for crew escape as well as other crew survival equipment. In addition, he was the first physician to successfully treat space motion sickness, and his approach has been the standard of care for astronauts since that time. He also served as an investigator in the inquiry following the 1986 Challenger accident and was appointed as medical consultant and chief flight surgeon for the Columbia Accident Investigation Board (CAIB) in 2003. Dr. Bagian's contributions to military service include advancing new methods of military aircraft ejection seat design and serving as a colonel in the U.S. Air Force Reserve. As the Special Consultant for Combat Search and Rescue to the Air Combat Command, he was a leader in standardizing pre-hospital combat rescue medical care across all Air Force major commands and is one of the founding members of the Department of Defense's Committee on Tactical Combat Casualty Care, whose work in pre-hospital trauma care has substantially reduced mortality of service members who suffer battlefield wounds. Dr. Bagian was elected as a member of the National Academy of Engineering in 2000 and as a member of the Institute of Medicine (now the National Academy of Medicine) in 2003. He received a B.S. in mechanical engineering from Drexel University in 1973 and earned an M.D. from Thomas Jefferson University in 1977.

Dr. Joan Bienvenue, Ph.D. (co-chair) is the director of the Applied Research Institute at the University of Virginia. She received a B.S. in chemistry from Rivier University, an M.S. in forensic science at the University of New Haven, a Ph.D. in chemistry from the University of Virginia, and an M.B.A. from the University of Mary Washington. She was a National Institute of Justice Research Fellow while at UVA, where her work focused on the development of microfluidic systems. This work was summarized in over fifteen peer-reviewed papers and book chapters and presented at many conferences; she is an inventor on five U.S. patents. In addition to this academic work, she is creator and conference chair for the annual Commonwealth Conference on National Defense and Intelligence, now entering its sixth year, and co-creator and inaugural chair of the Gordon Research Conference on Forensic Analysis of Human DNA. After completion of her graduate studies, Dr. Bienvenue was an ORISE Postdoctoral Research Fellow at the FBI. Following this appointment, she joined the Armed Forces DNA Identification Laboratory (AFDIL), as the Validation and Quality Control Supervisor where she managed a team that provided quality control and oversaw the evaluation, validation, and implementation of new technology for DNA casework analysis in support of remains identification. She joined Lockheed Martin in 2008 and most recently served as Chief Scientist and Program Manager, in support of the development of rapid microfluidic DNA analysis systems. In June of 2013, she returned to the UVA as director of the Applied Research Institute (ARI) and was promoted to Senior Executive Director in 2017. ARI serves the university and the defense and intelligence communities as a conduit to facilitate collaboration and innovation between the academia and government. ARI leverages UVA's human and capital assets to support research, education, and training, with a

focus on homeland security, national intelligence, and defense missions. Dr. Bienvenue is a Fellow of the American Academy of Forensic Sciences.

Dr. Frank Butler is a retired Navy Undersea Medical Officer and an ophthalmologist who served as a Navy SEAL platoon commander prior to attending medical school at the Medical College of Georgia, where he was President of Alpha Omega Alpha, the medical honor society. He spent most of his career in Navy Medicine supporting the Special Operations community and was the first Navy physician selected to serve as the Command Surgeon for the U.S. Special Operations Command. In his current position at the Joint Trauma System, he chairs the Department of Defense's Committee on Tactical Combat Casualty Care, helping to ensure optimal battlefield trauma care for our country's wounded service men and women. He also serves as co-chair of the Decompression Sickness and Arterial Gas Embolism Treatment Committee for the Undersea and Hyperbaric Medical Society. Dr. Butler spent five years at the Navy Experimental Diving Unit in Panama City, FL, where he helped to pioneer numerous advances in SEAL diving capabilities. He went on to found and lead the Navy SEAL Biomedical Research Program for 15 years. Landmark projects accomplished by this unique program included laser refractive surgery in the military, advanced diving procedures for Navy SEALs, the Naval Special Warfare decompression computer, diving and hyperbaric ophthalmology, one of the first operational medicine translators, human performance initiatives, and Tactical Combat Casualty Care (TCCC). The set of evidence-based, best practice battlefield trauma care guidelines embodied in TCCC has now been recognized as the major prehospital advance in combat casualty care achieved during the recent conflicts in Afghanistan and Iraq. It has been credited with saving the lives of many hundreds of casualties from those wars and units that have trained all of their members in TCCC have reported the lowest incidence of preventable death in the history of modern warfare. TCCC is now the prehospital component of the DoD's Joint Trauma System and has mandated as the standard for battlefield trauma care throughout the US Military and in the militaries of many allied nations. TCCC is now also gaining increasing acceptance in civilian prehospital trauma care. Dr. Butler has over 140 publications in the medical literature. He has been awarded the U.S. Special Operations Command Medal by Admiral Bill McRaven; the 2017 Distinguished Service Award from the US Military Health System for lifetime contributions to combat casualty care; the 2017 Letterman Award for Excellence in Battlefield Medicine; the 2018 Rocco Morando Award from the National Association of Emergency Medical Technicians for contributions to Emergency Medical Services; the 2011 Academy of Underwater Arts and Sciences NOGI Award for Distinguished Service to the diving community; the 2010 Auerbach Award for contributions to Wilderness Medicine; the 2007 Norman McSwain Award for leadership in Prehospital Trauma Care; and the first Committee on Tactical Combat Casualty Care Award for outstanding contributions to battlefield trauma care in 2006, an award that is now given annually and bears his name. He was recently honored by a Navy Forward Surgical Hospital in Iraq naming the road to the hospital "Frank Butler Boulevard" in honor of his work in developing and advancing TCCC concepts.

Dr. George Christ is Professor of Biomedical Engineering and Orthopaedic Surgery, and holds the Mary Muilenburg Stamp Chair in Orthopaedic Research, where he is director of Basic and Translational Research in Orthopaedics. He is co-director of the University of Virginia's Center for Advanced Biomanufacturing. He is the past chairman of the Division of Systems and Integrative Pharmacology of the American Society of Pharmacology and Experimental Therapeutics (ASPET), and past president of the North Carolina Tissue Engineering and Regenerative Medicine (NCTERM) group. He was inducted into AIMBE in 2017. He serves on the executive committee of the Division for Integrative Systems, Translational, and Clinical Pharmacology of ASPET. He is a member of the Regenerative Rehabilitation Consortium Leadership Council and serves on the Leadership Advisory Council for ARMI/BioFabUSA. He received the Ray Fuller Award and Lecture (ASPET, 2018). He serves on the editorial board of five journals and is an ad-hoc reviewer for two dozen others. Dr. Christ has authored more than 225 scientific publications and is co-editor of a book on integrative smooth muscle physiology and another on regenerative pharmacology. Dr. Christ has served on both national and international committees related to his expertise in muscle physiology, and on NIH study sections in the NIDDK, NICHD, NCRR, NAIAD,

NIAMS and NHLBI. He has chaired working groups for both the NIH and the WHO and is co-inventor on more than 26 patents (national and international) either issued or pending. Dr. Christ has also been the driving scientific force behind the preclinical studies and IND approvals supporting three Phase I clinical trials for gene therapy for benign human smooth muscle disorders. This technology has been evaluated in 55 patients in the US and 21 overseas. Dr. Christ is also spearheading several musculoskeletal-applicable translational research programs to develop novel regenerative medicine treatments with applications for Wounded Warriors and civilian patients, in particular, volumetric muscle loss injuries. He leads a DOD-funded (AFRIM) multi-institutional program for development of a tissue engineered muscle repair (TEMR) technology platform for VML repair. An IND has been submitted to support a five patient first-in-man pilot study to further develop this technology platform for treatment of cleft lip. He collaborates in another NIH and DOD funded translational multi-institutional effort as part of the C-DOCTOR (Center for Dental, Oral and Craniofacial Tissue and Organ Regeneration) consortium for development of a semi-synthetic hydrogel co-developed at UC-Berkeley and UVA for craniofacial and extremity trauma VML repair. Funding from the DOD and KeraNetics (W-S, NC) also supports development and evaluation of another proprietary hydrogel for the treatment of lower extremity traumatic injuries to the tibialis anterior muscle, where a five-patient clinical trial is planned for treatment of VML injuries at UVA following submission to, and approval of, an IDE by FDA.

Dr. Howard Champion is the founder and CEO of SimQuest, and has been since its establishment in 2001. He is a leading authority on civilian and combat injury. Dr. Champion is one of the pioneers of trauma centers and trauma systems both U.S. and globally. He practiced as a trauma surgeon for 30 years, teaching civilian and military healthcare providers and extensively researching and writing on the subject. He retired from active practice in 1994 after serving for 20 years as Chief of Trauma and Surgical Critical Care at the largest teaching hospital in Washington D.C. Dr. Champion currently provides consultative research policy and educational services to military medical leadership in a number of countries. He has provided consultation on trauma systems in Australasia, many European countries, South Africa, and NATO. He has given hundreds of invited lectures and presentations worldwide. Eponymous lectures include the Moynihan Lecture for the Association of Surgeons of Great Britain and Northern Ireland, the Mitchiner Lecture from the Royal Defense Medical College of the United Kingdom in 2002, the Zeppa Lecture at the University of Miami and Army Joint Trauma Training Center in 2003 and the Scott Frame Lecture from the Eastern Association for the Surgery of Trauma in 2010. He was co-convener of the Definitive Surgery for Trauma Skills Course at the Royal College of Surgeons of England from 1997 to 2007. In 2005 having established that course and the Definitive Surgical Trauma Care course taught globally by IATSC (below). For the past 30 years Dr. Champion has reviewed Combat Casualty Care Research proposals and programs for DARPA, ONR, MRMC, TATRC and CCCR. In 2005, Dr. Champion was awarded the Lifetime Achievement Award by the U.S. Army Medical Research & Materiel Command and the Combat Casualty Care Research Award for Excellence and a further award in 2016 for "Dedication and Service to the U.S. Combat Casualty Care Research Program". Dr. Champion has been a constant and successful advocate for trauma care systems in Maryland (since 1972), D.C. (since 1975) and on Capitol Hill (since 1988). He founded the Coalition for American Trauma Care in 1992 to provide a federal-level presence for trauma disciplines. He currently conducts surgical-related trauma research and development through numerous federal (NIH, USA MRMC, NIST ATP, and ONR) grants and contracts to his small business, SimQuest. Honorary membership in the European Association for Trauma and Emergency Surgery was conferred in 2011. He is a fellow of the American Surgical Association. Dr. Champion has been a member of the executive committee of the American College of Surgeons Committee on Trauma, vice president of the American Association for the Surgery of Trauma, vice president of the American Trauma Society, president of the American Association for Automotive Medicine. He served as president of the Eastern Association for the Surgery of Trauma (EAST) and president of the International Association for Trauma and Surgical Intensive Care (IATSIC): both of the which he founded. He has been a member of the Committee on Tactical Combat Casualty Care (CoTCCC) and its civilian counterpart the Committee on Tactical Emergency Casualty Care (C-TECC) since their inception. Dr. Champion has approximately 300 peer review publications,

publishes 5-10 per year and reviews for 12-15 medical journals. He has been a worldwide leader in injury severity qualification, trauma registries, trauma systems and quality of care. Dr. Champion's company, SimQuest, is a small business focused on developing technology-assisted training platforms for surgery and medicine. The company has had substantial ($55M) R&D and consultative funding from government sources (NSF, NIH, DoD, Dept. of Commerce), for this purpose.

Dr. Carolina Cruz-Neira is the Donaghey Distinguished Professor in Information Sciences and the Executive Director of the Emerging Analytics Center at the University of Arkansas at Little Rock and an Arkansas Research Scholar through the Arkansas Research Alliance. Dr. Cruz-Neira is also a member of the National Academy of Engineering, is a pioneer in the areas of virtual reality and interactive visualization, having created and deployed a variety of technologies that have become standard tools in industry, government and academia. She is known world-wide for being the creator of the CAVE virtual reality system. She has dedicated a part of her career to transfer research results into daily use by spearheading several Open Source initiatives to disseminate and grow VR technologies and by leading entrepreneurial initiatives to commercialize research results. She has over 100 publications as scientific articles, book chapters, magazine editorials, and others. She has been awarded over $75 million in grants, contracts, and donations. She is also recognized for having founded and led very successful virtual reality research centers: VRAC at Iowa State University, the Louisiana Immersive Technologies Enterprise and the Emerging Analytics Center. She has been named one of the top innovators in virtual reality and one of the top three greatest women visionaries in this field. She has been inducted as an ACM Computer Pioneer, received the IEEE Virtual Reality Technical Achievement Award and the Distinguished Career Award from the International Digital Media & Arts Society among other recognitions. She had given numerous keynote addresses and has been the guest of several governments to advice on how virtual reality technology can help to give industries a competitive edge leading to regional economic growth. She has appeared in numerous national and international TV shows and podcasts as an expert on her discipline and several documentaries have been produced about her life and career.

CAPT. Margaret Moore is an Assistant Professor of Clinical Surgery at the Louisiana State University Health Science Center. She earned a Bachelor of Science degree in music performance with a minor in chemistry from Indiana University in 1999. She received her M.D. degree from Pennsylvania State University in 2004. The Captain then completed her Transitional Internship at the Naval Medical Center San Diego. Following four years as a flight surgeon, she did her General Surgery Residency at Lehigh Valley Health Network in Allentown, Pennsylvania in 2014 and her Trauma and Surgical Critical Care fellowship at the Louisiana State University Health Science Center in New Orleans. She is board certified in General Surgery and Surgical Critical Care. In 2000 she entered the Navy as part of the Health Professions Scholarship Program. After graduating top of her class in internship, she attended flight school at the Naval Aviation Medicine Institute in Pensacola before taking her first assignment as a squadron flight surgeon with Marine Medium Helicopter Squadron 262 in Okinawa, Japan. While assigned to HMM-262, she served as the flight surgeon for the Air Combat Element on the 31st Marine Expeditionary Unit supporting joint exercises in Thailand and the Philippines. In January of 2007, HMM-262 deployed to Iraq in support of Operation Iraq Freedom. In addition to her duties as the squadron flight surgeon, CAPT Moore served with the II MEF CASEVAC team and as an adjunct to the Shock Trauma Platoon in Al Taqaddum. In March, 2008, she transferred to NAS Brunswick, Maine where she became the squadron flight surgeon for Special Projects Patrol Squadron-ONE. While with VPU-1, she deployed several times to Afghanistan and Africa in support of Operation Enduring Freedom. CAPT Moore completed her General Surgery residency as a reservist in the Training in Medical Specialty program and entered the IRR during her fellowship in Trauma/Surgical Critical Care. She re-affiliated with the reserves in July 2016 as a Surgeon in Surgical Company Alpha, 4th Medical Battalion, 4th Marine Logistics Group. In December 2016 she was appointed the Training Officer for Surgical Company Alpha and in February 2017, assumed the role of OIC for the Headquarters Detachment in Pittsburgh. During her time with SCOA, CAPT Moore served as the OIC for African Lion 2017 and Global Medic

2018. In December of 2018, CAPT Moore became the Wing Surgeon for the 4th Marine Aircraft Wing in New Orleans, LA. CAPT Moore holds added designations as a Flight Surgeon and Fleet Marine Forces Warfare Officer. She also serves as the Navy Reserve liaison to the National Committee on Surgical Combat Casualty Care as well as the Navy's Trauma Strategy Management Office where she is actively working on military-civilian partnerships and the integration of reservists into the Trauma training programs. She was selected as a scholar in the American College of Surgeons Future Trauma Leaders program and now has an active appointment to the Committee on Trauma where she is a member of the Trauma Systems Committee and the EMS Committee. Additionally, she is a member of the Curriculum and Skills Committee within the Military Health System Strategic Partnership and is currently working on the development of a standardized curriculum for the creation and qualification of a tri-service Expeditionary General Surgeon. CAPT Moore's awards include the Air Combat Medal, Navy and Marine Corps Commendation Medal, the Navy and Marine Corps Achievement Medal, as well as various other service and campaign awards.

COL Russ Kotwal is the Chief of Strategic Projects at the Joint Trauma System. COL Kotwal received a Bachelor of Science from Texas A&M University in College Station, Texas in 1985; a Doctor of Medicine from the Uniformed Services University in Bethesda, Maryland in 1996; and a Master of Public Health from the University of Texas Medical Branch in Galveston, Texas in 2004. He was commissioned onto active duty in the United States Army in 1985 and retired from the military in 2014. He received residency training in Family Medicine with the Army, and Aerospace Medicine with the Navy. His hospital assignments included Tripler Army Medical Center, Martin Army Community Hospital, Womack Army Medical Center, and Brooke Army Medical Center. His unit assignments included the 1/35 Infantry Battalion and 4/27 Infantry Battalion, 25th Infantry Division (Light); 3rd Battalion, 75th Ranger Regiment; Headquarters, 75th Ranger Regiment; and Headquarters, U.S. Army Special Operations Command. COL Kotwal has conducted multiple combat deployments to both Afghanistan and Iraq, where he participated in hundreds of combat ground and air missions as the senior prehospital medical provider. COL Kotwal currently works from College Station, Texas, as an independent consultant for multiple organizations to include the DoD Joint Trauma System. COL Kotwal is credited with numerous novel training and technology initiatives, professional publications, and national and international presentations related primarily to prehospital medicine on the battlefield. He served on the board of directors for the Special Operations Medical Association for seven years where he is currently the vice president. He is an adjunct professor for both the College of Medicine at Texas A&M University and the Department of Military and Emergency Medicine at the Uniformed Services University. COL Kotwal is also a fellow of the American Academy of Family Physicians and a senior advisor to the DoD Committees on Combat Casualty Care.

Speaker Biographies

Dr. Jeffrey M. Beaubien is a Distinguished Principal Scientist and Institutional Review Board (IRB) Chair at Aptima, Inc. For the past 20 years, his work has focused on training and assessing leadership, teamwork, and decision-making skills in the military, aviation, and healthcare. His has conducted training-related research for the Federal Aviation Administration, the National Aeronautics and Space Administration, the Agency for Healthcare Research and Quality, the U.S. Navy, the U.S. Army, the U.S. Air Force, and the Telemedicine and Advanced Technologies Research Center, among others. Dr. Beaubien holds a Ph.D. in Industrial and Organizational Psychology from George Mason University, a M.A. in Industrial and Organizational Psychology from the University of New Haven, and a B.A. in Psychology from the University of Rhode Island. He is a member of the American Psychological Association, the Society for Industrial and Organizational Psychology, and the Human Factors and Ergonomics Society.

Luke Burnett, PhD, is the CEO and Chief Science Officer of KeraNetics and an Adjunct Associate Professor in the Department of Orthopaedic Surgery at Wake Forest School of Medicine. Dr. Burnett has worked in the field of biomaterials for over a decade with a focus on product development of keratin biomaterial applications to wound healing and tissue engineering. Dr. Burnett has an extensive funding history where he has been the PI or Co-I on more than 27 federally-funded grants from CDMRP, DoD, NIH and BARDA in the last 8 years. Dr. Burnett has published research using trauma models in multiple species published in major scientific journals, and filed 7 patents on the work conducted in his lab. Dr. Burnett recently retired as a Colonel from the US Army where he served 27 years, including serving two tours in Iraq and graduating from the US Army War College.

Dr. Lee Cancio is the Director of the U.S. Army Burn Center at the U.S. Army Institute of Surgical Research (ISR), Fort Sam Houston, Texas. During his 27-year active-duty career in the U.S. Army, he deployed with the 504th Parachute Infantry Regiment of the 82d Airborne Division to Operation Just Cause, Panama, 1989-90 and to Operation Desert Storm, 1990-91. While on active duty at the ISR, he served in various positions culminating in service as the Director of the Burn Center, and established the Special Medical Augmentation Response Teams for Burns. During Operation Iraqi Freedom (OIF), he deployed with Special Operations Command – Central Command (SOCCENT) as the Principal Investigator in theater for the hemostatic dressing protocol in 2003. He served as the Deputy Commander for Clinical Services at the 86th Combat Support Hospital in Baghdad during OIF in 2005, and served there again in 2008. In 2013 he deployed with a Forward Surgical Team to Afghanistan during Operation Enduring Freedom. He retired in the rank of Colonel in 2014. His military awards and decorations include the Legion of Merit, Bronze Star Award (1 Oak Leaf Cluster), Parachutist Badge with Combat Jump Star, Air Assault Badge, Expert Field Medical Badge, Combat Medical Badge, Senior Aircraft Crewman Badge, Surgeon General's A Proficiency Designator, and Order of Military Medical Merit. In 2017 he became the second civilian Director and the first Government civilian Director of the Army Burn Center. Dr. Cancio is a graduate of Amherst College, of the Catholic University of America, and of Georgetown University School of Medicine. He completed a residency in General Surgery at Brooke Army Medical Center and a fellowship in Surgical Critical Care at the San Antonio Uniformed Services Health Education Consortium, San Antonio, TX. He is board-certified in Surgery and in Surgical Critical Care. Dr. Cancio's research interests include burn shock, hemorrhagic shock, acute respiratory distress syndrome, and blast injury. He established two successful research task areas within the Combat Casualty Care Research Program of the U.S. Army Medical Research and Materiel Command (Combat Critical Care Engineering and Multi-Organ Support Technology). He is the co-inventor of the first commercially available decision-support system for burn-shock resuscitation, the Burn Navigator (Arcos Medical, Inc., Houston, TX). He contributed preclinical data to the FDA approval of the ER-REBOA catheter (Prytime Medical, Boerne, TX). He is the

author of over 200 peer-reviewed papers, 25 chapters, and other works. Dr. Cancio is a member of the American College of Surgeons (including the Committee on Trauma), American Association for the Surgery of Trauma, Eastern Association for the Surgery of Trauma, Shock Society, International Society for Burn Injuries, Society for Critical Care Medicine, Surgical Discovery Club, and American Burn Association (ABA). He currently serves as the Secretary of the ABA and as a member of its Verification Committee for burn centers. He is a member of the editorial boards of *Burns, Journal of Burn Care and Research, and American Journal of Disaster Medicine*. He is a Professor of Surgery (Adjoint) at the University of Texas Health Science Center at San Antonio. Dr. Cancio's personal interest in technical scuba diving as a member of Global Underwater Explorers contributes to his efforts to enhance teamwork and communication in critical care medicine.

Dr. Robert Christy is currently Chief of the Burn and Soft Tissue Research Department and Battlefield Pain Research Section at the US Army Institute of Surgical Research. He also is an adjunct faculty member in the Department of Biomedical Engineering at the University of Texas at San Antonio. Dr. Christy received his Bachelor of Science degree in Biology from the University of California at Davis and his PhD degree from The Johns Hopkins University. After completion of his PhD degree, Dr Christy obtained a National Research Service Award from the National Institutes of Health and continued his scientific training as a postdoctoral fellow in the Department of Biological Chemistry and Department of Molecular Biology at The Johns Hopkins School of Medicine. Dr. Christy's research groups investigates: 1) novel biomaterial matrices for treatment of traumatic burn wounds on the battlefield; 2) development of novel antimicrobial approaches to prevent and control infections of soft tissue injuries including burn wounds; and 3) investigates non-opioid based pain management treatments for use by medical personnel throughout the spectrum of combat casualty care.

Dr. Cord Cunningham, MD, MPH, FACEP, FAEMS is a board-certified Emergency Medicine Physician with subspecialty board certification in EMS. He served as the Battalion Surgeon for 2nd Ranger BN and Surgical Resuscitation Team member for USSOCOM deploying in direct and prehospital medical support of special operations forces in both Iraq and Afghanistan. Dr Cunningham also served as a flight surgeon and medical director for a 15 ship Army MEDEVAC unit and 3,000 person aviation brigade at Fort Hood as well as the medical director for the Army's Critical Care Flight Paramedic Program. Dr Cunningham is a graduate of the US Army Ranger School, a Dive Medical Officer, Senior Rated Flight Surgeon, and Master Rated Parachutist. COL(USAR) Cord Cunningham began his active duty career when he was commissioned as a 2LT in the Signal Corps upon graduation from USMA at West Point in 1995 and served as a PL and XO in B Co, 112th Special Operations Signal BN, Signal Detachment Commander, and S-1 of 2nd BN/7th Special Forces Group at Ft Bragg, NC. He attended the Uniformed Services University of the Health Sciences from 1999-2003 and trained in Emergency Medicine at Brooke Army Medical Center from 2003-2006 as well training in EMS with COL(ret) Bob Mabry as his fellowship director from 2013-2015. After serving over 20 years on Active Duty, Dr Cunningham is currently in the US Army Reserves with the Army Reserve Element for USSOCOM and performs duties as the Chairman of the Joint Trauma System Committee on En Route Combat Casualty Care and faculty for the DoD Prehospital and Disaster Medicine Fellowship. Dr Cunningham is also still a full-time practicing EM Physician. Prehospital battlefield care and reduction of preventable prehospital battlefield mortality remains his primary military career pursuit and focus.

MAJ Karen Daigle was a member of the team that founded the Tactical Human Optimization, Rapid Rehabilitation and Reconditioning (THOR3) Program during a previous assignment to the U.S. Army Special Operations Command (USASOC). On her current assignment with USASOC, she serves as the Director of this program, which is now the Human Performance component of the USASOC Preservation of the Force and Family (POTFF) Program. She most recently served as the Lead Action Officer at U.S. Army Forces Command (FORSCOM) for the Army Holistic Health and Fitness (H2F) pilot. During her 22 years of military service, she has served as an enlisted aircrew member in the U.S. Navy, as an aircraft maintenance technician in the Louisiana Air National Guard, and now as a medical specialist corps officer in the U.S. Army. Prior to returning to the military after a break in service, Daigle worked as a sport physiologist and dietitian for the U.S. Olympic Committee where she supported Team USA at the 2004, 2006, and 2008 Olympic/Paralympic Games. Daigle received her bachelor's

Louisiana State University and her master's degrees in Movement Science and Food and Nutrition from Florida State University. She is a Certified Strength and Conditioning Specialist, Tactical Strength and Conditioning Facilitator, Registered Dietitian, and Certified Specialist in Sport Dietetics.

Christopher L. Dearth, PhD currently has the privilege of serving as the Facility Research Director for the Extremity Trauma & Amputation Center of Excellence (EACE) at Walter Reed National Military Medical Center (WRNMMC), the Flagship of the Military Health System, and the world's largest military medical center. Additionally, Dr. Dearth serves as the Director of Research for the Department of Rehabilitation at WRNMMC and holds a faculty position within the F Edward Hebert School of Medicine at the Uniformed Services University of the Health Sciences where he is the Founding Director of the Regenerative Medicine Therapeutics Laboratory. Within these roles, Dr. Dearth is responsible for leading a multidisciplinary team of clinicians and researchers who conduct a diverse portfolio of cutting edge, mission driven research projects which span the full spectrum of scientific inquiry – from contemporary 'basic science' (i.e., cell / molecular biology) experiments all the way up to multi-site, randomized, and controlled clinical trials. Of note, Dr. Dearth's team is spearheading research and clinical efforts towards implementation of a Regenerative Rehabilitation treatment paradigm, i.e. the interface between the traditional disciplines of Regenerative Medicine and Physical Rehabilitation which aims to capitalize on the synergy between next generation medical technologies and state-of-the-art rehabilitation programs. The overarching goal of these research efforts is to generate the knowledge to support evidence-based improvements in clinical practice such that the highest quality of life can be achieved by those who deserve it most -- our Nation's Service members and Veterans. Throughout his career, Dr. Dearth's research has been funded by a variety of organizations, including the National Institutes of Health and the Department of Defense; and has been published in numerous high impact peer-reviewed scientific journals. Dr. Dearth contributes to the scientific community by serving as a subject matter expert in a variety of professional activities, including as an invited manuscript reviewer, section editor, and board member for numerous peer-reviewed journals, and research grant review committees. Dr. Dearth received a Bachelor's degree from the University of Dayton and a Doctorate from the University of Toledo before conducting a Post-Doctoral Fellowship at the McGowan Institute of Regenerative Medicine (MIRM) at the University of Pittsburgh. Prior to joining WRNMMC, Dr. Dearth was a faculty member at the University of Pittsburgh School of Medicine with dual appointments in the Department of Surgery and MIRM.

Brian Eastridge, MD is Professor of Surgery and Chief of the Division of Trauma and Emergency General Surgery at the University of Texas Health Science Center at San Antonio, Trauma Medical Director of the University Health System and holds the Jocelyn and Joe Straus Endowed Chair in Trauma Research. He received his BS in biochemistry from Virginia Tech in 1985 and his MD from the University of Maryland School of Medicine in 1989. Dr Eastridge did his residency in general surgery at the University of Maryland Medical System and then pursued fellowship training in surgical critical care at the University of Texas Southwestern Medical Center in Dallas, after which he spent 8 years on the faculty of UT Southwestern. After 17 years of US Army Reserve service, Dr Eastridge transitioned to active duty as COL U.S Army, Medical Corp in 2005 and served as Trauma Medical Director for the Brooke Army Medical Center, Surgical Critical Care Program Director for SAUSHEC, and was instrumental in developing and implementing the Joint Trauma System, serving as the initial Director of the Joint Theater Trauma System (Deployed) as well as serving in that deployed leadership position on two more occasions. In addition, he served as Director of the Joint Trauma System (U.S. Army Institute of Surgical Research of the U.S. Army's Medical Research and Material Command (MRMC), and Trauma Consultant to the US Army Surgeon General. During his service, he has deployed six times to combat operations in Southwest Asia. COL Eastridge left active service and joined the faculty of UT Health San Antonio and transitioned back into the the US Army Reserves in late 2012. Dr. Eastridge is currently Vice Chairman of the Southwest Texas Regional Advisory Council and Chairman of the region PI Committee. In addition, he is an appointed member of the Texas Governor's EMS and Trauma Advisory Council. He was appointed to the American College of Surgeons Committee on Trauma National Faculty and currently serves as the Chairman of the Trauma Systems Committee and Trauma System Pillar. He maintains a steadfast commitment to the Department of Defense and is an active member of the Committee on Tactical Combat Casualty Care and Committee on Surgical Combat Casualty Care. During his career, Dr. Eastridge has published

extensively in the peer reviewed literature and has written / edited three books focused upon improving the military trauma system and improving combat casualty care outcomes for our Wounded Warriors. Dr Eastridge's current research is extensively grant funded and focused upon remote trauma outcomes, trauma system development, and predictive modelling of injury outcomes and pre-hospital mortality.

Dr. Jennifer Elisseeff is the Morton Goldberg Professor and Director of the Translational Tissue Engineering Center at Johns Hopkins Department of Biomedical Engineering and the Wilmer Eye Institute with appointments in Chemical and Biological Engineering, Materials Science and Orthopedic Surgery. She was elected a Fellow of the American Institute of Medical and Biological Engineering, the National Academy of Inventors, and a Young Global Leader by World Economic Forum. In 2018, she was elected to the National Academy of Engineering and National Academy of Medicine. Jennifer received a bachelor's degree in chemistry from Carnegie Mellon University and a PhD in medical engineering from the Harvard–MIT Division of Health Sciences and Technology. Later she was a Fellow at the National Institute of General Medical Sciences, Pharmacology Research Associate Program, where she worked in the National Institute of Dental and Craniofacial Research. She has published over 200 papers, book chapters, and patent applications and received a number of awards including the Carnegie Young Alumni Award and in 2002 she was named by *MIT Technology Review* as a top innovator under 35. Jennifer's research focus is the development of biomaterials for regenerative medicine applications in orthopedics, plastic and reconstructive surgery, and ophthalmology. She is now studying Biomaterials-directed Regenerative Immunology and the role of the adaptive immune system in tissue repair. She is committed to the translation of regenerative biomaterials and has founded several companies and participates in several industry advisory boards.

Mr. Michael Galarneau has a Master of Science in Industrial Organizational Psychology, with an emphasis in analytics and experimental design as well as a Nationally Registered Emergency Medical Technician (NREMT). Since 1995, Mr. Galarneau has served the United States as a researcher in government service and is currently the Naval Health Research Center Director of Operational Readiness & Health. Mr. Galarneau's responsibilities include the management of more than 40 research projects in the areas of warfighter performance, medical modeling and simulation, and deployment related injury and illness epidemiology. A number of the models and simulations developed under Mr. Galarneau's direction are designated by the DoD Joint Staff and the Office of the Secretary Defense Health Affairs as the tools required for planning and supporting combat casualty care in theater, for each of the service branches. In addition to his responsibilities as Director of Operational Readiness, Mr. Galarneau is the principal investigator for the Tri-service Expeditionary Medical Encounter Database (EMED) program. This program is dedicated to the development of comprehensive clinical profiles that describe the events associated with deployment-related injury and the care administered to casualties as they move through the medical chain of evacuation, from the point of injury, through to final rehabilitative outcome. Mr. Galarneau is also the principal investigator of the Wounded Warrior Recovery Project (WWRP). The WWRP is a comprehensive investigation of quality of life outcomes for U.S. casualties injured in overseas contingency operations. Mr. Galarneau has received two patents for his work at Naval Health Research Center (U.S. Patent No. 5,995,077, 1999 and U.S. Patent No. 7,707,042, 2010), with two additional patents pending. He is also the recipient of the Navy Meritorious Civilian Service Award.

John V. Gandy, III MD is a physician with 28 years of military medical service, first in the U.S. Navy as a Hospital Corpsman and then in the U.S. Air Force as an Emergency Medicine Physician and Flight Surgeon. He has been a contributor to the Tactical Combat Casualty Care effort since its inception. While on active duty, he provided direct and supervisory medical support to Joint Special Operations missions around the globe. After retirement from military service, Dr. Gandy has continued to practice Emergency Medicine, teach tactical medicine and develop medical and surgical resuscitative support solutions for operations in austere environments.

Mr. Ruben Garza works for the Defense Health Agency (DHA), Education & Training (J7) and besides being Chief of DMMSO, he is also the Deputy Chief to the Medical Modernization & Simulation Division. Mr. Garza's main duty is Chief of the Defense Medical Modeling & Simulation Office (DMMSO) in San Antonio, Texas. He leads the Central, Joint office that has the Air Force, Navy & Army Medical Simulation Programs. This encompasses a 106 Gov &

Contract staff that support the entire Military Health System facilities of over 600+ locations globally. He helps with standardizing and having a central location in which all requests for Medical Modeling & Simulation enters for review, adjudication and then to turn the requests to a validated requirement. Mr. Garza works with the Joint Project Manager (JPM) office located by PEO STRI for acquisition actions. His office takes on the full implementation of that particular solution by gathering data, metrics, encounters and usage, to forecast for future support. Additionally, he has oversight on the R&D for MM&S to support the MHS.

Dr. James Geracci is a Vice President/Chief Medical Officer for Ascension Healthcare Texas/Seton Family of Hospitals. He is responsible for strategy development and operational oversight of all aspects of healthcare delivery ensuring the achievement of Ascension's "quadruple aim" of delivering high-quality care, improved clinical outcomes, better patient and provider experiences, and lower overall cost of care consistent with the organizations mission, vision, and values. Jim is a senior physician executive with more than 26 years of leadership experience in one of the largest and most complex healthcare enterprise in the world (the United States Army). He retired at the rank of Colonel and has led military healthcare teams at all levels including as medical director of multiple large clinics, as department chief for the military's largest primary care department, and as chief medical officer for an Army Division and Corps. Jim is a proven effects-oriented leader experienced in building, developing, and leading multidisciplinary teams capable of planning and executing comprehensive health services support in the most complex environments including assignments and combat deployments to Bosnia, Korea, Iraq, and Afghanistan. A disruptive innovator, Jim has effectively driven and led organizational change from both the bottom up and the top down in an institution known for bureaucracy. Serving as Director of Prehospital Trauma Care for the Department of Defense's (DoD's) Joint Trauma System, Senior Combat Capability Developer for the Army Medical Department, Consultant to the Army Surgeon General for Operational and Deployment Medicine, and on the DoD's Committee on Tactical Combat Casualty Care, he helped to transform military medicine into a true learning healthcare system ensuring hard-learned lessons of nearly two decades of war were not lost but rather codified in doctrine and policy. Since transitioning from the military, Jim continues to innovate in his role as Director of Health Innovation at Capital Factory and in his healthcare consulting work. A native of Las Vegas, Nevada, Jim's education includes degrees/certifications from Arizona State University, Uniformed Services University School of Medicine, US Army Command and General Staff College, and both University of Pennsylvania/ Wharton and University of Texas/McCombs Schools of Business. He is certified by the American Board of Family Physicians and is a Fellow of the American Academy of Family Physicians. Jim has authored numerous scholarly articles/book chapters and presented lectures both nationally and internationally on various professional topics. He and his wife, Kristie, have been married for more than 25 years and have three sons. After living and working around the world, home is Austin, Texas.

Gary Gilbert, Ph.D. leads the TATRC Medical Intelligent Systems Laboratory. Composed of a robust group of research scientists and technologists in the fields of *artificial intelligence, robotics, engineering, computer science, telecommunications* as well as experienced research managers and field operators in combat health services support and force health protection, this lab is focused on engineering the future of military Army Medical Robotic & Autonomous Systems (MED-RAS) and Operational Telemedicine for Army Multi Domain Operations. After receiving advanced degrees in Agriculture, Dairy Science, and Management of Information Technology, from Cornell, Penn State and American University, Dr. Gilbert served in the U.S. Army as a Medical Service Corps Commander and Staff officer, which included service as a Special Forces Operational "A" Detachment Commander and Medical Plans, Operations, and Training Officer. Also while in the Army, he received a Ph.D. in Business with specialization in Artificial Intelligence and Medical Informatics from the University of Pittsburgh. He has served as Director of Information Systems (CIO) at Walter Reed and Tripler Army Medical Centers in Washington, DC, and Honolulu, HI; CIO of the USAMRMC and Director of the TATRC at Fort Detrick, MD. He was instrumental in developing and implementing numerous Department of Defense medical information systems, initiating a variety of military medical informatics projects, and creating the Army's telemedicine program. Appointed in 2017 as MRMC Capability Manager (CAM) for the new Army research task areas in MED-RAS he led development of a research roadmap, resource allocation

budget submission, and execution plan for those new Army S&T Task areas. He has many publications and has made numerous presentations in all of the areas of his research and project management. He currently chairs the DoD Medical Unmanned Systems and the NATO Human Factors in Medicine (HFM) Autonomous Tactical Evacuation workgroups. He has twice been selected as a finalist for the Jonathan Letterman award for lifetime achievements in the field of military medicine, has had Army Small Business Innovative Research Army Quality Award; a DoD Joint Technology Demonstration-of-the-year Award, and several Prestigious Small Business Administration Roland Tibbetts SBIR Awards. While in the Army, he received the Army Legion of Merit, the Meritorious Service Medal, the Army Commendation Medal, and subsequently, the General Max Thurmond Award for lifetime achievements in the field of Telemedicine.

Dan Irizarry, MD, COL(R), US Army, graduated from Auburn University and earned his medical doctorate at the Uniformed Services University of the Health Sciences. A board-certified family physician with 26 years of active duty service, including over 20 years supporting special operations forces, he has been a medical advisor to combat leaders at the tactical, operational and strategic levels both in the United States and internationally. His final assignment was the Department of Defense's first clinical advisor to the Joint Project Manager for Medical Modeling and Simulation (JPM MM&S). In this capacity, he helped lead combat and hospital-based simulation advance development and acquisition to support training and readiness. He also served as the Defense Health Board's Committee on Tactical Combat Casualty Care's advisor in the area of combat casualty response training technologies and simulation. Today, he provides subject matter expertise in the areas of medicine and medical simulation to a wide variety of clients and practices medicine in Orlando, Florida. Dan also serves on the advisory board of the Global Special Operations Forces Foundation, a 501(c)(3) non-profit organization that aims to build and grow an international SOF network of military, government, commercial, and educational stakeholders in order to advance SOF capabilities and partnerships to confront global and networked threats. Dan lives in Orlando, Florida, with his wife, Kelly and their seven children.

Dr. Donald Jenkins earned a BS in Biochemistry from the University of Scranton in Scranton PA and MD at the Uniformed Services University in Bethesda MD. He performed his surgical residency at Wilford Hall USAF hospital in San Antonio TX, trauma fellowship at the University of Pennsylvania in Philadelphia PA and retired after nearly 25 years of active duty service from the USAF in 2008. As former trauma medical director at the American College of Surgeons verified Level I trauma center at Saint Marys Hospital at Mayo Clinic in Rochester, Dr. Jenkins had oversight for the entire spectrum of care for all trauma patients, from prevention and pre-hospital care to rehabilitation and repatriation. Dr. Jenkins has been the trauma director for the ACS Level I verified trauma center for the United States Air Force (2000-2008), he has been the trauma director for the 44th Medical Command for all medical care in Iraq (2004-2005), helped to develop the Joint Theater Trauma System for the United States Central Command (all of southwest Asia), was the trauma director of the Joint Theater Trauma System (Baghdad Iraq and Bagram Afghanistan 2006), helped develop the Joint Trauma System and was the trauma medical director of the Joint Trauma System (Fort Sam Houston, TX 2007-2008). He was a founding member of the National Trauma Institute and Center for National Trauma Research and served for 8 years on the Defense Health Board. He was also on the inaugural Committee on Tactical Combat Casualty Care and Committee on Combat Surgical Care and remains as an advisor to both groups. He is currently Professor of Surgery, Vice Chair for Quality and Associate Deputy Director of the Military Health Institute at the University of Texas Health Science Center in San Antonio.

Jay A. Johannigman, M.D., F.A.C.S., FCCM currently serves as a contracted trauma surgeon at Brooke Army Medical Center, San Antonio Texas (August 2019). Prior to this, Dr. Johannigman served as the Director of the Institute of Military Medicine at the University of Cincinnati and the University of Cincinnati College of Medicine. He also served as the director of Trauma, Surgical Critical Care & Acute Care Surgery at University Hospital in Cincinnati, Ohio from 2001 to 2017. During his tenure as Division director the group grew for four surgeons to a multidisciplinary group of over forty medical professionals spanning services across two verified trauma centers to include trauma, acute and elective general surgery and surgical critical care. Dr. Johannigman is a native Cincinnatian and graduate of St. Xavier High School. He completed his undergraduate studies at Kenyon College and graduated Medical School from Case Western Reserve University. He subsequently completed a general

surgery residency at University Hospital, Cincinnati, Ohio. From 1988 to 1990, Dr. Johannigman completed a Surgical Critical Care and Trauma Fellowship, also at University Hospital. Dr. Johannigman entered active duty military service at the United States Air Force Wilford Hall Medical Center in 1990. During the ensuing years, he served as Director of the Surgical Critical Care Service as well as Associate Director of the hospital's Trauma Service. In 1994, Dr. Johannigman returned to Cincinnati, Ohio where he has been a member of the Division of Trauma and Critical Care since that time. Most recently in Cincinnati, Dr. Johannigman oversaw the development and American College of Surgeons verification of West Chester Hospital to a Level III trauma center, thus giving the Cincinnati Tristate area a Level I & Level III trauma system. Dr. Johannigman is a member of numerous professional organizations, including a Fellow of the American College of Surgeons, a member of the Eastern Association for the Surgery of Trauma, a member of the American Association for the Surgery of Trauma and the Western Trauma Society. He served as the Chief of Region 5 Committee on Trauma for the American College of Surgeons Committee on Trauma and now serves as the Liaison to the ACS for the TCCC (The Committee on Tactical Combat Casualty Care). Dr. Johannigman is an original member of the Committee on Tactical Combat Casualty Care and also participates as a member of the Committees on EnRoute Care and Surgical Combat Casualty Care. Dr. Johannigman is a Colonel in the Medical Corps of the United States Army Reserves. His most recent deployment was to Forward Operating Base Fenty as a combat surgeon for the 624th Forward Surgical team in Jalalabad Afghanistan (August 2017-January 2018). Prior to this most recent deployment Dr. Johannigman completed six combat tours to southern Iraq and Afghanistan. From August to November of 2003, he served as Deputy Commander of the 332nd AEW/EMEDDS hospital in Talil, Iraq. From January to March 2005, he served as a CCATT team member and from May to July 2006 and January to March 2008 he served as Deputy Commander of the 332nd AEW theater hospital in Balad. His most recent deployment was serving as Trauma Czar at the 455th Hospital Air Base in Bagram, Afghanistan from July thru December 2010 and he deployed once again August 2012 to serve in Afghanistan. Dr. Johannigman has been awarded the Bronze Star, the Army Commendation medal and the Air Force Meritorious Service Award amongst other decorations. With the Air Force he served as a Flight Surgeon. His current assignment is serving in an advisory role to The Uniformed Services Health Sciences University in Washington DC. Dr. Johannigman maintains an active clinical practice across the surgical disciplines of trauma, surgical critical care, emergency general surgery as well as an elective practice in general surgery. Dr. Johannigman has active research interests in pulmonary failure, critical care monitoring and controlled loop ventilation. He is the funded principal investigator on seven active protocols and leads a robust research effort. He has participated in the publication of over one-hundred peer reviewed publications, eighteen book chapters and one hundred abstracts. Dr. Johannigman resides in San Antonio Texas and is the proud father of two young adults, Taylor and Evan.

Dr. Chetan Kharod is a retired Air Force Colonel and is dual board-certified in Emergency Medicine (EM) and Emergency Medical Services (EMS). He has completed sub-specialty fellowships in International Emergency Medicine and EMS/Disaster Medicine. Dr. Kharod served in the USAF for over 26 years. He deployed multiple times to Southwest Asia and other locations worldwide providing Critical Care Air Transport, frontline emergency care, special operations medical support, and leadership of multifunctional combat support teams. He has served as a Special Operations flight surgeon and Squadron Commander. His military experience spans clinical, operational, academic, research, and leadership domains with a variety of emergency response, field oversight, and executive roles. He has extensive prehospital experience in a variety of settings, including medical oversight of special operations medics, independent duty medical technicians, pararescuemen, and combat medics. Dr Kharod has delivered invited talks and keynote presentations in numerous national and international venues. He is a subject matter expert in resiliency advocacy, human performance optimization program development, leadership, and education innovation. He is proud of following in his father's footsteps by serving in the US Air Force. Dr Kharod is dedicated to being an excellent role model for his sons, and is fortunate to be married to the most caring and compassionate wife.

Lisa M Larkin, PhD, is an Associate Professor of Molecular & Integrative Physiology at the University of Michigan. She holds a joint appointment in the Biomedical Engineering Department at the University of Michigan. Dr. Larkin is co-director of the Skeletal Tissue Engineering Laboratory at the University of Michigan and has 28 years of

expertise on musculoskeletal physiology and small and large animal surgical procedures and more than 15 years experience specifically with ligament, tendon, muscle and bone tissue engineering. Larkin, has pioneered methods to co-culture scaffold-free tissue constructs to engineer functional tissues and their interfaces. Dr. Larkin has five patents and two pending patents for her work. She has co-authored 28 peer-reviewed journal papers, 4 reviews and two book chapters specifically on tissue engineering, another 34 on the physiology of muscle. Dr. Larkin is a member of the following societies: The American Physiological Society, Society for Neuroscience, Tissue Engineering Society International, Biomedical Engineering Society, and Orthopaedic Research Society.

Jerry Leverich assumed his current duties as the Director of Fusion & Assessments Directorate for the G2 (Intelligence) of the U.S. Army Training and Doctrine Command (TRADOC) in March 2019. He has served in multiple intelligence positions within the G2 following his retirement from the Army in February 2005. In his current capacity, he is responsible for providing intelligence and operational environment advice and considerations to a wide variety of analytic products for the TRADOC G-2 focused on defining the future operational environment. The directorate provides TRADOC and the Army with multi-disciplined intelligence assessments, briefings and reports required to facilitate training, leadership development, material acquisition and doctrine/concept development for the future U.S. Army. Because of his extensive threat background, Leverich also served as a core member of the Army's Russia New Generation Warfare study team. A career intelligence officer, Leverich retired as a senior all-source intelligence warrant officer after over 22 years on active duty. He served in a wide variety of intelligence assignments culminating as the senior intelligence warrant officer to the US Army Pacific (USARPAC), G2 from 2002 to 2005. During his military career, Leverich held key intelligence assignments from battalion to Corps; at the operational, joint and strategic level including assignments at the Defense Intelligence Agency, the Pentagon and among many embassies in Latin America. His overseas assignments include Korea, Germany and Hawaii. He served in Operations, Desert Shield/Desert Storm, Uphold Democracy, as part of US Army, Europe (FWD) in Taszar, Hungary, he supported the Implementation Force (IFOR) and Stability Force (SFOR) in Bosnia Herzegovina, and supported Operation Enduring Freedom -Philippines (OEF-P). Leverich graduated from Excelsior University in 2007 with a Bachelor of Arts. He earned a Master of Science from Redlands University in 2009. He is a graduate of the Advanced Course at the Army Management Staff College, and has received a Strategic Leadership post graduate certificate from the Darden Business School executive program at the University of Virginia. He is a mentor and graduate of TRADOC's Senior Leader Development Program.

Dr. Travis K. Lunasco is the Director of Human Performance Optimization (HPO) Future Operations and Senior Human Performance Optimization Integrator (HPO-I) at the Consortium for Health and Military Performance (CHAMP). Dr. Lunasco holds a Masters and Doctoral Degree in Psychology and completed his Residency and Post-doctoral Fellowship in Health Psychology at Tripler Army Medical Center in Hawaii. Dr. Lunasco served over 28 years both as a United States Marine and Airman to include combat deployments to Operation DESERT SHIELD AND DESERT STORM (1990-1991), Iraq (2007), and to Afghanistan (2010) in support of Operation ENDURING FREEDOM. Prior to his current position, Dr. Lunasco served in a number of capacities to include clinical provider, program designer and manager, officer-in-charge and director, embedded and organic line asset, operational consultant, author, and educator. He currently resides with his family in Portland, Oregon.

Kazmer Meszaros is the Implementation Manager for the Defense Medical Modeling and Simulation Office (DMMSO) under the Defense Health Agency (DHA) and is responsible to make sure the central program office has continuous support of the 600+ Medical Treatment Facilities across the MHS. He oversees the Operations cell of 7 contract staff, as well as the Analysis, Curriculum Support, Info Technology and Logistics departments within DMMSO. One of his main focus is to assure any requirement that is acquired, has an implementation process that includes metrics & data to make sure there is a good return-of-investment at each facility. In addition, he assures training healthcare providers to deliver safe, effective, patient-centered care with good methods and technologies.

Dr. Edward J. Perkins, a Senior Research Scientist for the U.S. Army Engineer Research and Development Center in Vicksburg, Miss. is focused on Environmental Networks and Genetic Toxicology. He leads an active and diverse

group of scientists using genetics and emerging technologies to investigate chemical effects on to aquatic, avian and terrestrial species; fundamental aspects of biological networks; computational biology; and the development of new approaches in environmental toxicology. Dr. Perkins also advises national and international organizations on Adverse Outcome Pathways and screening chemicals for toxicity.

Colonel Todd Rasmussen completed his medical degree at Mayo Medical School in 1993 and surgical training at Wilford Hall Medical Center on Lackland Air Force Base in 1999. He returned to Mayo for vascular surgery training in 1999 after which he was assigned to the National Capital Area just before 9/11/2001. Soon after, he began caring for injured returning from Afghanistan at Walter Reed Army Medical Center in Washington, DC. In 2004 Colonel Rasmussen returned to San Antonio and deployed to Operation Iraqi Freedom at the Air Force Theater Hospital on Balad Air Base. Following this he initiated a vascular injury and hemorrhage control research and innovation program. He's completed tours as a surgeon in Iraq and Afghanistan. Colonel Rasmussen has led surgical training missions in Morocco, Pakistan and Russia and his research efforts have resulted in 200+ publications, 25 book chapters, 2 textbooks and 4 patents. In 2012 he gave a TED talk on the transformation of military trauma care and its impact on medicine. Colonel Rasmussen served as Deputy Commander of the Institute of Surgical Research from 2010 to 2013 and then directed the larger DoD Combat Casualty Care Research Program at Fort Detrick, Maryland. In 2017 he became Associate Dean for Research at the F. Edward Hébert School of Medicine – "America's Medical School" at the Uniformed Service University where he is Professor of Surgery. Colonel Rasmussen is attending vascular surgeon at Walter Reed National Military Medical Center and consultant vascular surgeon and scientist at the National Institutes of Health.

Harald Scheirich is the Principal Software Engineer and Simquest International LLC. He is the lead architect on SimQuest OpenSurgSim (OSS http://www.opensurgsim.org), responsible for the overall architecture, leading distributed team in the development of the Burrhole and Vascular simulators. Mentoring and developing junior team members, developing and driving towards milestone targets. Amongst other implemented base component system and reflection/serialisation system of OSS. Responsible of OSS graphics subsystem. Responsible for creating the technological concepts and overseeing, implementing and delivering multiple Phase I and II SBIRs that are focused on game-based technologies (e.g. Pandemic Response) and Rapid Trauma Training, and participating in the game design of these SBIRs. For Pandemic response I implemented a parser and runtime system in C++ for the commercially available Dynamics Simulation Package VenSim. Implemented data driven configuration systems for the serious games solution to give instructional designers editing and content creation capabilities for our solutions using C++ and C# inside of Unity 3D. Implemented and delivered the Exsanguinating Limb Simulator (ElSim™) hemorrhage-control system.

Dr. Mary Ann Spott joined the Joint Trauma System in 2006 to lead the establishment of the DoD's first and only trauma system and trauma patient registry. Dr. Spott was responsible for developing the strategic vision for trauma operations across the DoD and was instrumental in building the trauma system from the ground up. As the Deputy Director, Dr. Spott manages all aspects of the JTS and DoD Trauma Registry and its integrated clinical registries and databases. The U.S. Secretary of Defense awarded Distinguished Civilian Award (DCS) to Dr. Spott in Dec 2016 for her outstanding work at the JTS. The DCS Award is the highest recognition the DoD can award an employee, and it is presented to a small number of civilian employees whose careers reflect exceptional devotion to duty and significant contributions of broad scope of policy, scientific, technical or administrative fields that increase effectiveness and efficiency. As Deputy Director, Dr. Spott is the principal Health Informatics Officer. Dr. Spott was awarded the first ever AHIMA e-HIM award for her contributions to the development and implementation of an outcomes and performance improvement software application that is now used in many trauma centers across the United States. Her current responsibilities include coordinating the JTS components across the continuum of care which include prevention, pre-hospital, education, leadership and communication, quality assurance/performance improvement, research and information systems, including the DoD Trauma Registry. She also participates as a subject matter expert for the NATO trauma registry project. Prior to her leadership at the JTS, she was the Associate Director for Management Information Systems and Trauma Registry at Pennsylvania Trauma Systems Foundation and worked at the State Health Data Center, Division of Health

Statistics and Research and Pennsylvania Cancer Registry. Dr. Spott received her Bachelor's Degree in Biology from the University of Scranton and a Master's in Business Administration at Pennsylvania State University where she completed her Master of Science in Information Systems. She also received a Master's Degree in Public Administration from Pennsylvania State University as well as a certificate in Economic Development. She received her Bachelor's Degree in Health Record Administration from York College. Dr. Spott graduated from the Harvard's John F. Kennedy School of Business Senior Executives Fellows Program in March 2010. In 2015, she earned her doctoral degree in Leadership Studies from Our Lady of the Lake University in San Antonio, Texas.

Nicholas Tsantinis began his career with the US Army at the Natick Soldier Research Engineering and Development Center in a science and technology based role conducting materials R&D on individual protection equipment such as body armor, helmets and eyewear. He is a 2007 Graduate of Rensselaer Polytechnic Institute with a dual B.S. in Aeronautical and Mechanical Engineering and a 2014 Graduate of Northeastern University with a M.S. in Mechanical Engineering, In 2013 he moved on to the program management side of armor development with USSOCOM where he has been since.

Michael J. Yaszemski, M.D., Ph.D., is a professor of orthopaedic surgery and biomedical engineering at the Mayo Clinic College of Medicine. Dr. Yaszemski investigates bone, cartilage and spinal cord regeneration using synthetic polymeric scaffolds, cells and controlled delivery of bioactive molecules. Dr. Yaszemski's Tissue Engineering and Biomaterials Laboratory is equipped to perform polymer synthesis and characterization and scaffold fabrication utilizing injectable techniques and solid freeform fabrication techniques. Dr. Yaszemski's research team cultures cell-polymer constructs, studies delivery kinetics of bioactive molecules from microparticles and microparticle-scaffold combinations, and studies these scaffold-cell-biomolecule combinations in vivo. The team investigates musculoskeletal sarcoma biology and works on the controlled local delivery of chemotherapeutic agents to osteosarcoma, chordoma and chrondrosarcoma. His laboratory is fully equipped for molecular biology and bone histomorphometry, with a focus on translational research for current clinical needs.

SPEAKER ABSTRACTS

(Listed in the order that they appear on the Agenda)

John Gandy: Overview of Tactical Combat Casualty Care (TCCC) is a set of trauma care management strategies customized for the combat environment. Since almost 90% of combat fatalities die before ever reaching a military treatment facility (Role 2, Role 3), point of injury care (Role 1) and care during transport to a higher echelon is of paramount importance. The goal of TCCC is to give the first responders, ground medics and flight medics the best chance of sustaining a patient with a potentially survivable wound to the next echelon of trauma care. These strategies focus on aggressively identifying and treating common causes of preventable death on the battlefield and initiating damage control resuscitation if required. Priorities of treatment are divided into three tactically appropriate Phases of Care: Care Under Fire, Tactical Field Care and CASEVAC (Casualty Evacuation) Care. TCCC has been repeatedly proven to dramatically reduce the incidence of preventable deaths on the battlefield and TCCC training is now mandated for everyone in the US military. Although the Joint Trauma System (JTS) has had a standardized TCCC training curriculum since 2013, there is at present no provision in the Department of Defense (DoD) for oversight and quality assurance of TCCC training. Repeated incidents of incorrect messaging and inappropriate training modalities have been reported both by the JTS and the media. Similarly, there is no methodology for ensuring that combat units maintain the TCCC training status of unit individuals and execute it properly on the battlefield. Divided authorities and distributed responsibilities between service Combat Commanders, service Medical Departments, the Defense Health Agency, and the Combatant Commanders create a situation in which no single individual or organization has overall responsibility for this critically important aspect of medical readiness.
Opportunities for improvement in the current combat casualty care status of the US military include:
1) Clearly establishing combat casualty care as a line commander responsibility with oversight at the appropriate level - the Chairman of the Joint Chiefs of Staff.
2) The Service Chiefs should be clearly identified as having responsibility for TCCC training and equipping.
4) Combatant Commanders should be clearly identified as responsible for ensuring that deploying forces are adequately trained and equipped to execute TCCC while deployed in support of combat operations.
5) Combatant Commanders should be clearly identified as responsible for ensuring that battlefield trauma care is properly documented for all casualties and reported to the JTS to enable ongoing performance improvement in combat casualty care.

Jay Johannigman- Continuum of Care:
Will discuss the aspects of provision of care of the wounded soldier from the entry point at Role II (first surgical capability) through and onto the transition to role III (Theater Hospital) and onto Role IV (Regional Medical center). The discussion will include nominal expected capabilities at each role of care as well as the movement of patient(s) from one role to the next via an integrated enroute care system. The current challenges to provision of care will be described and opportunities for improvement will be highlighted

Brian Eastridge: Combat Casualty Mortality:
Death from injury was described as the neglected epidemic of modern medicine by the Institutes of Medicine in 1966. On the battlefield, the challenges of injury care and mortality are substantively compounded. Despite dramatic advances over the last several decades in trauma system development and acute trauma care, including resuscitation of massive hemorrhage, damage control surgery, and technological advances in critical care, the burden of injury on our military remains substantial. The majority of injury mortality occurs in the field prior to medical treatment facility admission. An analysis of pre-hospital mortality during the first 10 years of combat operations in Southwest Asia demonstrated that nearly 90 percent of combat fatalities occur in the pre-hospital phase of care and that approximately 25% of the approximately 4,000 casualties who died on the battlefield prior

to reaching an MTF had injuries that were potentially survivable under optimal circumstances. Of those with potentially survivable injury, 88% succumbed to the effects of hemorrhage. This data dramatically altered the landscape of combat casualty care, emphasizing research and development of strategies to temporize or control life-threatening hemorrhage proximate to the point of wounding. The DoD has identified capability gaps in combat casualty care directly related to combat casualty mortality. Further developing the anatomic and physiologic mechanisms of battlefield injury mortality, particularly within the bounds of context of the injury event, has great potential to remediate these gaps in combat casualty care and revolutionize the Joint Trauma System (JTS). Likewise, this information would be critical to line commanders for mission planning and developing operational risk matricies. In the current state, combat casualty mortalities are reviewed in a near real-time manner assessing potential opportunities for improvement by the JTS. Several significant liabilities exist which limit the value and promulgation of these efforts.

- Ability of Armed Forces Medical Examiner System to perform full autopsy analysis of combat casualty deaths contingent upon staffing and operational tempo
- Ability of JTS subject matter experts to perform comprehensive reviews of battlefield deaths proximate to date of death supported by low operational tempo
- Review and cataloging of combat mortality injury survivability data is not codified by "requirement"
- Leadership have not embraced the value of this information.
- No clear pathway exists to disseminate mortality review assessments to leadership
    - Medical: performance improvement
    - Line: Training, prehospital combat casualty care, operational support

Mary Ann Spott: The Joint Trauma System (JTS) Overview:
The JTS has been in existence for many years, but did not have the congressional authority until NDAA 2017 to directly affect trauma across all combatant commands. The NDAA provides the authority for JTS to be the reference body for trauma. Joint Requirement Oversight Council Memorandums and an organizational assessment have provided guidance on how the JTS is to be enhanced across the global continuum of care. The initiatives require funding and leadership support. There are many challenges and opportunities as the system evolves but the highest quality of care remains paramount.

Lee Cancio: Burns
From a medical and physiological perspective, maximize the probability that the warfighter can accomplish the mission and, if injured, can both survive and return to function as soon as possible.
1. Status: Burns constitute 5-10% of combat injuries and are more common during war at sea and combat involving armored vehicles. During recent wars in Iraq and Afghanistan, use of improvised explosive devices increased the prevalence of burns to over 10% of casualties in the JTTR. Additionally, burns are particularly labor- and resource-intensive and are frequently incapacitating even when non-lethal. During future multi-domain operations vs. near-peer adversaries, burns are projected to be more common, along with a higher rate of inhalation injury. Meanwhile, expertise in burn care is concentrated in burn centers, and within the Department of Defense at the U.S Army Institute of Surgical Research; few deployed medics, nurses, or medical personnel have any experience in burn care. 2. Gap Analysis: Post-burn survival has plateaued over the last 20 years, although significant advances have occurred in techniques and technology for fluid resuscitation, organ support, and rehabilitation. Current gaps include:

(1) Deployable information technology to provide just-in-time know-how and to facilitate determination of burn-wound depth and extent.
(2) Knowledge on the safety and efficacy of burn-shock resuscitation using plasma.
(3) Wound care products that provide protection, pain management, and infection prevention for war fighters with minor injuries.
(4) Massive burns.

a. More rapid skin-culture techniques
b. Bilaminar (dermis/epidermis) cultured skin for grafting massive burns

(5) Deployable extracorporeal organ support.
a. Renal
b. Lung/low-flow
c. Combined lung/renal/other functions

(6) Optimal strategies for prevention of scar contracture through rehabilitation, photonics, and pharmacology.
(7) Knowledge on safety and efficacy of oral resuscitation for austere environments.
(8) Multi-modal pain-management strategies, focusing on analgesia for severe pain without cognitive impairment.
(9) Early detection of infection in injured patients.
(10) Improved pharmacologic, nutritional, and rehabilitation-based strategies for maintenance of strength and lean body mass in injured patients.
(11) Non-antibiotic-based strategies for treatment of severe infections in injured patients.
(12) Strategies for prevention and treatment of PTSD in injured patients.

3. Suggested opportunities for improvement in the following time periods: Refer to Gaps, above

	Near/immediate	5-year	15-year
Gap	1, 5a, 7, 12	2, 3, 4a, 5b, 6, 8, 9, 10, 12	4b, 5c, 6, 8, 10, 11

Donald H Jenkins- Fluid Resuscitation for Hemorrhagic Shock:
Hemorrhage from traumatic injury is a leading cause of mortality in Operation Enduring Freedom/Operation Iraqi Freedom (OEF/OIF). Military operations in Iraq and Afghanistan have provided an understanding of where and how trauma patients die. Most battlefield casualties, who died, did so before reaching a surgeon. To impact the outcome of combat casualties with potentially survivable injuries, strategies must be developed to mitigate shock and hemorrhage. A recent U.S. Army analysis found improved survival if blood products are used to resuscitate patients within 30 minutes of traumatic injury. Blood product transfusion as far-forward to the point of injury has been explored in military medical rotary wing evacuation platforms and Role 1 and 2 levels. The military has been able to push Damage Control Resuscitation (DCR) capability closer to patients for earlier intervention. By extending lessons learned in the combat setting to domestic hemorrhagic shock, prehospital transfusion has expanded rapidly and holds the potential to improve clinical outcomes and disparities of care. Low antibody titer O+ whole blood (LTO+WB) transfusion provides a single step therapy for hemorrhaging patients.

Statement of the problem—the gap

The National Academies of Science, Engineering, and Medicine (NASEM) recently issued a report, "A National Trauma Care System: Integrating Military and Civilian Trauma Systems to Achieve Zero Preventable Deaths after Injury," that identified gaps in the quality of trauma care and outcomes and noted gaps in resuscitation of injured patients with hemorrhagic shock. Delayed initiation of treatment for hemorrhagic shock reduces survival. Currently, resuscitation with blood products, particularly in the rural civilian or prolonged field care setting, is limited due to a lack of resources and knowledge. When military health care providers are not exposed to injured patients routinely, have no access to WB and rarely treat hemorrhagic shock, they will not automatically know to or how to do this in the combat setting. It is routine that military residents rotating at a civilian trauma center administer 1 to 2 liters of crystalloid before administering red blood cells even though LTO+WB is readily available. Cold stored platelets are yet another 'new' product that has been used in a very limited fashion but is safer and more functional than traditionally stored room temperature platelets.

Harald Scheirich- Military Functional Incapacity Scale:
Injury descriptors severity scoring and modeling systems an essential prerequisite to quantifying injury and improving outcome. General injury coding schemes are not well suited for coding an analyzing wounding in the military environment. We introduce the Military Combat Injury Scale (MCIS) which is optimized for combat trauma injuries. Based on MCIS the Military Functional Incapacity Scale (MFIS) allows tactical decision making with regard to the wounded warfighter. MCIS and MFIS are combat injury specific and have been validated against several thousand contemporary combat injuries.

Gary Gilbert- "Army S&T Program in Virtual Health, Medical Robotic Autonomous Systems":
Over the past 20 years the DoD and component services have invested significant amounts of money in research, development, acquisition and fielding of so-called telemedicine, telehealth, or virtual health systems in support of both peace time health care provided in fixed facilities as well as expeditionary care provided to deployed forces. Now, in the wake of more than 15 years counterinsurgency (COIN) operations and the "War on Terrorism" the US military services, both jointly and independently, are realigning their long term strategic goals toward preparing for imposing future conflicts against potential peer adversaries with equivalent or superior component combined military capabilities. Such potential future conflicts will be fought in multiple domains probably without air superiority nor reliable communications; hence success on the battlefield will depend extensively on the capability of potentially isolated maneuver forces to act independently and be self-supported. Moreover, autonomy will be a key enabling technology and force multiplier for maneuver forces and their organic maneuver support and maneuver sustainment elements as well, to include medical. "Virtual", autonomous and unmanned systems have great potential to serve as force multipliers in support of prolonged care and evacuation, especially when sufficient manned systems are not available or denied entry. Recent developments, emerging technologies, and expanded threats associated with multi-domain type operations, especially in cyber security, potential for denied, intermittent, and low bandwidth communications, space-based systems, cloud technologies, artificial intelligence, robotics, and autonomous systems have brought into question the scope and understanding of the scientific and operational discipline of "Virtual Health". Considered by many to essentially be another name for telemedicine, teleconsultation, or telehealth, VH should more correctly be defined as providing or augmenting health care via information technology. In accordance with the 2018 Army Robotic and Autonomous Systems (RAS) Strategy and the 14 December 2018 Army RAS Initial Capability Document, the Army plans to utilize RAS to penetrate high-risk areas. In 2019 the Army initiated two new medical intelligent systems science and technology task areas in Virtual Health and Medical Robotic and Medical Autonomous Systems. Work is underway at the Army Medical Directorate of Concepts and Doctrine, the Army Training and Doctrine Command, the Army Futures Command, the Armed Services Biomedical Research & Evaluation Management (ASBREM) community, and the NATO Human Factors in Medicine Panel to establish capability needs, develop concepts of operation, create research roadmaps, and provide for cross functional collaboration among the services and various applicable communities of interest in both VH and MED-RAS. We will report on both research progress within the Army and the afore-mentioned joint and international efforts to establish requirements, develop and execute research roadmaps.

Gerald Leverich- Future Operational Environments, Gaps, Needs, Opportunities: Operational Environment:
Over the last 18 years the Army has optimized itself for counter insurgency operations in Iraq and Afghanistan. The most recent National Defense Strategy, however, directs the US military to refocus on great power competition. Strategic competition, and the increased potential for large scale combat operations, leads to changes in the character of future conflict, in which increased lethality and speed will have direct impacts on future combat trauma requirements. Compared to last 18 years, and the renewed potential for large scale combat operations, this presentation will discuss past trends in combat trauma, and present future forecasts and their implications for the combat trauma community.

James J. Geracci, MD: Role of Military Line Leadership in Ensuring Excellence in Combat Casualty Care
Who owns battlefield medicine? Who should own battlefield medicine? In this presentation I will use my military career experience as an operational medicine provider and leader at all levels from Army Battalion to Corps spanning more than 27 years and multiple combat deployments to illustrate and punctuate the critical role of military line leadership in ensuring excellence in combat casualty care. I will provide specific examples of line leadership's impact on all aspects (manning, equipping, training, operational planning, and execution) of combat casualty care and how that leadership has been essential to mission success. The presentation will make the case for the critical role that military line leadership plays in not only sustaining and codifying the combat casualty care gains of the past two decades of war but ensuring that the art and science of saving lives and caring for the combat wounded continues to evolve to meet the needs of future battlefields.

Mike Galarneau: Department of Defense Medical Planning Today and Tomorrow: Injury and Treatment Gaps
Department of Defense medical planning has advanced substantially over the last decade. The science has progressed from "back-of-the-envelope" calculations utilizing few empirically derived planning factors to very advanced, complex simulations using highly characterized, objective combat casualty injury and treatment data. Ground combat data generated during overseas contingency operations following 9/11 have, for the first time, allowed sophisticated planning tools to be developed that provide validated and accredited information to US Combatant Commands, services, and their medical Operations Plan developers. The Joint Chiefs of Staff, Office of the Chief of Naval Operations, and the Defense Health Agency (DHA) tasked the Naval Health Research Center to develop joint medical planning tools that have been validated, verified, and accredited for use by all of the services using a unified, comparable approach. These tools, the Medical Planners' Toolkit (MPTk) and the Joint Medical Planning Tool (JMPT), provide scenario-driven, empirically derived casualty estimates, patient stream estimates, theater medical requirements, and detailed medical supply projections. Further, these tools allow simulation of small, regional, or global medical theater laydowns (e.g., points of injury, medical treatment facilities, providers, transportation assets, distances) for ground, sea-based, or combinations of both scenarios. The projected casualty rates and patient stream estimates can then be run through the simulated theater laydown to perform medical systems analysis, operational risk assessment, and field medical services planning. The predictive accuracy of these tools, however, is dependent upon the casualty injury and illness profile. For ground-based scenarios, recent historical data provide a rich source of empirically derived data to develop reasonable casualty type- and frequency-generating algorithms. For sea-based scenarios, there have only been a few recent events to assess the human injury and treatment effects of modern weaponry against the Navy fleet, leading to gaps identified by Joint Staff, DHA, and naval forces. These gaps, including near-peer ballistic missile attacks on ships and the effect of blast propagation through multiple enclosed spaces, the clinical effects of prolonged exposure in the sea prior to rescue, and the potential of chemical, biological, radiological, and nuclear overlay on traumatic injuries will be discussed in terms of casualty type, delayed care, and prolonged field care.
Disclaimer: I am a military service member or employee of the U.S. Government. This work was prepared as part of my official duties. Title 17, U.S.C. §105 provides that copyright protection under this title is not available for any work of the U.S. Government. Title 17, U.S.C. §101 defines a U.S. Government work as work prepared by a military service member or employee of the U.S. Government as part of that person's official duties. This work was supported by the Joint Chiefs of Staff, Defense Health Agency, Office of the Chief of Naval Operations, and the U.S. Navy Bureau of Medicine and Surgery under work unit no. N1214. The views expressed in this article are those of the authors and do not necessarily reflect the official policy or position of the Department of the Navy, Department of Defense, nor the U.S. Government.

Jeffrey Beaubien- Initial, Recurrency, Personalized, Mission Specific Competent Assessment & Team Based Training:
There is a critical gap between the science and practice of learning. For example, even though personalized tutoring is one of the most effective instructional strategies (VanLehn, 2011), many schoolhouses still rely heavily

on the one-size-fits-all "crawl, walk, run" approach. Similarly, despite the fact that nearly 70% of all learning occurs informally on the job (Cerasoli et al., 2018), formal training events still receive the lion's share of organizational attention and resources. Fortunately, the DoD's Advanced Distributed Learning Initiative has recently put forth a vision for the future of learning called the "Total Learning Architecture" (TLA). The TLA represents a paradigm shift away from disconnected formal training events in favor of a continuum of personalized, lifelong learning that spans across time, instructional media, and duty assignments (TLA; Walcutt & Schatz, 2019). The primary purpose of this presentation is to extend several of the TLA concepts with an emphasis on military medical training, education, and lifelong learning. In particular, I will emphasize how individual learning events – such as watching a video demonstration, completing a simulation, or performing a medical procedure (even without performance feedback) – can all be documented using Experience Application Program Interface (xAPI) protocol. Moreover, by capturing every formal and informal learning event as an xAPI learning record, DoD organizations can quickly compile a large corpus of learner data that can subsequently be mined to answer critical questions such as "How many training trials are required to achieve mastery on skill X?," "When should retraining events be scheduled to maintain proficiency?," and "To what extent do simulator fidelity cues actually improve learning-related outcomes?," among others. Currently, these questions are all answered by eliciting Subject Matter Expert (SME) opinion. However, what organization would not want to make these critical decisions based on their own learners' empirical data? The ideas described in this presentation will identify opportunities for helping to realize this vision.

Dan Irizarry- Integration with Line Tactical Training, Synthetic Training Environment (STE) Med Sim:
Training and education establish the foundation for combat trauma care. Lecture based training modalities and experiential learning through actual patient encounters are not meeting today's combat trauma training needs and will certainly need to evolve to meet the demands of a 2035 battlefield. The use of artificial intelligence machine learning platforms and live, virtual and constructive simulation capabilities will be critical to creating an integrated Joint Trauma System with objectively measurable readiness. That system must link point of injury, evacuation and definitive treatment into an efficient, reliable and affordable capability that provides ethical casualty response while operationally supporting a combatant commander's objectives. The presenter will discuss emerging trends and technologies in training and simulation that will have impact on future capabilities, such as the Army's Synthetic Training Environment, necessary to support combat trauma care in 2035.

Todd Rasmussen- How Long Can the Military's Golden Hour Last?
To overcome the challenges that are predicted to be associated with military battle in multi-domain operations (MDO) against a sophisticated nation state, or a near-peer adversary, the U.S. military will have to make system-wide, holistic changes in its three areas:
1. Medical technologies
2. Medical training
3. Expectations of who can be saved from combat injury.
From a practical standpoint, the military's methodology should remain focused on new ways for the DoD Joint Trauma System to extend the "Golden Hour" of survival. It is a useful framework for military and civilian leaders, medical researchers and innovators, and for the U.S. public to understand. However, maintaining U.S. force lethality in future battles, ones in which overmatch and victory are not assured, requires that major changes be made the military's approach to the Golden Hour of survival (i.e. changes from the military's approach to the Golden Hour during the mostly counterinsurgent wars in Iraq and Afghanistan). In this lecture Col Rasmussen will review the history of the Golden Hour framework, remark on its relevance in Iraq and Afghanistan, and discuss how the military can adapt technology, training and expectations to sustain the Golden Hour concept, but in a way that is realistic and that optimizes force lethality and victory.

Michael Davis: Ever Adapting for the Warfighter: Combat Casualty Care for the Future Battlespace
Warfare conducted as part of low-level counter-insurgency and counter-terrorism operations over the past two decades has enabled military medicine to achieve the highest rate of survival from combat-related injuries. A significant factor in this success has been the military's ability to provide lifesaving care within a short time frame after injury known as the "Golden hour". In contrast, military operations projected to occur in the future against peer or near-peer forces will greatly limit access to casualties, casualty evacuation, and the sustainability of medical capabilities. Moreover, global access to technology and scientific talent by adversaries now and in the future will challenge US superiority. In aggregate, it can be anticipated that complexities associated with the future battle space will significantly challenge the military's "Golden Hour" paradigm and thus its ability to maintain a sub-10% case fatality rate. Responding to this challenge and taking measures to maintain high rates of survival and recovery among injured Warfighters requires innovative short and long term solutions with regard to knowledge and materiel products to prevent strategic surprise and sustain/build medical capability and force lethality.

Cord Cunningham: "Who owns battlefield medicine" was questioned first posed by COL(ret) Bob Mabry in discussion about the diffusion of responsibility for battlefield medical care within the DoD and how this creates significant challenges to improvement. This presentation addresses this challenge along with others from his 2014 Military Medicine article with COL(ret) Rob DeLorenzo titled "Challenges to Improving Combat Casualty Survival on the Battlefield." The five challenge areas are 1) Ownership, 2) Data & Metrics, 3) Prehospital and Trauma Expertise, 4) Research and Development, and 5) MHS Hospital Culture. The ownership challenge is found in each of the services medical departments that are primarily responsible for the manning, equipping, and training of their medical personnel but historically were predominantly funded to deliver the healthcare benefit. "Combat arms commanders are neither experts in nor do they have the resources to train their medical providers for forward medical care". Ultimately the Chairman of the Joint Chiefs of Staff owns overall responsibility and this mission needs that level of visibility and prioritization. Dashboards and tracking via Unit Status Report (USR) type mechanisms are opportunities for improvement. Data and metrics are still lacking in the prehospital environment stemming from multiple factors and the opportunity for improvement can come in better material solutions, system processes, and command emphasis alike. Prehospital and trauma expertise are still at critical levels as highlighted in recent news articles and overall service numbers. Reshaping and prioritizing these manning efforts in addition to clearer deployed utilization are all opportunities for improvement in this regard. Research and development is focused to a large degree on material solutions that can improve battlefield survival while excluding significant efforts on training methodology research. As per the SOF truths "humans are more important than hardware" and this should be displayed in our research priorities and is a great opportunity for improvement. Hospital culture and the enormity of the defense health program budget for direct care delivery and the healthcare benefit still seems to overshadow the importance of combat casualty care. The 43rd Army SG quote we are a "HMO that goes to war" highlights the mission and priority confusion. An opportunity for improvement is further analysis of our prioritization to perform combat casualty care while also supporting the healthcare benefit.

Mary Ann Spott- Data Analysis and Performance Improvement:
Data collection and performance improvement are inextricably linked. The DoDTR serves as the cornerstone of most JTS activities and supports the performance improvement (PI) activities. Data collection on the battlefield for the JTS began in 2006 and became standardized in 2007. The quality of the data is critical to quality PI. The DoDTR has supported multiple clinical practice guidelines, research and policies. This has resulted in improved outcomes for our wounded and also translated to our civilian counterparts in national campaigns. Prehospital data is difficult to document and report, including our canine Service Members. There are many IT solutions that may assist in this data capture and PI, but resourcing remains a challenge.

Ruben Garza and Kazmer Meszaros
DMMSO will provide an overview of types of Simulation technologies from manikins to other training tools. Also, how the DMMS Office was established thru documentation and instructions, as well provide mission statement and organizational structure. Main focus is the DMMSO's central program office established in a joint effort and how the addition of the Air Force, Navy & Army Simulation Programs are set to support the MHS medical facilities to have mission ready, deployable military personnel. In addition, the process on how to submit for simulation requests and how they are validated to a requirement. Lastly, how DMMSO is set to deliver medical training capabilities and partnerships to make this office complete its mission—to have Medically Ready Force…Ready Medical Force.

Travis Lunasco: Human Performance Optimization (HPO)/Total Force Fitness (TFF) Capability-Based Blueprint (CBB) and Targeting System: A Commander's Tool to Realign Service Delivery
Warfighter population represents an impressive degree of diversity in talents and risk exposures across Service branches, their career fields, and units. As outlined in the 2018 National Defense Strategy, future conflicts will require the Military Health System (MHS) to advance business practices from managing illness to supporting Warfighter mission capabilities, mission readiness, and the performance of mission essential tasks. Human Performance Optimization (HPO) and Total Force Fitness (TFF) continues to provide an orientation and framework key to this realignment at all levels. More recently, HPO and TFF have been operationalized for Warfighter communities. The HPO/TFF Capability-Based Blueprint (CBB) and Targeting System provides unit Commanders and their career fields with a tool to inform resource realignment, targeting, and validation of efforts within their respective communities. The information provided by each CBB can also help to synergize MHS realignment efforts. This presentation will examine HPO and TFFs use in MHS realignments efforts, followed by a brief overview of the HPO/TFF-CBB and Targeting System, and concluded with a review of a recently completed HPO/TFF-CBB Workshop and Targeting System Report (USAF 1U Sensor Operators) being used realign, target, and validate embedded and installation services at Creech Air Force Base.

Chetan Kharod: Cutting Edge Concepts in Human Performance Optimization: Lessons Learned from the US Special Operations Community
Objectives:
1. To describe the human stress response and how to recognize its effects
2. To define 4 domains of resiliency development common to all professions
3. To demonstrate several techniques of real-time threat stress control
"Humans are more important than hardware"…what can we do to protect ourselves from and to overcome the cumulative physical and emotional strain of frontline service? The US Special Operations Command empowered an interdisciplinary team to build and implement innovative solutions to improve the well-being of the force and their families. In this presentation, hear from one of the key leaders in the AF Special Operations' human performance optimization programs and learn how those mind-body-spirit solutions can be applied to your organization.

Karen Daigle: Practical Application of Military Human Performance Programs
Although the DoD has developed a framework for understanding, assessing, and maintaining Service Members' wellbeing and sustaining their ability to carry out missions, the application of this framework to military human performance (HP) programs has been disjointed. This presentation describes current gaps in human performance programs' approach to unit mission preparedness including a lack of integration and synchronization within the disciplines of HP programs and the disproportionate emphasis on select components of each preparedness domain. Obstacles to human performance program success include competition between various funding sources and the perceived "ownership" of domains by specific disciplines/professionals. Also

addressed are opportunities for improvement including ensuring position descriptions and performance work statements for HP program medical professionals place emphasis on being present with Soldiers where they work and train over RVU generation, providing training for military leadership and HP program team members on scopes of practice, focusing human performance education timing and type on METL crosswalk and training plan/ operational calendar, recognizing the importance of team and unit relationships and culture to program effectiveness, determining unit-specific professional to population ratios, and providing adequate management structure to all program echelons. The effects of HP programs on combat trauma care include the potential decrease in musculoskeletal injury and expedited injury recovery and return to mission readiness as well as potential decrease in suffering trauma during missions by Soldiers optimally prepared to perform their mission tasks.

Rick Tsantinis: Improvements to PPE & Warfighter Survivability Based on Real-Time Combat Trauma Information
Historically, advancements in body armor and individual protection technology has been at an evolutionary pace. Small gains in weight, performance and cost have been made every few years. Armor testing methodologies and requirements have generally been informed by the performance of legacy equipment and not tied to operationally-relevant medical data. In order to continue the advancement of individual protection equipment and ensure the operational relevance of said equipment a tool is required. This tool would be statistically-based and allow for analysis of real-time combat trauma information to inform both material and combat developers in their requirements generation process.

Luke Burnett: The field of biomaterials and bioengineering is a critical component of the regenerative medicine triad of cells, materials and growth factors that will likely be required to engineer the replacement tissues of the future for the warfighter. Though prevailing dogma holds that optimal tissue engineering solutions will require each of these components, the commercial and clinical activity of regenerative medicine is completely dominated by cell and gene therapy products. Despite significant advances and the development of hundreds of different biomaterials optimized for various tissue environments, there are only a handful that have any human clinical experience, and almost none that have moved from the clinic to the market. This lack of clinical and commercial experience for new materials has hindered the potential of cell based therapies, as they continue to be used with either collagen or PBS injection strategies given the FDA familiarity with these “carriers”.
Over the last two decades, combat injuries have become more significant and require more advanced treatment strategies for repair. However very few of the regenerative medicine technologies that have received significant DoD funding have resulted in products that can repair or regenerate warfighter injuries, decreasing return to duty rates and increasing long-term rehabilitation costs. Material solutions exist that have significant clinical potential, and when combined with cell and growth factor/drug treatments, have the potential to finally realize the promise of regenerative medicine. This promise is to develop solutions that provide functional repair to tissue injury so that US service personnel can return to the fight or regain lost quality of life. Sadly without new strategies, this promise remains a long way off.

Robert Christy: Next Generation Dressing for Burn and Soft Tissue Injuries
Burn trauma-related challenges in MDO have the potential to substantially impact the tactical advantage of the fighting force, and significantly contribute to both loss of life and reduced force mobility due to the large logistical footprint of current capabilities to sustain severe burns casualties. New biomaterial based dressing and biodegradable treatments that can be applied on the battlefield must be developed. These new dressing must be able to minimize evacuation needs while maximizing combat effectiveness of units with severely burned casualties during PC scenarios. Advanced wound based solutions must allow treatment at point of need, be easy to use and reduce the need for surgical interventions. Initial wounds care biomaterial solutions should prevent infection and detoxify the burn with definitive care solutions should prevent burn conversion, provide wound coverage and temporize the wound to allow rapid functional recovery.

Lisa Larkin: End-stage organ failure or tissue loss is one of the most devastating and costly problems in medicine. Limitations associated with tissue donation such as tissue availability, donor site morbidity, and immune rejection has led investigators to develop strategies to engineer tissue for replacement. The creation of engineered musculoskeletal tissues will not only restore the function of complex tissues such as muscle, tendon, ligament, bone and nerve following traumatic injury, but can also be used as a model for studying developmental biology and tissue level pharmacology. Dr. Larkin directs a laboratory the Skeletal Tissue Engineering Laboratory (STEL) at the University of Michigan that has developed a scaffold-less method to engineer three-dimensional (3D) muscle, nerve conduit, tendon, bone and ligament constructs from primary, bone marrow stromal cells (BMSCs) and adipose stem cells (ASCs). The research aims of STEL are to fabricate 3D musculoskeletal tissues, interface the tissues and evaluate the structural and histological characteristics, implant the tissues in vivo to expose them to the actual mechanical and biochemical environments of a hind limb, evaluate alterations in the structural, functional and histological characteristics of the tissues in response to strain-shielded and unshielded mechanical environments, and utilize the engineered tissues for tissue repair and replacement.

The New York Times

Botched Medical Procedures May Have Led to Death of U.S. Soldier

Staff Sgt. Alex Conrad, 26, died from wounds he received during a militant attack on a small outpost in Somalia.

By Thomas Gibbons-Neff

Oct. 11, 2019

A complex and difficult medical procedure that ultimately failed might have contributed to the death of an American Special Forces soldier killed last year in a firefight in Somalia, according to an investigation into the episode obtained by The New York Times.

The redacted Army investigation illustrates the intense violence that can accompany the Pentagon's quiet "train, advise and assist" missions in distant corners of the globe, and the limitations of the American military despite its ambitious reach, vast resources and extensive training.

Staff Sgt. Alex Conrad, 26, died from wounds he received during an attack on June 8, 2018, at a small outpost near the town of Jamaame, about 200 miles southwest of Mogadishu, the capital. He was hit with shrapnel from a mortar round, peppering his face, neck, stomach and legs, starting an hourlong effort to save his life. Three other Americans and a Somali soldier were wounded in the attack by militants from al Shabab.

The investigation's documents also highlight the disparity in resources between different countries overseen by the American military command in Africa. Failures from the Oct. 4, 2017, ambush in Niger that left four American soldiers and five Nigeriens dead pointed to a lack of medical evacuation support, overhead surveillance and intelligence about their enemy.

But despite the influx of resources in Somalia, where troops there had medical helicopters minutes away and drones orbiting above them, the Shabab militants still managed to organize a rapid and deadly attack that killed Sergeant Conrad before they quickly disappeared back into the underbrush without detection.

Around 2:45 that afternoon, minutes after small-arms fire was directed at the American and Somali outpost, mortar fire landed within the position. The firefight was fast and intense. The blasts from the mortars immediately wounded Sergeant Conrad and the three other Americans.

Sergeant Conrad in Somalia last year, in an image provided by his family.

As the Americans scurried to tend to the wounded, Sergeant Conrad complained about the pain from the injury in his left leg, the documents say. Although he was still alert, blood from the wound in his jaw was slowly suffocating him. Ultimately, the team's medic performed a surgical cricothyrotomy, in which he would cut into Sergeant Conrad's neck — at his cricoid membrane — before inserting a

tube that would allow unobstructed air to flow into his lungs.

The medic, whose name was redacted in the report, noted the spot with a marker before making a vertical, then horizontal, incision. Sergeant Conrad twice dislodged the tube, labeled in the report as a Shiley tube. The team's medic tried at least once to make his initial incision longer in an effort to open the newly made airway.

Sergeant Conrad was still breathing when he was loaded in a truck to rush him to the landing zone. Two HH-60 Pave Hawk helicopters, crewed by elite Air Force pararescue medics, were racing from a larger American base outside the town of Kismayo, roughly 40 miles away. The helicopters arrived about 15 minutes after the Americans called for the medical evacuation.

Three of the wounded Americans, including Sergeant Conrad, were loaded onto one of the Pave Hawks, where those aboard began their own assessment. One of the pararescue team members started using a bag valve mask to push air into a newly inserted tube that was placed in the same incision made by the Green Beret's medic. The Air Force medic noted that "the compression of the bag valve mask had become more difficult."

At around 3:15, the flight arrived back at Kismayo, where a surgical team was waiting. Sergeant Conrad was pronounced dead about 15 minutes later.

The investigation found that "although fully qualified medical personnel made multiple attempts to establish an airway via surgical cricothyrotomy" on Sergeant Conrad "after he received his injuries, no incision was made through the tissue plane into his airway. This might have contributed to SSG Conrad succumbing to his injuries."

To be sure, a cricothyrotomy in a combat zone is fraught with hazard and is often a last-ditch effort to help someone's breathing. Even in a controlled environment, such as a hospital, the procedure is extremely challenging.

"The attempted procedure under the conditions that existed on June 8, 2018, was extraordinary in itself," the report says. An addendum to the investigation stated that the Special Operations Command that oversees operations in Africa, and subsequent units, had already moved to review medical training related to the procedure.

Ultimately, the investigating officer concluded that no "individual, unit or organization acted in a negligent manner" during the operation and ensuing medical care.

The American military's Africa Command had no immediate comment on the investigation.

The Green Beret team's mission on June 8, alongside their Somali counterparts, was to push into Shabab-held territory, where the militants had been instigating attacks from, and build the small base that would later be renamed after Sergeant Conrad.

Sergeant Conrad, from Chandler, Ariz., joined the Army in 2010 and was trained to interact with local populations to glean information about militant groups. He had been to Afghanistan twice before finding himself attached to a Green Beret team from Third Special Forces Group in Somalia. When he was killed, his team had less than a month left on their deployment. He was posthumously awarded a Bronze Star with valor for running out in the early minutes of the firefight on June 8 and ushering a civilian linguist to safety.

The Shabab, an extremist group that has long tried to overthrow Somalia's Western-backed government, has lost much of the territory it once controlled, but Pentagon officials fear the group still might be growing in Somalia and elsewhere in East Africa. Last month, Shabaab militants attacked a Somali air base used by American forces with multiple car bombs, injuring civilians there.

About 500 American troops are in Somalia, and they are mostly Special Operations units. Last year, after a broad review under Jim Mattis, the defense secretary at the time, the Pentagon announced that it was reducing the number of troops on the continent. In 2017, a member of the Navy SEALs, Senior Chief Petty Officer Kyle Milliken, was killed and two other American troops were wounded in a raid 40 miles west of Mogadishu.

The focus on providing emergency medical care to wounded troops in what is called "the golden hour" has long been a concern of Defense Department officials, especially during the height of combat in the wars that followed the attacks of Sept. 11, 2001. As defense secretary in 2009, Robert M. Gates became concerned that the rugged terrain and vast distances of the Afghanistan war zone were keeping wounded troops from reaching hospital care within 60 minutes.

Mr. Gates ordered more helicopters to Afghanistan to evacuate wounded troops, and directed that helicopters previously set aside for rescuing downed pilots be reassigned to medical evacuation. Mr. Gates also increased the number of field hospitals.

A peer-reviewed medical study published in 2015 found that those initiatives saved an estimated 359 lives from June 2009 to March 2014. Applying the same standard to operations elsewhere has proved difficult, as was evident in the ambush in Niger.

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Deployments Sap Surgeons' Skills

Military push to station surgeons wherever casualties may occur keeps them out of the operating room.

By **Steve Sternberg** Assistant Managing Editor, Health Initiatives

April 19, 2018, at 12:00 p.m.

Studies of the operative logs of surgeons deployed to Afghanistan, Iraq, Kuwait, Egypt's Sinai Peninsula and Africa show that many perform less than one operation – and may encounter less than one patient – per month. (GETTY IMAGES)

IN AN ERA WHEN CLASHING armies have given way to drone strikes and targeted special-forces operations, surgeons may be deployed in remote forward units for months and perform only a handful of operations. The smaller, targeted engagements of today produce far fewer casualties, leaving surgeons to file reports and help out on the motor pool, while their skills erode.

interviewed by U.S. News, requested anonymity because he fears retribution from military higher ups.

"I understand why generals, whose soldiers are kicking down doors, want surgeons nearby in case they get shot, " the surgeon says. "I want to be there, but I don't want to be there if I'm not operating."

The deployments reflect the military's determination to assure that seriously injured combatants are evacuated to a major medical center as quickly as possible. But the long deployments sideline military surgeons who were already struggling to perform enough procedures to sustain their proficiency, because active-duty personnel and their families are relatively young and healthy and less likely to need routine surgery.

Today's forward surgical unit might consist of a single surgeon and three or four other personnel with just enough instruments to pack into their rucksacks. Their mission is to stabilize wounded combatants for transport to other surgeons waiting at major medical centers, such as Landstuhl Regional Medical Center, in Germany. The system is geared to get severely injured patients into the operating room within the so-called "Golden Hour," a standard established by the Department of Defense in 2009.

Prompt medical transport increases the odds that combatants will survive until they reach the hospital, but there's no evidence that this approach improves the eventual outcomes of care, writes Army Col. Mary Edwards, a surgeon at San Antonio Military Medical Center, in a commentary published online this month by the Journal of the American College of Surgeons.

minimized damage control teams or surgeons kept on standby to deploy in this capacity," Edwards and her colleagues write.

Some surgical teams are in such remote locations that they struggle to accomplish such basic tasks as sterilizing their instruments. Given these constraints, Army Forward Surgical Teams and other such units must conserve resources for combatants with life- or limb-threatening injuries.

Studies of the operative logs of surgeons deployed to Afghanistan, Iraq, Kuwait, Egypt's Sinai Peninsula and Africa show that many perform less than one operation – and may encounter less than one patient – per month. Their inaction has implications that reach back into operating rooms in the United States.

"We're least ready when we get back from deployment, because we haven't really operated," says Edwards, who carried out the study of deployed surgeons' caseloads.

Edwards participated in a task force in 2016 that laid out a plan designed to enable military surgeons to sustain their skills. The pillars of the plan are:

- Core surgical competence. Basic credentials, training and skills necessary to carry out battlefield surgery.
- Basic and advanced medical combat readiness skills. The capabilities necessary to treat patients injured in a war zone.
- Mission-specific medical readiness skills. Any special skills needed for a particular mission, such as caring for patients in the field or treating victims of a chemical weapons attack.

And even before the surgeons are deployed, they struggle to prepare for the types of injuries they see on a battlefield. Edwards and other surgeons acknowledge that the Military Health System lacks enough cases of sufficient complexity to train surgeons for the carnage of war. Troops believed to fight harder if they can expect top-flight care when they're injured may not realize that military surgeons themselves are gravely concerned about their increasingly limited operative and trauma experience.

"We get very little trauma experience," says Dr. Benjamin Starnes, chief of vascular surgery at the UW Medicine – Harborview Medical Center, in Seattle, who served as an Army surgeon for 15 years with three combat tours. "Yet we're thrust into a battlefield environment, and we're expected to take care of patients with blast injuries that you never see in civilian medicine."

The 2017 Defense Authorization Act calls upon the military to embed more military surgeons in civilian hospitals. Partnerships are especially prized with hospitals that have level-one trauma centers, those prepared to take patients with the most severe injuries. The Department of Defense has just one level-one trauma center, the Army's San Antonio Military Medical Center, and it competes for patients with the University Hospital's trauma center just 16 miles away.

Some partnerships are already in place. The Navy, with its heavily populated coastal bases, has long-standing relationships with Sentara Norfolk General Hospital near the Portsmouth Naval Base and with Scripps Mercy and Sharp Memorial hospitals near the San Diego Naval Base, says Navy Surgeon General C. Forrest Faison. As for the Air Force, Surgeon General Mark Ediger says, "Eighty-five percent of our trauma surgeons are permanently embedded in trauma centers in the U.S., most of them outside the department of defense."

hospitals – Norfolk Norwich University Hospital, Cambridge University Hospital, and West Suffolk NHS Foundation Trust Hospital – where surgeons work side-by-side with British colleagues on a variety of surgical patients, including those who have suffered major trauma.

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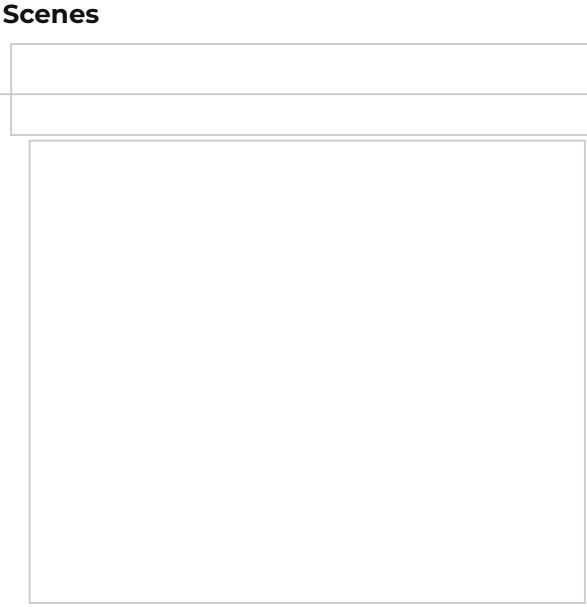

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Two Decades of Saving Lives on the Battlefield: Tactical Combat Casualty Care Turns 20

Frank K. Butler, MD, FAAO, FUHM

ABSTRACT Background: Twenty years ago, the original Tactical Combat Casualty Care (TCCC) article was published in this journal. Since TCCC is essentially a set of best-practice prehospital trauma care guidelines customized for use on the battlefield, the presence of a journal with a specific focus on military medicine was a profound benefit to the initial presentation of TCCC to the U.S. Military. Methods: In the two ensuing decades, which included the longest continuous period of armed conflict in our nation's history, TCCC steadily evolved as the prehospital trauma care evidence base was augmented and as feedback from user medics, corpsmen, and pararescuemen was obtained. Findings: TCCC has taken a leadership role in advocating for battlefield trauma care advances such as the aggressive use of tourniquets and hemostatic dressings to control life-threatening external hemorrhage; improved fluid resuscitation techniques for casualties in hemorrhagic shock; increased emphasis on airway positioning and surgical airways to manage the traumatized airway; faster, safer, and more effective battlefield analgesia; the increased use of intraosseous vascular access when needed; battlefield antibiotics; and combining good medicine with good small-unit tactics. With the continuing assistance of Military Medicine, these advances and the evidence base that supports them have been presented to TCCC stakeholders. Discussion/Impact: Now—20 years later—TCCC has been documented to produce unprecedented decreases in preventable combat death in military units that have trained all of their members in TCCC. As a result of this proven success, TCCC has become the standard for battlefield trauma care in the U.S. military and for the militaries of many of our allied nations. Committee on TCCC members and the Joint Trauma System also work closely with civilian trauma colleagues through initiatives such as the Hartford Consensus, the White House Stop the Bleed campaign, and the development of National Association of Emergency Medical Technicians TCCC-based courses to ensure that advances in prehospital trauma care pioneered by the military on the battlefield are translated into civilian practice on the streets of America. Active shooter incidents, terrorist bombings, and the day-to-day trauma that results from motor vehicle accidents and criminal violence create the potential for many additional lives to be saved in the civilian sector. Along with the other components of the Department of Defense's Joint Trauma System, the Committee on TCCC, and the TCCC Working Group have been recognized as a national resource and will continue to advocate for advances in best-practice battlefield trauma care as opportunities to improve are identified.

This article is dedicated to Dr. Norman McSwain, one of the central figures in the development of Tactical Combat Casualty Care (TCCC). Dr. McSwain was a giant in trauma surgery, a world leader in prehospital trauma care, and a friend to everyone that he met. After the initial connection was made between Dr. McSwain and TCCC through VADM Mike Cowan, then the Commander at the Defense Medical Readiness Training Institute in San Antonio, Texas, Dr. McSwain subsequently became a powerful contributor to and advocate for the evolving concepts of TCCC. Both the clinical and the organizational advances that TCCC has experienced over the last 20 years are due in large measure to this remarkable surgeon and inspirational leader.

Committee on Tactical Combat Casualty Care, Joint Trauma System, U.S. Army Institute of Surgical Research, Joint Base San Antonio, San Antonio, TX 78234.

The opinions or assertions contained herein are the private views of the author and are not to be construed as official or as reflecting the views of the Department of the Army or the Department of Defense.

This document was reviewed by the Director of the Joint Trauma System and by the Public Affairs Office and the Operational Security Office at the U.S. Army Institute of Surgical Research. It is approved for unlimited public release.

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INTRODUCTION

Twenty years ago, the original TCCC article was published in this journal. Since TCCC is essentially a set of best-practice prehospital trauma care guidelines customized for use on the battlefield, the presence of a journal with a specific focus on military medicine was a profound benefit to the initial presentation of TCCC to the U.S. Military. The novel concepts that the original TCCC article presented were very different from both military and civilian prehospital trauma care practice at the time. Since TCCC was developed specifically for use on the battlefield, the large armed services readership of Military Medicine made it the perfect journal for publication.

TOURNIQUETS RECONSIDERED AND THE NEED FOR TCCC

The need for TCCC was first brought to light by the recognition of a striking paradox in military prehospital trauma care in the early 1990s. Extremity hemorrhage had been documented to be a leading cause of preventable death among combat casualties in Vietnam.[1] If the 7.4% incidence of death from extremity hemorrhage as a percentage of total combat fatalities in Maughon's study (193 out of a cohort of 2,600) is extrapolated to the total number of U.S. military deaths in

Vietnam (46,233), then the estimated number of preventable deaths resulting from extremity hemorrhage in that conflict would be 3,421, a staggering figure. The U.S. Military had neither a Department of Defense (DoD) Trauma Registry nor a functioning trauma system during the Vietnam conflict, so no one was tracking the number of preventable deaths from extremity hemorrhage during that war and, therefore, no one was undertaking corrective action. Even after the conclusion of hostilities in Vietnam, there continued to be no corrective action in the military, despite the writings of Maughon and COL Ron Bellamy that documented this large number of potentially preventable deaths.

Well-designed tourniquets can unquestionably stop extremity hemorrhage and prevent loss of life from this cause, as long as the tourniquet is applied quickly and the source of the hemorrhage is not so proximal on the limb so as to preclude the use of extremity tourniquets. Despite this fact, tourniquet use was strongly discouraged in both military and civilian prehospital trauma care courses in 1992 because of the fear that tourniquets would cause ischemic damage to limbs. Completely ignored in this contention was the fact that tourniquets are used routinely during orthopedic surgical procedures and ischemic damage is not sustained in that setting as long as the tourniquet application time is limited to acceptable norms. The aversion to tourniquet use in 1992 was therefore neither evidence-based nor logic-based—but it was nearly universal and over 3,000 U.S. soldiers likely paid for this mistake with their lives in Vietnam.

After the 1992 realization by the Naval Special Warfare (NSW) Biomedical Research Program that this aspect of prehospital trauma care was in error and needed to be revisited, a subsequent review of the pertinent literature revealed that there were many other elements of prehospital trauma care as it was practiced at that time that were not well supported by the available evidence—fluid resuscitation, spinal precautions in penetrating trauma, battlefield analgesia, prehospital cardiopulmonary resuscitation, and management of the traumatized airway, to list a few. Additionally, most Special Operations medics at the time were being taught to do procedures such as venous cutdowns, pericardiocentesis, and tube thoracostomy at the point of injury despite a lack of evidence for the benefit of these procedures when performed by combat medical providers on the battlefield.

A research effort was therefore undertaken to systematically review the elements of battlefield trauma care as it was being practiced at the time and to make recommendations for improvements as indicated. This project was initiated as a combined effort of the Naval Special Warfare Command and the Uniformed Services University of the Health Sciences; it was later expanded to include all of the components of the U.S. Special Operations Command.

In addition to an exhaustive relook at the evidence base for prehospital trauma care recommendations, all of the newly proposed interventions were considered in the context of the lethal chaos of the battlefield. In this setting, preventing additional casualties and successful completion of the combat mission at hand must also be given weight.

Factors specific to the battlefield include (1) the fact that the enemy may be actively shooting at you while care is being rendered—which requires that care be rendered selectively and expeditiously; (2) interventions should be strongly focused on the leading causes of preventable death in combat—hemorrhage, airway obstruction, and tension pneumothorax; (3) evacuation times may be much longer than those seen in urban Emergency Medical Services systems; (4) combat medics are well trained, but those serving in ground units often have much less trauma care experience than civilian Emergency Medical Services personnel; (5) there are often multiple casualties sustained in a single incident; and (6) combat medics may be required to care for their casualties in challenging environments—deserts, mountains, water, night operations—and must have a plan of care that accounts for those conditions.[2]

Also, since battlefield trauma care will be provided by combat medical personnel, the input of military medics, corpsmen, and Air Force pararescuemen (PJs) was essential to this re-evaluation of battlefield trauma care standards and extensive input from these communities was obtained.[2] At the end of this process, the draft of the original TCCC guidelines was sent out to 26 volunteer reviewers from the surgical, emergency medicine, and critical care communities and their feedback considered and incorporated as appropriate. The article as published in Military Medicine in 1996 thus contained a unique set of prehospital trauma care guidelines that combined good clinical medicine with good small-unit tactics to the greatest extent possible.

BEGINNINGS

Shortly after the publication of the 1996 TCCC article, the concepts of TCCC were presented to MG Les Berger, then the surgeon for the Chairman of the Joint Chiefs of Staff. He subsequently arranged for a summary of these concepts to be presented to both the Senior Military Medical Advisory Committee and the Defense Medical Oversight Committee, two groups of very senior leaders in the DoD. Both groups had a generally favorable response to the information presented, but no specific plan of action emerged from the briefings.

Subsequently, the initial set of TCCC guidelines were presented at a series of both military and civilian medical conferences to introduce these new concepts and to obtain feedback from a variety of medical audiences on the recommendations that they contained.

COL Bob Mabry has outlined the challenges inherent in trying to effect changes in battlefield trauma care in the U.S. Military.[3] Although the initial series of presentations was well received and had not revealed any significant conceptual errors in the TCCC recommendations, there was no DoD-level effort to revamp prehospital combat casualty care practice.

A unit-by-unit introduction program was therefore launched. TCCC was briefed to Rear Admiral Tom Richards, the Commander of the Naval Special Warfare Command, who approved the TCCC Guidelines for use in the NSW community in 1997. TCCC was subsequently presented to the leadership of the 75th Ranger Regiment, the Army Special Missions Unit, and the Air Force Pararescue community. These units and a few other innovative units scattered throughout the military were the only users of TCCC at the start of the war in Afghanistan.[4]

THE COMMITTEE ON TCCC AND THE TCCC WORKING GROUP

The group responsible for the advances made in TCCC beyond the original guidelines published in 1996 has been the Committee on TCCC (CoTCCC).[4] The original TCCC article noted that it was essential to establish a process to update the TCCC guidelines as required by experience, new evidence, and new technology. This need became more pressing with the onset of hostilities in Afghanistan in October 2001. That war, followed in 2003 by the U. S. invasion of Iraq, created a steady flow of casualty information that required collection, evaluation, processing, and corrective action as needed. Further, the recognized presence of preventable deaths among our nation's combat fatalities in the early years of the war[5] imparted additional urgency to this effort.

The CoTCCC was first funded as a medical research effort by the U.S. Special Operations Command (USSOCOM). Through the efforts of CAPT Doug Freer and CAPT Stephen Giebner, the CoTCCC was first established at the Naval Operational Medicine Institute in 2001. The members of the CoTCCC are all volunteers who perform their committee activities in addition to their other duties as military or government employees. The membership includes trauma surgeons, emergency medicine physicians, combatant unit physicians and physician assistants, and combat medical educators. Also—and of critical importance—the group includes combat medical providers. In accordance with both tradition and charter, the CoTCCC must have no less than 30% of its membership comprised of active or former combat medics, corpsmen, and PJs. The 42 members of the CoTCCC include representation from all of the U.S. armed services and, at present, every one of its members has deployed in support of combat operations. Additionally, national leaders in trauma care such as former U.S. Surgeon General Richard Carmona and former Chair of the American College of Surgeons Committee on Trauma David Hoyt have contributed their time and expertise as CoTCCC members.

The CoTCCC was moved in 2007 to the Defense Health Board at the direction of Ms. Ellen Embry, acting Assistant Secretary of Defense for Health Affairs at the time; the CoTCCC was subsequently moved by the Undersecretary of Defense for Personnel and Readiness to the Joint Trauma System (JTS) in 2013. The JTS is located at the U.S. Army Institute of Surgical Research. Despite being located at an Army command, the JTS presently serves as the lead agency for trauma care in the DoD and provides trauma care recommendations to all of the services in the U.S. Military as well as to the Geographic Combat Commands. Experience has shown that the JTS is clearly the right place for the CoTCCC to function optimally. Figure 1 is the CoTCCC logo.

It is through the untiring efforts of the CoTCCC—and its liaison members from allied nations, interagency partners, and various military organizations that collectively comprise the TCCC Working Group—that TCCC has been regularly updated as new medical technologies have become available and combat trauma experience has been gained throughout 14 years of war.

The CoTCCC communicates its recommendations on battlefield trauma care in several ways designed to meet a variety of needs. The TCCC Guidelines present the basics of TCCC in an outline form. The TCCC Curriculum is designed to convey the elements of TCCC in a format suitable for training combat medical providers. The TCCC chapters in the Prehospital Trauma Life Support (PHTLS) textbook present a discussion of the evidence base that supports the current TCCC recommendations.[6] The latest addition to the TCCC knowledge products is the publication of a position paper for each new change to the TCCC Guidelines in the Journal of Special Operations Medicine. This series of articles (presently 11 in all) provides an in-depth discussion of each new TCCC recommendation with an expanded review of the evidence base for the change. Since the Journal of Special Operations Medicine is included in the Index Medicus, the TCCC change papers published in that journal become a permanent part of the medical literature.

FIGURE 1. CoTCCC Logo.

CLINICAL ADVANCES IN TCCC

The evolution of the interventions recommended in TCCC since the original TCCC guidelines has been well documented in the position papers mentioned above and in other publications[4,6,7] and the evidence base for the current TCCC guidelines will not be re-presented in this article. It is noteworthy that current TCCC methodology includes a monthly PUBMED search focused on interventions that are—or potentially could be—used in the prehospital setting. Thus, the evidence base presented in the publications noted above includes studies from the civilian sector as well as from the military. The state of the art in battlefield trauma care in 1992 (before TCCC) is summarized in Table I. The recommendations in the current TCCC guidelines are shown in Table II. The reader will note that there is very little overlap between these two sets of recommendations, indicating how far prehospital trauma care has evolved through the TCCC best-practice guideline development methodology.

CHANGING THE CULTURE IN BATTLEFIELD TRAUMA CARE

Hundreds of people have played key roles in moving TCCC forward from publications into military medical practice over the past 2 decades. Dr. Norman McSwain was one of the first when he established the link between the nascent TCCC effort and PHTLS in 1998. PHTLS works closely with National Association of Emergency Medical Technicians (NAEMT) and the American College of Surgeons Committee on Trauma. Inclusion of TCCC in the 4th Edition of the PHTLS textbook was the first step toward mainstreaming TCCC beyond the few Special Operations units that were the original users. There are now 13 TCCC chapters in the Military 8th Edition of the PHTLS textbook. These chapters are maintained primarily by the CoTCCC Developmental Editor, retired Navy Captain, and first Chairman of the CoTCCC, Dr. Stephen Giebner.[6] Dr. McSwain's personal participation as a member of the CoTCCC for over a decade and his steadfast support for TCCC in civilian trauma organizations was invaluable to the TCCC effort and resulted in his being honored by both USSOCOM and the CoTCCC for his contributions to improving battlefield trauma care.

COL John Holcomb, at the time the Commander of the U.S. Army Institute of Surgical Research (USAISR) and the Trauma Consultant for the Army Surgeon General, led a team from USSOCOM, USAISR, and the Armed Forces Medical Examiners System that documented in early 2005 that preventable deaths were in fact still occurring at a significant rate, even among elite Special Operations forces.[5] This work and USAISR's subsequent evaluations of commercial tourniquets and hemostatic dressings were largely responsible for USSOCOM mandating TCCC training and equipment for all Special Operations Forces units and for the U.S. Central Command directing that all U.S. Military members deploying to Afghanistan and Iraq be equipped with a tourniquet and a hemostatic dressing. Subsequently, the USAISR was also instrumental in expediting the equipping and training of deploying USSOCOM units through the conduct of the TCCC Transition Initiative. The project, led by SFC Dom Greydanus, also obtained user feedback from the units after their return from combat operations, which provided early documentation of the success of TCCC interventions.[7] It is often difficult to identify precisely which elements of TCCC

TABLE I. Battlefield Trauma Care 1992

Before the development of Tactical Combat Casualty Care, U.S. military medics, corpsmen, and PJs were taught to perform battlefield trauma care in accordance with prehospital trauma courses that were not developed for combat casualty care. Thus their training in 1995 included the following:
To render care on the battlefield with no structured consideration of the evolving tactical situation
Not to use tourniquets to control extremity hemorrhage, even when the hemorrhage was severe enough to be life threatening
To manage external hemorrhage with prolonged direct pressure, thereby precluding the medic from attending to the casualty's other injuries or rendering care to other casualties
No use of hemostatic dressings (not yet fielded for combat medicine)
Two large-bore IVs started on all patients with significant trauma, even if there was no immediate need for fluid resuscitation or IV medications
Treatment of hypovolemic shock with large-volume crystalloid fluid resuscitation (2 liters of Lactated Ringers or normal saline) given as rapidly as possible
No special consideration of traumatic brain injury with respect to oxygenation and fluid resuscitation, specifically the need to avoid hypotension or hypoxia
Management of the airway in unconscious or hypoxic casualties with endotracheal intervention, despite the lack of evidence documenting the efficacy of this intervention when performed by medics on the battlefield
No specific interventions or equipment to prevent hypothermia and the resultant coagulopathy that it causes in combat casualties
Battlefield analgesia was accomplished with IM morphine—a technique that dates back to the Civil War
No use of intraosseous access techniques
No monitoring of oxygenation or heart rate at the point of injury with pulse oximetry; no electronic monitoring capability on Casualty Evacuation platforms
No use of nonparenteral analgesic medications
No administration of prehospital antibiotics for open wounds
No recommendations regarding which casualties might benefit most from supplemental oxygen when it becomes available during evacuation
Spinal precautions were applied broadly to all casualties with significant trauma, without consideration being given to tactical concerns or the mechanism of injury

TABLE II. Tactical Combat Casualty Care—2016

A partial list of the elements of battlefield trauma care as contained in the present TCCC guidelines includes the following:
Phased care in the prehospital tactical environment to ensure that good medicine is combined with good small-unit tactics.
The aggressive use of CoTCCC-recommended tourniquets for the initial control of life-threatening extremity hemorrhage, followed by removal of the tourniquet when feasible in the Tactical Field Care or Tactical Evacuation phases of care
The use of CoTCCC-recommended hemostatic dressings to control life-threatening external hemorrhage from sites that are not amenable to tourniquet use.
The use of junctional tourniquets as an adjunct to external hemorrhage control at junctional bleeding sites (e.g., axilla and groin)
Initial management of the airway in casualties with maxillofacial trauma through having the casualty sit up and lean forward if he or she is able, thus allowing blood to simply drain out of the oropharynx and thereby clearing the airway
Surgical airways using the Cric-Key for airway obstruction when the use of the sit-up and lean-forward position is not feasible or not successful
Aggressive needle thoracostomy with a 14-gauge, 3.25-inch needle for suspected tension pneumothorax
Vented chest seals for casualties with open pneumothoraces
Intravenous access only when required for medications or fluid resuscitation
The preferential use of a saline lock for intravenous access instead of having to have intravenous fluids running to keep the vein open
The use of intraosseous techniques when vascular access is needed but difficult to obtain
Early use of tranexamic acid in the prehospital phase of care (before fluid resuscitation) for casualties in or at risk of hemorrhagic shock
Prehospital fluid resuscitation that emphasizes the use of Damage Control Resuscitation with whole blood or blood components in a 1:1 RBCs:plasma ratio as soon as logistically feasible, even in the prehospital environment
Hypotensive resuscitation with Hextend (Hospira Inc, Lake Forest, Illinois) when blood products are not available
Safer, faster, and more effective relief of pain from combat wounds through the use of the "Triple-Option" approach to battlefield analgesia that emphasizes the use of ketamine and/or oral transmucosal fentanyl citrate lozenges rather than IM morphine for severe pain
Ondansetron for trauma or opioid-related nausea and vomiting
Prevention of hypothermia and secondary coagulopathy with improved technology to prevent heat loss in casualties
The prehospital use of moxifloxacin or ertapenem to reduce preventable deaths and morbidity from wound infections
Tactical scenario-based combat trauma training to help combat medical providers grasp that battlefield trauma care must be consistent with good small-unit tactics and the particulars of each combat situation
The use of the Department of Defense Form 1380 (TCCC casualty card—June 2014) and electronic TCCC Medical After-Action Report to improve the documentation of prehospital care

save lives. An exception to this general statement is tourniquets. COL John Kragh, an orthopedic surgeon at the Ibn Sina hospital in Baghdad documented that 31 lives were saved with tourniquets at his facility in one 6-month period.[8] Extrapolated to all U.S. casualties in Iraq and Afghanistan, these findings indicated that, as of 2008, well over 1,000 U.S. service members' lives had been saved with tourniquets during the recent conflicts without loss of limbs to tourniquet ischemia. COL Kragh's findings indisputably confirmed the lifesaving benefits of one of the most controversial aspects of TCCC and helped to promote the rapid expansion of TCCC acceptance throughout the U.S. Military.[4]

TCCC: THE EVIDENCE FROM 14 YEARS OF WAR

The first published report of the success of TCCC on the battlefield was presented in the Army Medical Department Journal by the surgeon for an Army unit that had participated on the drive to Baghdad at the start of the Iraq conflict.[9] With respect to tourniquets, the author noted that "Tourniquets played a decisive role in quickly and effectively stopping hemorrhage under fire and keeping a number of Soldiers with serious extremity wounds involving arterial bleeding alive until they could eventually undergo emergent surgery at the Forward Surgical Team (FST)." The author concluded that "The adoption and implementation of the principles of TCCC by the medical platoon of TF 1–15 IN in OIF 1 resulted in overwhelming success."[9]

Six years later, COL Russ Kotwal, MSG Harold Montgomery, and their co-authors documented that the 75th Ranger Regiment had achieved the lowest preventable death rate in the history of modern warfare through the implementation of the Ranger First Responder program, which trained all unit members in TCCC.[10] The Army Special Missions Unit also trains every one of its combat troops in TCCC and noted in an unpublished report in 2008 that they too had suffered no preventable deaths among their unit's casualties up to that point in time.[4] The 2011 article by Savage and her co-authors reported that the Canadian Military had achieved its highest casualty survival rate in history and attributed that in large part to training all of their combatants, not just medics, in TCCC.[11] COL Brian Eastridge and his co-authors, in their landmark 2012 article, examined the causes of death for all 4,596 U.S. Military combat deaths occurring from October 2001 to June 2011.[12] The findings in this paper included: 87% of combat-related deaths occurred in the prehospital setting; 24% of those deaths were potentially preventable; hemorrhage is the predominant cause of preventable death on the battlefield; and that the TCCC-led use of tourniquets in the U.S. Military caused the incidence of death from extremity hemorrhage to drop from the 7.8% incidence noted by Kelly early in the wars[13]—which was essentially the same as in Vietnam—to 2.6% of the total combat fatalities by the end of 2011—a 67% decrease in deaths from this cause.

The accumulated published evidence and battlefield experience has at this point in time resulted in all services in the U.S. Military using TCCC to care for their combat wounded. Many allied nations have also embraced these concepts and several have made significant contributions to advancing and improving TCCC concepts.[4]

GOING FORWARD

Through the collective efforts of military medical and line leaders, unit surgeons, insightful researchers, and the heroic actions of thousands of combat medics, corpsmen, and PJs, the U.S. Military has redefined battlefield trauma care. Further, and very importantly, the CoTCCC and the TCCC Working Group have now established a methodology through which the DoD can ensure that battlefield trauma care practice is a continuous learning process that can adapt quickly to new evidence and combat experience.

The challenge now is to preserve the advances that military medicine has made on behalf of our nation's wounded. Medical advances from past wars have been lost in the ensuing peace intervals and the advances made in our recent conflicts may also not be sustained unless definitive steps are taken to ensure that these advances remain lessons learned and do not become lessons lost.[14]

Active shooter incidents, terrorist bombings, and the day-to-day trauma resulting from motor vehicle accidents and criminal violence create the potential for many additional lives to be saved by the use of TCCC concepts in the civilian sector. CoTCCC members and the Joint Trauma System work closely with civilian trauma colleagues through initiatives such as the Hartford Consensus,[15] the White House Stop the Bleed campaign, and the development of NAEMT TCCC-based courses to ensure that advances in prehospital trauma care pioneered by the military on the battlefield are translated into civilian practice on the streets of America. Informing civilian leaders and inspiring changes in civilian trauma care where the military experience suggests that that is appropriate will entail new challenges, new interactions, and new processes—and Military Medicine, the journal that first introduced TCCC to both U.S. and allied militaries, will continue to play a key role in this effort.

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The author gratefully acknowledges the leadership, friendship, assistance, and inspiration of the late Dr. Norman E, McSwain in turning TCCC from a set of promising concepts into many hundreds of lives saved in both the U.S. and allied militaries as well as in the civilian sector.

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Death on the battlefield (2001–2011): Implications for the future of combat casualty care

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BACKGROUND: Critical evaluation of all aspects of combat casualty care, including mortality, with a special focus on the incidence and causes of potentially preventable deaths among US combat fatalities, is central to identifying gaps in knowledge, training, equipment, and execution of battlefield trauma care. The impetus to produce this analysis was to develop a comprehensive perspective of battlefield death, concentrating on deaths that occurred in the pre–medical treatment facility (pre-MTF) environment.

METHODS: The Armed Forces Medical Examiner Service Mortality Surveillance Division was used to identify Operation Iraqi Freedom and Operation Enduring Freedom combat casualties from October 2001 to June 2011 who died from injury in the deployed environment. The autopsy records, perimortem records, photographs on file, and Mortality Trauma Registry of the Armed Forces Medical Examiner Service were used to compile mechanism of injury, cause of injury, medical intervention performed, Abbreviated Injury Scale (AIS) score, and Injury Severity Score (ISS) on all lethal injuries. All data were used by the expert panel for the conduct of the potential for injury survivability assessment of this study.

RESULTS: For the study interval between October 2001 and June 2011, 4,596 battlefield fatalities were reviewed and analyzed. The stratification of mortality demonstrated that 87.3% of all injury mortality occurred in the pre-MTF environment. Of the pre-MTF deaths, 75.7% (n = 3,040) were classified as nonsurvivable, and 24.3% (n = 976) were deemed potentially survivable (PS). The injury/physiologic focus of PS acute mortality was largely associated with hemorrhage (90.9%). The site of lethal hemorrhage was truncal (67.3%), followed by junctional (19.2%) and peripheral-extremity (13.5%) hemorrhage.

CONCLUSION: Most battlefield casualties died of their injuries before ever reaching a surgeon. As most pre-MTF deaths are nonsurvivable, mitigation strategies to impact outcomes in this population need to be directed toward injury prevention. To significantly impact the outcome of combat casualties with PS injury, strategies must be developed to mitigate hemorrhage and optimize airway management or reduce the time interval between the battlefield point of injury and surgical intervention.

Understanding battlefield mortality is a vital component of the military trauma system. Emphasis on this analysis should be placed on trauma system optimization, evidence-based improvements in Tactical Combat Casualty Care guidelines, data-driven research, and development to remediate gaps in care and relevant training and equipment enhancements that will increase the survivability of the fighting force. (*J Trauma Acute Care Surg*. 2012;73: S431–S437. Copyright © 2012 by Lippincott Williams & Wilkins)

KEY WORDS: Military; mortality; hemorrhage; prehospital; outcomes.

The vision of the Joint Trauma System is that every soldier, marine, sailor, or airman injured in the battlefield or in the theater of operations has the optimal chance for survival and maximal potential for functional recovery. Implicit within this vision is the mission to improve trauma care delivery and patient outcomes across the entire continuum from point of injury through rehabilitation using techniques for continuous performance improvement driven by evidence-based medicine across the entire continuum. A preliminary study evaluated these issues in Special Operations forces early in the war.[1] Within the past decade, a tremendous amount of evidence has been amassed validating improvements in combat casualty care once a casualty has reached a military medical treatment facility (MTF). However, no studies have comprehensively evaluated the outcomes of wounded warriors who died of their injuries before reaching an MTF. This relative blind spot is exacerbated by several factors, including lack of prehospital data,[2] the incomplete understanding of the tactical circumstances during which the injuries were sustained, and the integration of existing data sources into the Joint Theater Trauma Registry.

For the last decade of continuous war, the dominant mechanism of injury on the battlefield has been overwhelmingly penetrating in nature occurring in nearly 75% of casualties associated with explosive fragmentation and gunshot wounds. The survivability of those injured on the battlefield is an unprecedented historical level of 90%, compared with

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84% in Vietnam and 80% in World War II.[3] Some of the likely factors influencing this improved survivability include advances in personal protective equipment, a deployed trauma system, and improved training of medics and corpsman based on the concepts of Tactical Combat Casualty Care (TCCC).[4] In addition, within the historical context, the nature of the current war is different in that enemy tactics using small explosive devices are intrinsically different compared with small unit fire and maneuver prominent in Vietnam or large set piece battle with artillery, aerial bombs, armor, and littoral and sea-based engagements seen in World War II.

Historically, the epidemiology of combat injury has been documented by individual observers, by compilations of medical administrative data or by post hoc evaluations of data sources such as the Wound Data and Munitions Effectiveness Team from Vietnam.[5] Data derived from these sources from the wars of the last century note that 90% of battlefield casualties died in the battlefield before ever reaching medical care.[6–9] The technological advances of the 21st century have improved battlefield communications and data capture, thereby improving the quality and quantity of combat casualty care data available for review and analysis. Most of the previous writing on this topic has focused on casualties who reached the hospital, leading to significant selection bias because we did not have visibility on those casualties who died before reaching medical care. As a result, the past decade of combat has produced, for the first time in history, near-census data on serious combat injuries and deaths contained in a number of trauma registries. This has enabled us to identify the most significant causes of lethal pathophysiology in the pre-MTF subset of fatalities and determine which lethal injuries may be potentially survivable, thus facilitating development of a blueprint to guide future mitigation strategies.

MATERIALS AND METHODS

Institutional review board approval and oversight for this study was provided by the US Army Medical Research and Materiel Command and the former Armed Forces Institute of Pathology.

All US combat casualty deaths from theater are recovered and transported to Dover Air Force Base, Delaware, where complete identification and forensic examination are performed by the Armed Forces Medical Examiner System (AFMES). The AFMES Mortality Surveillance Division maintains the Department of Defense Medical Mortality Registry, which has the broader mission of analyzing all active-duty deaths for trends and preventable or modifiable risk factors. For this analysis, the AFMES Mortality Surveillance Division was used to identify US military casualties who died from an injury that occurred while they were deployed to Afghanistan or Iraq from October 2001 to June 2011. The primary focus of this analysis was to specifically evaluate casualties who died of injury in the battlefield with particular emphasis on those who died before reaching a military MTF. The autopsy records and Mortality Trauma Registry (MTR) of the AFMES was used to compile mechanism of injury, cause of injury, medical intervention performed, Abbreviated Injury Scale (AIS) score, and Injury Severity Score (ISS) on all lethal injuries. The autopsy reports and other perimortem records, the MTR, and photographs on file with the AFMES were used by the expert panel to conduct the study.

The expert review panel for this study consisted of military trauma surgeons, forensic pathologists, preventive medicine physicians, an emergency medicine physician with expertise in prehospital care, an expert injury coder with MTR expertise, and a trauma epidemiologist. As in the earlier mortality review, the panel used a consensus rule paradigm.[10,11] To maintain consistency and potential comparison value with past combat mortality analyses, the panel classified the fatalities as "nonsurvivable" (NS) or "potentially survivable" (PS) after evaluation of the individual perimortem records mentioned previously.[10,11] Similar analyses in the civilian trauma literature denote these as "preventable" deaths. For this analysis, we chose not to use this language because it invokes the perception of wrongdoing or blame. Instead, language monikers were specifically used to denote opportunities for performance improvement. As in previous analyses, when multiple wounds were identified, each injury focus was evaluated independently with respect to the potential for survivability. The consensus was to err toward the maximal inclusion of these casualties as "PS" to be introspective and critical to further develop the paradigm of combat casualty care performance improvement and identify potential gaps requiring further research and development. Specific wounds deemed to be NS were physical dismemberment, catastrophic brain injury (brain evisceration, transcranial penetrating brain injury involving deep nuclei or critical vasculature, and brain stem injury), cervical cord transection (above cervical level 3), airway transection within thorax, cardiac injury (>1/2 inch), thoracic aorta injury, pulmonary artery, hepatic avulsion, and catastrophic abdominopelvic injury characterized by lower-extremity amputations with open pelvis and large soft tissue loss/traumatic hemipelvectomy. All other injuries were deemed to be medically PS with the caveat that this analysis did not take into account the context of the mission and combat scenario, the nature of the enemy force, equipment and supply constraints, limitations in evacuation time and platforms, as well as the impact of weather, terrain, and other environmental factors. In addition, care was idealized with the assumption of immediate access to a US military MTF with advanced surgical capabilities and robust clinical resources.

To demonstrate the effectiveness of instituting interventions in the pre-MTF environment on mortality, we evaluated the fielding of tourniquets for the control of extremity bleeding.

RESULTS

For the study interval between October 2001 and June 2011, 4,596 battlefield fatalities were reviewed and analyzed. The causes for the lethal injuries were 73.7% explosive, 22.1% gunshot wounds, and 4.2% other (vehicle crash, industrial, crush, etc.). The stratification of mortality was notable that 87.3% of all injury mortality occurred in the pre-MTF environment (Fig. 1). Of the composite of all battlefield deaths, 35.2% (n = 1,619) were instantaneous, 52.1% (n = 2,397) were acute (minutes to hours) pre-MTF, and 12.7% (n = 580) of casualties died of wounds after reaching an MTF.

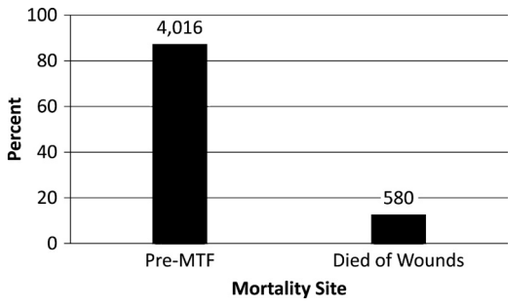

Figure 1. Battlefield mortality location.

Of the pre-MTF deaths, 75.7% (n = 3,040) were classified as NS, and 24.3% (n = 976) were deemed PS (Fig. 2). The ISSs of the PS mortality casualties are shown in Figure 3.

The injury focus of casualties who died instantaneously was substantively related to physical dismemberment, catastrophic brain injury, and destructive cardiac and thoracic great vessel injury (Table 1). The most prominent injury focus of NS casualties who died acutely before admission at an MTF was traumatic brain injury, heart and thoracic vessel, high spinal cord injury (above C3), and destructive abdominopelvic injury (Table 1). In contrast, the primary injury/physiologic focus of PS acute mortality was associated with hemorrhage (90.9%) and airway compromise (8.0%) (Fig. 4). Further stratifying the site of lethal hemorrhage, the most substantial anatomic region of hemorrhage was truncal (67.3%), followed by junctional (19.2%) and peripheral-extremity (13.5%) hemorrhage (Fig. 5). Truncal injury was characterized as 36% thoracic (maximum AIS score, 3) and 64% abdominopelvic (maximum AIS score, 4 and 5). PS junctional injury was noted to be cervical in 63 (39.2%) and axillary and groin in 104 (60.8%) of these casualties.

To assess the effectiveness of fielding pre-MTF medical interventions, we evaluated the system-wide introduction of tourniquets. Modern tourniquets were initially fielded to conventional US forces in late 2005. Implementation was ubiquitous after 2007. Before the introduction of tourniquets, the death rate from peripheral-extremity hemorrhage was 23.3 deaths per year, which was reduced to 17.5 deaths per year during the training and dissemination period from 2006 to 2007. After full implementation, this number was reduced to 3.5 deaths per year, an 85% decrease in mortality. If not for the innovative and improvised tourniquets used by Special Operations forces and unit-based initiatives of some conventional forces before modern tourniquet fielding, this reduction in mortality would have probably been even greater.

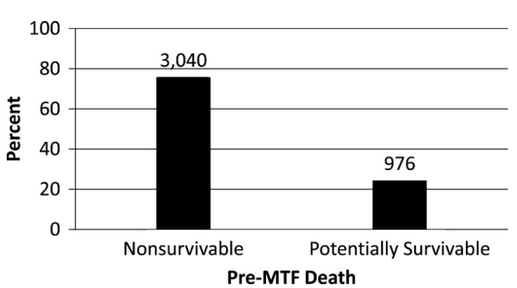

Figure 2. Survivability pre-MTF casualties.

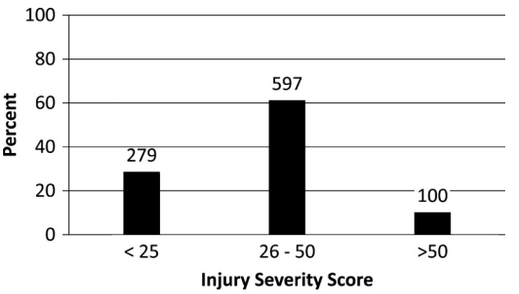

Figure 3. ISS PS pre-MTF deaths.

DISCUSSION

In-depth analysis of injury death is vital to improving trauma systems and injury outcomes.[12] Previous studies of wars of the last century have demonstrated substantial casualty loss on the battlefield before the wounded could reach surgical care. These studies were developed from convenience samples and administrative manpower data and weapons effectiveness analyses.[7,13–15] Before the current study, the most contemporary analysis of casualty deaths before admission at an MTF was a convenience sample during the early phases of current military operations, which demonstrated that 75% to 85% of deaths occur on the battlefield.[1,11] The importance of the current study is that it is comprehensive and is built on the evidence of previous analyses and includes all battlefield deaths from the current military operations to portray a composite overview of mortality on the battlefield. Despite the limitations of civilian injury taxonomies and multiple injury modeling for combat injured, the casualty databases and injury descriptions used here provide a standardized and reasonable approach to addressing some of the challenges in categorizing the macroanatomic and early pathologic consequences of injuries that occur in the battlefield.

Of the 4,596 casualties in our analysis, 87% died before reaching surgical care. This is in contrast to lower number presented in earlier reports.[11] This difference could be caused by a reduction in the died-of-wounds rate, an increase in immediate deaths, which were not previously reported, or the conduct of operations in more extreme environments dissociated

TABLE 1. Injury Focus of Patient With NS Injuries Who Died Instantaneously or Acutely Before Admission at a MTF (pre-MTF)

Cause of Death	Instantaneous (n = 1,619)	Acute (n = 1,624)
Brain injury	38.3% (620)	53.0% (753)
High spinal cord injury	—	9.2% (131)
Dismemberment	31.6% (512)	—
Heart/thoracic injury	23.6% (383)	21.8% (310)
Open pelvic injury	—	6.5% (93)
Other	6.5% (104)	9.5% (134)

Values are percentages of the total deaths and the number of deaths.

from definitive treatment facilities. The present analysis is hampered by the lack of correlation with the confounding variables of operational and evacuation scenarios necessary to address these differences.

The cause of injury in these casualties was predominantly explosions. The causality of explosions (primary through quaternary effects) was not specifically determined in this analysis.[16] Casualty deaths on the battlefield occurred in two discrete time phases: 35% of combat casualty deaths occurred instantaneously and 52% acutely in the minutes to hours after injury. Further stratification of pre-MTF deaths indicated that 3,040 (75.7%) of the prehospital deaths were NS, whereas 976 (24.3%) of deaths were PS from a strictly medical perspective. These results are similar to analyses conducted earlier in the war and validate the experimental design, reiterating the opportunity for effective interventions.[1,11]

The injury focus of the instantaneous NS mortalities included physical dismemberment, catastrophic brain injury, and destructive cardiovascular injury. From the perspective of acute, but not instantaneous NS pathology, most casualties died of severe traumatic brain injury, thoracic vascular injury, high spinal cord injury, and destructive abdominal pelvic injury. This latter category became a more prominent injury pattern during the counterinsurgency phase of military operations in Afghanistan from 2010 until the present, when service members were injured by explosive devices while conducting dismounted (foot) patrols. This injury pattern was coined *dismounted complex blast injury* (DCBI) and was the focus of a task force convened by the US Army Surgeon General. DCBI was characterized by multiple amputations, especially of the lower extremities; massive abdominal, pelvic, and urogenital injury; and often, exsanguination from truncal or junctional hemorrhage. These casualties are especially challenging to care for since they may involve concurrent extremity, junctional, and truncal hemorrhage, all in the same individual.[17] From the qualified perspective of the review panel, since these NS injuries would not have been survivable with currently fielded medical therapies, the only way to impact this mortality cohort would be through injury prevention. During analyses of these multimechanistic, multisystem injuries, it was further emphasized that the current civilian injury taxonomies have limitations in characterizing complex combat injury. To that end, since 2008, a triservice, multidiscipline team has been developing a combat-specific injury taxonomy and appropriate multimechanistic modeling scheme to be published shortly.

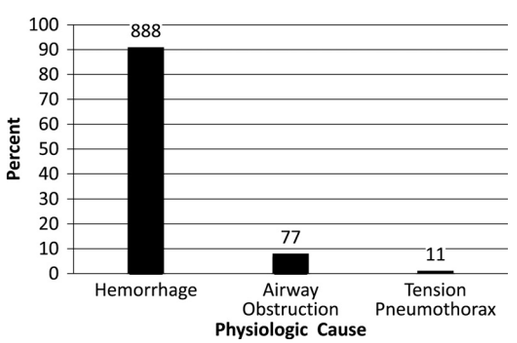

Figure 4. Injury/physiologic focus PS acute mortality (n = 976).

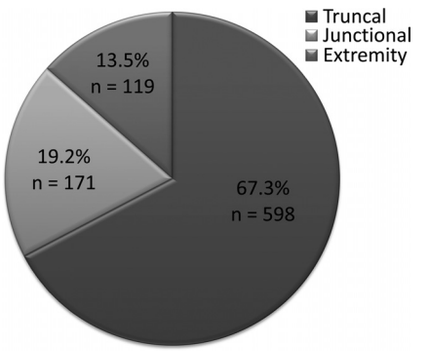

Figure 5. Anatomic focus of lethal PS hemorrhage.

In the cohort of casualties with PS wounds, the majority of mortality was associated with hemorrhage (90.9%). This hemorrhage was further stratified by anatomic focus with 67.3% of the hemorrhage being truncal, 19.2% junctional, and 13.5% extremity. These data are a slight divergence from previous recent reports of combat deaths[1,11] and may represent the impact of the dissemination of the prehospital battlefield treatment algorithms of TCCC[4] during the course of the current wars. More specifically, the difference in hemorrhage outcome data should be considered in light of the following two factors: TCCC was being used by only a few select units in the US military at the start of the wars in Afghanistan but is now used throughout the US military and by most coalition partner nations[4,18] and the DCBI injury pattern has been more commonly encountered since 2010 in Afghanistan and accounts for a very severely wounded cohort of casualties. From previous studies of casualties who died of wounds, the focus of PS hemorrhage was 48% truncal, 31% extremity, and 21% junctional.[19] The disparity in these two data sets may be a representation of survival bias in that some casualties with extremity and junctional hemorrhage may have been more likely to have survived long enough to reach MTF secondary to TCCC hemorrhage control modalities such as tourniquets, pressure dressings, and hemostatic dressings that have slowly but continuously increased in quantity, quality, and use during the past decade.

In contrast, during this study period, there was no effective means to control or temporize junctional or truncal sources of hemorrhage in the battlefield. This signifies a clear and persistent gap in medical treatment capability that has been present for the entire history of warfare and well documented for nearly a century.[1,5,6,11,20–23] This scenario concomitantly represents a potential high impact opportunity for research and development to improve combat casualty outcomes.[7,24] Recent emphasis in battlefield trauma care has focused on reducing death from noncompressible hemorrhage through the use of tranexamic acid,[25,26] controlling junctional hemorrhage with the Combat Ready Clamp, providing fluid resuscitation that minimizes dilutional coagulopathy and providing a battlefield analgesia option that does not cause respiratory depression or exacerbate hemorrhagic shock. Research resources should be heavily focused on both local hemostatic capabilities for field

care and systemic, procoagulant therapies that might help mitigate the exsanguination process.

The second most common cause of the PS physiologic cause of mortality was upper-airway obstruction caused most prominently by direct injury to the airway structures of the face and neck. Our data corroborates the analysis of previous studies, which demonstrated the 1% to 2% incidence of fatal airway obstruction in the battlefield.[6,11,27] Although our data demonstrated that airway obstruction represented 8.0% of the PS fatal pathology, it likewise represented 1.6% of the total lethal pathology overall. Many of the casualties with physiologic airway compromise had concomitant cervical vascular injury, which compounded the deleterious effect of the injury. The ability to manage the airway in the austere tactical situation is a challenge that must be met with improved airway devices as well as training the medics and corpsmen on the battlefield and maintaining their skills.

Casualty loss from extremity hemorrhage is one area of battlefield mortality in which a clear outcome impact has been made through the use of tourniquets. Previous studies during current military operations have demonstrated a consistent and profound survival advantage for casualties in whom tourniquets were applied early and effectively on the battlefield.[11,28–30] Our analysis substantiates this claim in that casualty deaths from extremity hemorrhage occurred at a rate of 23.3 deaths per year in the pretourniquet years of the war but decreased to 3.5 deaths per year after tourniquets were fully fielded.

Understanding the change in the rate of PS injury throughout the course of the wars in Afghanistan and Iraq is complicated by ongoing changes in battlefield trauma care techniques used to treat casualties. There has been a dramatic transition in the concepts and execution of battlefield trauma care during the last decade of war. Beginning with innovations pioneered by the US Special Operations Command and using new combat trauma technologies tested by the US Army Institute of Surgical Research,[31–35] TCCC has revolutionized how combat medicine is practiced in the battlefield. Use of TCCC concepts progressed sporadically throughout the US military, with widespread concept acceptance occurring in the latter part of the war. The value of TCCC implementation and use was highlighted in a recent study of preventable death on the battlefield in the 75th Ranger Regiment. Investigators demonstrated that the use of an aggressive command-directed casualty response system and TCCC-based Ranger First Responder program was able to reduce the incidence of preventable death to the unprecedented low level of 3% of their total fatalities.[22]

From the perspective of injury severity in the PS casualties, 28.6% had an ISS of less than or equal to 25; 61.2% had an ISS between 25 and 50; and 10.2 had an ISS greater than 50. It should be noted that with an ISS of 25, there is a predicted mortality of 20% to 30% with a near linear increase in mortality from an ISS of 25 to 75, which is associated with an approximately 75% mortality. Therefore, even in our idealized construct of immediate access to surgical care, a substantial number of the PS casualties would have ultimately died of their injury or complications of injury.

Frustration with the lack of improvement in the outcomes of casualties who die in the battlefield has been voiced as a primary concern of battlefield surgeons for 50 years. During the Korean war, Bowers and Hughes[36] noted that "little, if any, improvement have been made in the prehospital phase of treatment of combat wounds in the past 100 years, most of the startling developments and improvements having been in the field of definitive care." In Vietnam, Maughon[23] commented, "Have we made no progress in control of initial non-lethal wounds, or has our attention been diverted from such simple matters to the complicated physiology of massive trauma in the Hospital?" During current overseas contingency operations, Blackbourne[37] insightfully noted that "while the technology to locate, track, and destroy our enemies has taken huge strides since 1831, our prehospital technology to help save life and limb has not kept pace."

As with previous studies on the topic, the study has limitations intrinsic to retrospective nature of the analysis and the limitations associated with large data repositories such as the MTR, including misclassification bias, observer bias, and data integrity. The expert review panel and consensus rule paradigm are inherently sources of potential bias. Exacerbating the limitations of investigating this facet of pre-MTF death is that very few clinical data are generated from the prehospital environment on which to make performance improvement evaluations.[2] Since unit-level medical support is not controlled by the military medical community, but rather the line, the onus to ameliorate this issue is education, sustainment, and emphasis by line commanders. Another valid limitation of the outcomes of this analysis is intrinsic in the definition of casualty statistics and assumes capability for casualty salvage at the lowest level of MTF. To more appropriately classify battlefield injury, outcomes would require restructuring of casualty definitions using a level of care at which surgical capability was possible, the lowest current level being forward deployed surgical elements. Another limitation of the study includes the fact that the data are almost entirely drawn from ground combat and thus cannot be extrapolated to littoral/shipboard environments in which drowning, burns, toxic gas, steam, and particulate inhalation add to the complexity of injuries and further emphasize the need to continue to capture combat injury data from all sources and events.

Among the limitations of this study was that the determination of casualty survivability was based purely on clinical metrics. It is extremely important to caveat this analysis with the fact that the concept of potentially preventable death in this study was conceptualized based on an idealized medical scenario excluding the influence of the confounding variables of operational and evacuation scenarios, mission requirements, enemy forces, logistic constraints, evacuation limitations, and environmental factors. In reality, these confounding variables impact greatly on the outcome of casualties. To minimize the impact of these factors, line commanders should have casualty response training provided as part of their initial and refresher training in combat leadership.[22,38] In addition, focused improvements in the provision of care during tactical evacuation[39,40] have the potential to mitigate tactical and evacuation factors in contributing to preventable death.

We are duly sensitive to the potential for misperception of the data and in no way intend to undermine public

confidence or the confidence of the war fighter or their families relative to medical care rendered on the battlefield. It is important to note that this analysis is not an impeachment of any aspect of the trauma system but rather an attempt to identify knowledge gaps to apply resources to substantively improve combat casualty care across the battlefield in the future.

CONCLUSION

Most battlefield casualties die of their injuries before ever reaching a surgeon. As most deaths are NS, mitigation strategies to impact outcomes in this population need to be directed toward injury prevention. To impact the outcome of combat casualties with PS injury, strategies must be developed to mitigate hemorrhage on the battlefield, optimize airway management, and decrease the time from point of injury to surgical intervention. The most substantial, although not exclusive, opportunity to improve these casualty outcomes seems to be in the pre-MTF setting.

Understanding battlefield mortality is a vital component of the military trauma system. Future studies should focus on casualty deaths both before and after reaching the MTF, exploring strategies to impact and improve outcomes. Our analysis suggests that a continuous real-time review of combat fatalities should be a component of the trauma system as a means to evaluate and make concurrent improvements in combat casualty care. This analysis demonstrates that emphasis should be placed on trauma system optimization, evidence-based TCCC improvements, and a comprehensive ongoing analysis of all deaths. This approach will result in data-driven research and device and doctrine development to remediate gaps in training and skill sustainment for immediate care of the combat casualty by all of deployed personnel. Approaching battlefield death in this fashion will result in even lower death rates in the next war.

AUTHORSHIP

B.J.E., R.L.M., J.C., L.O.-G., T.E.R., and L.H.B. contributed in the study design; B.J.E., R.L.M., P.S., J.C., T.T., P.U., O.M., T.Z., and L.O.-G. performed the data collection; B.J.E., R.L.M., and L.H.B. performed the data analysis; all authors participated in the preparation of the article.

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We acknowledge the remarkable courage and accomplishments of the intrepid warrior medics, corpsmen, and pararescuemen who have cared for our injured brothers in arms throughout a decade of war, often being called upon to treat multiple casualties with severe wounds under the most difficult circumstances imaginable. In addition, we want to recognize all of the deployed medical personnel throughout the continuum of care for their unwavering efforts to ease suffering and improve combat casualty care outcomes.

DISCLOSURE

The authors declare no conflicts of interest.

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Leadership and a casualty response system for eliminating preventable death

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ABSTRACT: Combat casualties who die from their injuries do so primarily in the prehospital setting. Although most of these deaths result from injuries that are nonsurvivable, some are potentially survivable. Of injuries that are potentially survivable, most are from hemorrhage. Thus, military organizations should direct efforts toward prehospital care, particularly through early hemorrhage control and remote damage control resuscitation, to eliminate preventable death on the battlefield. A systems-based approach and priority of effort for institutionalizing such care was developed and maintained by medical personnel and command-directed by nonmedical combatant leaders within the 75th Ranger Regiment, U.S. Army Special Operations Command. The objective of this article is to describe the key components of this prehospital casualty response system, emphasize the importance of leadership, underscore the synergy achieved through collaboration between medical and nonmedical leaders, and provide an example to other organizations and communities striving to achieve success in trauma as measured through improved casualty survival. (*J Trauma Acute Care Surg.* 2017;82: S9–S15.

Four brave men who do not know each other will not dare to attack a lion. Four less brave, but knowing each other well, sure of their reliability and consequently of mutual aid, will attack resolutely.—Col. Ardant du Picq, 1870

The mission of the 75th Ranger Regiment is to support the U.S. National Defense through the precise and timely execution of special operations and light infantry tactics.[1] To achieve this, rangers must be ready on short notice and also be proficient in conducting complex combat operations during both the day and night and in extremes of weather and terrain. The 75th Ranger Regiment is the U.S. Army's premier raid force and largest special operations combat element. Composed of more than 3,500 personnel, rangers conduct combat missions to include airborne, air assault, and other direct-action raids to seize key targets, destroy strategic facilities, and capture or kill enemy forces. Providing care to casualties during such missions can prove challenging.

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BACKGROUND

Critical Assessment

The success of a trauma system can be measured through lives saved.[2] Lives saved in combat can be directly correlated to improvements in casualty care and transport.[3] Combat casualty care statistics can provide comparisons of trauma systems within a conflict,[4–6] as well as between conflicts.[6,7] These statistics provide a foundation for the general understanding of combat trauma data which may prove helpful for identifying areas for performance improvement; particularly, in the realms of killed in action (KIA) mortality, or prehospital death; died of wound (DOW) mortality, or hospital death; and all mortality, both KIA and DOW, through a combined case fatality rate (CFR).[3]

In October 1993, Task Force Ranger conducted a direct-action raid into a heavily armed and densely populated region of Mogadishu, Somalia. During the subsequent 15-hour battle, the task force sustained 125 casualties to include 14 who were KIA and 111 who were wounded in action (WIA). Of the WIA, 4 were DOW and 49 were rapidly returned to duty (RTD) with minor wounds.[8] This event resulted in a %KIA of 18.4, %DOW of 6.4, and a CFR of 23.7. In contrast, from 2001 to 2010, rangers conducted more than 8,000 combat missions which were primarily direct-action raids and incurred a total of 419 casualties during 8.5 years of continuous combat in Afghanistan and 7 years in Iraq.[5] For Afghanistan, rangers sustained 180 casualties to include 13 who were KIA and 167 who were WIA. Of the WIA, 2 were DOW and 76 were RTD with minor wounds resulting in a %KIA of 12.5, %DOW of 2.2, and a CFR of 8.4. For Iraq, rangers sustained 239 casualties to include 15 who were KIA and 224 who were WIA. Of the WIA, 2 were DOW and 81 were RTD with minor wounds resulting in a %KIA of 9.5, %DOW of 1.4, and a CFR of 7.1.

Between 1993 and 2001, critical assessments of the Somalia conflict with commensurate adjustments in "TTPs" or

tactics (employment and arrangement of forces), techniques (nonprescriptive methods to perform missions, functions, or tasks), and procedures (standards and detailed steps that prescribe how to perform specific tasks); personal protective equipment (PPE); and casualty care and transport have proved invaluable for saving ranger lives in subsequent conflicts.[5] Although it initially came at a cost of ranger lives, a "silver lining" of the Somalia conflict was the subsequent ranger pursuit of eliminating preventable death during the Afghanistan and Iraq conflicts. As evidenced by ranger reductions in %KIA, % DOW, and CFR between conflicts, parallel efforts from the Department of Defense (DoD) Joint Trauma System and the Ranger Casualty Response System have been vital in mitigating morbidity and mortality through an integrated whole-community approach to a continuous learning health system and evidence-based performance improvement model.[2,3,5,9,10] Of the 419 battle injury casualties incurred by rangers between 2001 and 2010, this model resulted in no casualties who died from injuries that were potentially survivable through additional prehospital medical intervention, and only one casualty who died from injuries that were potentially survivable in the hospital setting.[5] A notable and integral component of this model of success was the leadership- and culture-driven integration of modern prehospital combat casualty care practices.

Ownership and Priorities

Responsibility, accountability, and ownership are core leadership traits. Developing a culture of personal accountability, where leaders and subordinates alike possess the freedom to make bold decisions and the courage to assume risk and take ownership, is a vital characteristic of a successful organization. Individuals who are invested in what they are doing, and engaged with the greater good of the organization, will exhibit ownership. Once individuals are engaged and have ownership, they will be compelled to accomplish tasks and innovate solutions for the betterment of the organization and to complete the mission.

Leadership is the key component of combat power, and combat power is the total means of destructive and/or disruptive force which a military organization can apply against an opposing force at a given time. As leaders can direct priorities of effort; and as leaders can enforce expectations or standards; and as leaders are also the standard bearers for their organization; leaders must retain visibility, ownership, accountability, and responsibility for major programs within their organization, regardless of subject domain. Subject matter experts can propagate a leader's intent by developing and continuously refining systems-based programs that achieve standards, goals, and expectations for performance as measured and analyzed through data and metrics. Thus, for combatant units, many challenges in military medicine can be overcome through ownership, prehospital trauma training and expertise, and data collection and metrics that inform leader decisions.[11–14]

Combatant units within the U.S. Military are normally led by a leadership team comprised of a commanding officer and a command sergeant major or senior enlisted advisor. For the 75th Ranger Regiment from 1997 to 1999, this team was comprised of Colonel Stanley A. McChrystal and Command Sergeant Major Michael T. Hall. Early on, this command team decided to focus primarily on four major priorities—marksmanship, physical training, small unit tactics, medical training—which they called "the Big Four."[15] As this team realized that they would not have the time to do everything that they wanted to do, they decided to do what they could do very well. Thus, prioritizing and continuously reinforcing high standards and a mastery within these four basic domains of effort. They accomplished this feat by upholding a regimented culture of excellence through standards while also inspiring all to "flatten the organization" so as to encourage leadership, innovation, and cohesion at all levels.

Cohesion is a critical factor for performance within an organization. Cohesion creates shared responsibility for success, while giving each individual the confidence that someone else is watching over them—"sure of their reliability and consequently of mutual aid." As medical training and readiness became a leader priority, it created another cultural opportunity for cohesion that primed the regiment for a prehospital casualty response system.

Also imparting support to this system, was the fact that the other three leader priorities overlapped with the medical domain and were viewed as components of a holistic approach. Expert skills in marksmanship and small unit tactics translated readily into preventive medicine, and heightened physical training established a conduit for both prehabilitation and rehabilitation. Although additional study is needed, rangers have supported the concept that a conditioned body may be more apt to complete the mission and avoid injury, and if injured, may have improved outcomes and shortened periods of recovery.[16–18] In addition, in 2005, the commanding officer of the regiment, then Colonel Paul J. LaCamera, added a fifth priority of "mobility." Once again, this domain overlapped with medical training in respect to the transport and en route care of casualties.

Best Practices

Regardless of military or civilian sector, for trauma, the greatest opportunity to save lives is in the prehospital setting.[2–8,11–14,19,20] Thus, for the military, efforts directed toward reducing KIA mortality, or prehospital combat trauma death, can have the largest impact on eliminating preventable death on the battlefield.[2–8,11–14,19,20] As rangers and ranger leaders realized the importance of prehospital care early on, before the recent conflicts in Afghanistan and Iraq, they implemented best practices that would ultimately increase survival in their population.[2,3,5]

For critically injured combat casualties, survival from trauma is associated with the time that has elapsed between injury and receiving a required intervention or capability.[6,21] Although rapid prehospital transport to a higher level of medical care is important, it is rather the timely administration of a needed capability that is ultimately paramount.[5,6,21–25] Thus, as demonstrated by the 75th Ranger Regiment, both medical and nonmedical first responders must have the capability to successfully provide life-sustaining prehospital trauma care.[5] Because most potentially survivable combat deaths are from hemorrhage,[20] hemorrhage control and blood transfusion capabilities are paramount.

A modern-day revolution in prehospital trauma care was born from the principles of Tactical Combat Casualty Care (TCCC) in 1996.[26–30] These principles have been continuously updated, refined, and propagated since the advent of the Committee on Tactical Combat Casualty Care in 2001,[28–30] which currently resides under the DoD Joint Trauma System. The three core goals of TCCC are to treat the casualty, prevent additional

casualties, and complete the mission. These goals merge mission tactics with casualty care to optimize casualty response TTPs. The resultant protocols are a standard of care that should be expected from all first responders in a tactical or prehospital battlefield setting. The 75th Ranger Regiment integrated TCCC into training in the four years preceding the events of September 11, 2001.[5,27] During more than a decade and a half of continuous involvement in combat thereafter, this standard of care has become interwoven into the very fabric of its organizational structure.

As has been previously described,[11] prehospital combat morbidity and mortality can be prevented by combatant and medical leaders at multiple levels through: (1) primary prevention; prevent injury incident through physical and mental conditioning, TTPs, and evidence-based findings from tactical and medical After Action Reviews (AARs), (2) secondary prevention; mitigate injury extent through tactical contingency planning and PPE, and (3) tertiary prevention; optimize injury care through properly executed TCCC, optimized tactical casualty response, and remote damage control resuscitation.

CASUALTY RESPONSE SYSTEM

The 75th Ranger Regiment has three line battalions staggered by three months onto a 9-month operational readiness training cycle. The cycle begins with individual training, moves through small unit collective training, and then culminates into large scale training exercises, which are followed by combat deployments as directed. Ranger leader integration of casualty care and evacuation into their operational readiness training cycle was absolutely vital, because it provided graduated levels of knowledge and skill application in the context of and synchronized with other combat-related TTPs that occur within fighting formations. Every stage of training was evaluated for opportunities to provide casualty care training, and where appropriate, the training was integrated for all personnel—medical officers, medics, nonmedical leaders, and nonmedical first responders. Thus, all received continuous casualty response training throughout the 9-month cycle. A key underpinning of casualty response training is the use of the term casualty response rather than medical training, as it conveys a communal obligation for the entire force to take action as with any other battle drill.[5] When a casualty occurs on a mission, the incident is a tactical and leader problem to be solved and not just an isolated issue consigned to medical personnel alone. Although comprehensive medical training was previously implemented and described by one battalion in the regiment before the Somalia conflict,[31] it was not ubiquitously practiced by all in a casualty response system, nor was it based on a standard dictated by TCCC guidelines.

Standards for the Nonmedic

Distributed knowledge and capability are major force multipliers.[9] The principles of TCCC, coupled with the directive for all rangers to focus on four priorities of training to include medical readiness and casualty care, proved to be a timely catalyst for developing a TCCC-based Ranger First Responder (RFR) program of instruction in 1999.[27] The RFR course is taught to all personnel prior to assignment within the 75th Ranger Regiment, and on a recurrent basis thereafter.[5,9,27,32] The initial and refresher 2-day course teaches critical first aid and advanced combat lifesaver procedures through didactic lectures, hands-on skill stations, and realistic trauma lanes that were conducted during the day and night, and as frequently as possible, integrated into live fire and other training exercises.

Standards for training were based on TCCC guidelines, and all were expected to be current and competent on these standards. Regardless of military occupational specialty, this course afforded every ranger the basic knowledge and operational skills required to treat and save lives. Fundamental expectations are divided into three categories of familiarization, proficiency, and mastery within the fields of hemorrhage control, airway problems, breathing issues and chest trauma, and damage control resuscitation.[9] The required skills to be mastered in this course are practiced, reinforced, and rehearsed continuously throughout the training cycle during the conduct of small-unit battle drills and training exercises at every level—team, squad, platoon, company, battalion, and regiment. For first responders with a propensity toward medicine, and in accordance with a command directive for at least one advanced nonmedic provider per squad or seven-man element, additional training was provided through Emergency Medical Technician (EMT) courses which has evolved into a more tactical advanced RFR training.

Confidence and competence was gained through training and real-world experiences. These real-world experiences, in both training and combat, prompted a cultural sense of immediacy where casualties are expected. Because confidence does not equate to competence, integrating performance measures was paramount. The key to training was conditioning all to do the right thing at the right time. Guidelines, protocols, and procedures were established based on best practices from the medical literature. Trainers were trained and provided performance measures based on guidelines so as to reduce variability in training.

Self and buddy care should be the foundation of a whole-community approach to reducing mortality from trauma. Because all have the potential to be a casualty, and all have the potential to be a first responder, then all were directed to carry a bleeder control kit with commensurate ability to provide and document initial care. Bleeder control kits were carried in a standard location with contents directed toward the rapid treatment of the three major causes of preventable death as outlined by TCCC guidelines—extremity wound hemorrhage, tension pneumothorax, and airway obstruction.[26] Included in the bleeder control kits were extremity tourniquets, hemostatic gauze, pressure dressings, needles for decompression of a tension pneumothorax, nasopharyngeal airways, and casualty cards. Notable was that these kits became a model for the modernization of individual first aid kits throughout the DoD. Additionally, ranger squads were also expected to carry aid and litter kits that contained a compact and collapsible lightweight litter and additional medical supplies for the TCCC management of casualties.

Standards for the Medic

Ranger medics are highly trained physician extenders with trauma care expertise. Although training standards for ranger medics have been previously described,[33] their training has continued to evolve as commensurate to the needs of the mission and their casualty population. Ranger medics are expected to teach and have a mastery of prehospital trauma care practices. Following initial EMT basic and TCCC training through the

Army medical department, ranger medics complete the Special Operations Combat Medic course where they receive EMT paramedic training combined with advanced TCCC applications as well as special operations-specific tactical medical emergency protocols. Recurrent training is received through formal refresher and certification courses, trauma center rotations, and a culminating combat trauma management and assessment and validation program. This program included written and oral tests, multiple hands on skill stations, and a variety of human patient simulator and live tissue scenarios. This assessment occurred each training cycle, just prior to large scale exercises or combat deployments.

Because knowledge plus experience equate to wisdom, those medics who gained real-world experiences in addition to the knowledge provided during training tended to perform better and to have better judgement when providing care as they had real-world applications and references for context. Thus, integrating trauma center rotations, ambulance ride along call, and clinical rotations into the training cycle was very important. These rotations provided a venue for applying judgement, skills, and knowledge. These rotations also provided experience and objective performance measures through patient outcomes of morbidity and mortality.

Knowledge products provided to ranger medics included TCCC guidelines and updates, the military version of the Prehospital Trauma Life Support manual,[34] and a comprehensive Ranger Medic Handbook that has been published and updated since 2001.[35–38] The Ranger Medic Handbook succinctly outlines standards, a scope of practice, and details and algorithms on protocols and procedures that are expected of the ranger medic; and as stated in the handbook, ranger medics are expected to have a "Mastery in Close Combat Medicine."

Medical equipment and supplies carried by the ranger medic are primarily geared toward the acute prehospital management of trauma casualties, and secondarily tailored to support specific mission profiles. Ranger medic aid bag contents are synchronized with TCCC guidelines, and all medics pack in accordance with a standardized and routinely updated packing list. The regiment also maintained additional modified packing lists to accommodate specific mission profiles (e.g. airfield seizure) so as to assist medics with adjustments based on mission requirements. A ranger medic's kit worn on their body armor was standardized for the care of at least one acute multi-system trauma patient, and afforded the opportunity to rapidly provide lifesaving treatment without the need to open their aid bag.

Standards for Ranger Leaders

Because tactical leaders manage all resources (e.g. personnel, training, equipment, time, money, etc.) dedicated to preparing for and completing a mission, it is this nonmedical leader who is ultimately responsible for the prehospital casualty response system. Thus, a Casualty Response Training for Ranger Leaders (CRTRL) course was developed and initiated in 1999,[5] and has been integrated into initial training for leaders as they are assigned to the regiment; as well as during an internal team leader's course for enlisted personnel assuming their first leadership position. This training event focused primarily on providing each leader, at every level from team leader to ground force commander, with an enhanced understanding and expectation of their role and responsibilities in the casualty response system, as well as how their individual decisions can affect both successful completion of the mission and survivability of casualties. In addition to leader management of casualty response TTPs, to include casualty evacuation procedures, contingency planning for the possibility of taking casualties during each phase of the mission was stressed as paramount to casualty survival and the overall success of the mission. Contingency planning and an appropriately conditioned tactical response to casualties are just as important as medical interventions for eliminating preventable death.

A critical component of CRTRL was the detailed instruction on capabilities, limitations, and employment methods of internal and external medical assets, because it was vital for leaders to understand the intricacies of getting the right capability to the right casualty at the right time and place; and balancing such so as to not misappropriate or misuse limited resources. Additionally, an important and routinely updated component of CRTRL was that of casualty vignettes and AARs from recent combat missions. These cases would demonstrate currency and relevance of training, highlight casualty events they would likely encounter, and prompt potential solutions for future casualty events.

Before and in response to casualty events, CRTRL teaches leaders to take charge and to develop TTPs that are based on organization-specific missions, assets, and capabilities; to imagine and rehearse contingency plans; and to leverage first responders as their most abundant and responsive resource. As leaders assume higher positions of responsibility, they are also taught to be cognizant of their broader casualty response role. A junior leader's first encounter and decision-making on behalf of a casualty should not be during a real-world event; it should be during training. Ranger senior leaders have often injected unexpected events (e.g., complex casualty scenarios) during training to challenge and progress the organization to a higher level,[39] and force junior leaders to think, react quickly, and execute contingency plans. As key leaders have often been designated as the casualty during training, junior leaders were also forced to assume higher-level roles and responsibilities while also ensuring care for the casualty. The practice of "next-man-up" drills have become a hallmark of ranger leader training and is paramount to the development of junior leaders.

Casualty Transport

During the planning phase of operations, contingencies to accommodate rapid casualty transport included standard medical evacuation as well as use of mission aircraft and ground vehicles. Some of the aviation units supporting rangers developed and provided highly-trained special operations casualty transport personnel; most achieving the level of critical care and flight paramedic certification. Preparatory and synchronized training with these casualty transport personnel, as well as with surgery and resuscitation teams, afforded a seamless transition and cohesive effort of care during combat operations.

Damage Control Resuscitation

In addition to implementing hypotensive resuscitation practices historically recommended by TCCC guidelines,[26,30] Rangers have also been at the forefront of evolving techniques in tactical or remote damage control resuscitation.[40–42] Following the approval of a U.S. Army Special Operations Command and Food and Drug Administration (FDA) Investigational New

Drug protocol, ranger medical providers started routinely carrying French freeze dried plasma during combat missions starting in 2011. This effort, in combination with aggressive hemorrhage control techniques, attempted to provide a more homeostatic resuscitation fluid compared with colloids and crystalloids while retaining the ultimate goal of negating hemorrhagic shock and increasing survivability.

In 2014, after a revision to the TCCC guidelines which advocated use of blood products over colloid or crystalloid solutions,[40] continued ranger efforts directed toward preventing or reducing effects from hemorrhagic shock was initiated through the development of a unit-wide whole blood program.[41,42] With active support from ranger leaders, this program identified blood group O rangers who demonstrated antibody (IgM to group A and B antigen) levels of less than 1:256. These individuals were categorized as ranger O Low Titer, or "ROLO," and tested before deployment for standard transmittable diseases. This group served as an immediate walking blood bank of universal donors for prehospital casualty care. In 2015, the 75th Ranger Regiment deployed its first group of ROLO personnel. Since that time, every ranger task force has deployed with a fully functional ROLO program. In 2016, prescreened Low Titer O Whole Blood (LTOWB) was also supplied to ranger task forces from U.S. blood bank facilities. This permitted ranger medical personnel to rapidly use LTOWB, and if needed, also activate the ROLO walking blood bank to obtain additional whole blood within minutes.

As of December 2016, rangers have thus far administered freeze dried plasma to 10 combat casualties. Of these casualties, eight arrived alive at a surgical treatment facility. Rangers have also administered cold-stored LTOWB to three combat casualties with two receiving one unit and one receiving two units. Two of these casualties arrived alive at a surgical treatment facility, but only one ultimately survived. Company- and platoon-level leadership have been essential to the preparatory success of the ROLO program through integrated training and rehearsal of this protocol as a contingency battle drill. Although the person-to-person ROLO protocol has not been activated and used on a real-world combat casualty as of yet, this capability is ready and available.

Performance Improvement—Integrating and Distributing Lessons Learned

To continuously validate, refine, and solidify standards for TCCC practice, the ranger casualty response system integrated a performance improvement cycle, with components to include: (1) provide casualty care; (2) document care; (3) collect and consolidate data; (4) analyze data; (5) enact performance improvement by refining best practice guidelines and personnel, training, and equipment requirements; (6) publish findings internally and externally to activate force modernization, research and development, and to integrate and distribute lessons learned; and (7) provide casualty care. Lessons learned are not lessons learned unless you learn them; thus, a performance improvement cycle is required to preserve and advance lessons learned. Data and lessons learned can not only inform and educate they can also recruit and garner support from leaders.

Data help to drive requirements and authorizations for personnel, training, and equipment. Leaders appreciate data that informs decisions and justifies expenditures of time and monies. However, data rely on personnel to document efforts, and documentation of prehospital care in combat has historically been suboptimal.[3,6,11–13,43–45] In contrast, rangers developed, and their leaders mandated and enforced, two simple documentation tools—a casualty card and a casualty AAR—which have proven successful in collecting combat casualty care data since 2001.[3,5,44–49] Additionally, as funded and supported by ranger leaders, a Web-based prehospital trauma registry (PHTR) was developed to consolidate and analyze data from cards and AARs for near real-time feedback, performance improvement, and sharing lessons learned.[2,3,5,44–50] In addition to improving command and organizational visibility of casualties, the PHTR provided leaders with data-driven evidence for decision making; validated and refined casualty response system TTPs, PPE, and TCCC treatment strategies; and refined medical and nonmedical personnel, training, and equipment requirements through cost-effective and directed procurement.

For parent commands, ranger efforts have influenced medical sustainment training efforts within U.S. Army Special Operations Command (regulation 350–1, Appendix G) and special operations forces medical training within U.S. Special Operations Command (directive 350–29). As ranger medical personnel have been integral members of the CoTCCC since its inception, they have also routinely used data to influence and propagate novel practices and changes to TCCC guidelines which are distributed throughout the DoD and beyond.[2,3,5,44–50] Ranger casualty cards, AARs, and PHTR have been, and continue to be, a vital component of ranger performance improvement. Additionally, this methodology has become a model of excellence from which to guide documentation and data collection for the Department of Defense.[3,10,21,44,50,51]

Ranger medical force modernization efforts are based on requirements directly related to casualty care dictated by TCCC guidelines, battlefield lessons learned, and most importantly, the tactical mission. As self and buddy aid are paramount to rapid care and eliminating preventable combat death, medical capability development priorities start with the individual ranger or nonmedic first responder; then the ranger squad; followed closely by the ranger Medic. The Regiment's medical force modernization efforts are synchronized with other special operations forces, as well as DoD research and development. Thus, the regiment is often a lead in the testing and evaluation of medical products and equipment.

CONCLUSION

The efforts described in this article support the charters for the 75th Ranger Regiment as mandated by former U.S. Army Chiefs of Staff General Creighton W. Abrams, General John A. Wickham, and General Gordon R. Sullivan,[52] and reinforced by recent Army Chief of Staff General Raymond T. Odierno. The regiment is to lead the way in modernizing doctrine, tactics, techniques, procedures, and equipment to meet the challenges of the future, and will share its philosophy and standards.

Eliminating preventable death is an organizational and community issue that requires the attention of all leaders, both medical and nonmedical. It is a matter of morale and moral obligation that battlefield casualties receive the best care possible to optimize survival and recovery from traumatic injury. However, this should

not be left to chance. The ability to set, know, enforce, and exceed established standards is what sets a good organization apart from others. Good leadership can instill what is required to fight on to the objective to complete the mission, and good leadership can also instill what is required to save lives during such missions.

Continuous performance improvement processes and focused empiricism must be used to inform practice and evolve standards.[2] This article outlined several steps undertaken by the 75th Ranger Regiment to improve combat casualty care through organizational structure, culture, and strategy to include: (1) conduct a critical assessment of the organization's state of affairs; (2) establish priorities of effort and ownership for those priorities; (3) identify and integrate best practices into organizational structure as dictated by mission and culture; (4) establish cohesion and a flat organizational construct for which to develop subject matter experts and to train all to be masters of the basics through standards; (5) establish a continuous performance improvement cycle through metrics and data collection, consolidation, and analysis; and (6) share lessons learned.

The 75th Ranger Regiment institutional goal and commitment to the relentless pursuit of eliminating preventable death, which has been embedded within their special operations and infantry tactics and culture, has and will continue to help preserve advances in combat casualty care. Regardless of personnel and personality turnover, this organization and its systems-based approach has consistently and continuously sustained this goal for nearly two decades. Several challenges to improving combat casualty care and survival on the battlefield had to be overcome, particularly in the realms of ownership, prehospital trauma expertise, data collection, and metrics. For military medicine as a whole, these challenges and others remain as friction points to performance improvement.[11–14] As U.S. national goals have now aligned to develop a national trauma action plan to pursue zero preventable deaths from trauma,[2,53–55] intensified momentum of bidirectional translation of efforts will aid in overcoming challenges in both military and civilian populations.

The 75th Ranger Regiment model is readily translatable to others throughout the military and civilian sectors. Organizing, unifying, and training casualty response systems can provide all levels of leadership with invaluable insight into strengths and weaknesses found within their communities. As with leaders within the 75th Ranger Regiment, community leaders at the local, state, and national levels must recognize that severe and critical trauma injuries are inevitable, but death from such is not. Medical and nonmedical community leaders alike can take ownership of their casualty response systems, and promote awareness, cohesion, and creative solutions that will ultimately achieve the desired outcome of eliminating preventable death.

FINAL COMMENTS FROM CURRENT RANGER LEADERSHIP

"Standards of excellence for providing care to our fellow rangers were firmly established and have become an integral part of the Ranger Regiment culture. A mastery of the basics—marksmanship, physical training, small unit tactics, and medical proficiency—remain fundamental to our training and critical to our success on the battlefield. An RFR's ability to master the basics of casualty care remains a top priority of the Regiment. Likewise, our medical personnel must deliberately maintain a learning posture that seeks to develop and implement innovative approaches to confront and overcome the innate difficulties of providing care to battlefield casualties. Accounting for the challenges inherent to the extreme conditions in which we are expected to operate, the Ranger Regiment will continue to maintain focus on mastering the basics while also seeking cutting edge solutions for trauma care. We will do this first and foremost through our investment in our people—by providing realistic training that holds every individual ranger and leader accountable for medical skills proficiency and ensures all are the best trained on the battlefield."

Rangers Lead The Way!

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AUTHORSHIP

All authors contributed to the draft and critical revision of this manuscript.

DISCLOSURE

The authors declare no conflicts of interest.

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COMMENTARIES

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Challenges to Improving Combat Casualty Survival on the Battlefield

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> "We succeed only as we identify in life, or in war, or in anything else, a single overriding objective, and make all other considerations bend to that one objective."
>
> *-Dwight D. Eisenhower*

The United States has achieved unprecedented survival rates (as high as 98%) for casualties arriving alive to the combat hospital. Official briefings, informal communications, and even television documentaries such as CNN Presents Combat Hospital highlight the remarkable surgical care taking place overseas. Military physicians, medics, corpsman, and other providers of battlefield medical care are rightly proud of this achievement. Commanders and their troops can be confident that once a wounded service member reaches the combat hospital, their care will be the best in the world.

Combat casualty care, however, does not begin at the hospital. It begins in the field at the point of injury and continues through evacuation to the combat hospital or forward surgery. This prehospital phase of care is the first link in the chain of survival for those injured in combat and represents the next frontier for making further significant improvements in battlefield trauma care.

Even with superb in-hospital care, recent evidence suggests up to 25% of deaths on the battlefield are potentially preventable.[1,2] The vast majority of these deaths happen in the prehospital setting. The indisputable conclusion is that any meaningful future improvement in combat casualty outcomes depends on closing the gap in prehospital survival. Improving prehospital combat casualty care, however, may be significantly more challenging than improving hospital based casualty care because of significant structural challenges facing the military medical establishment. We describe 5 key challenges and a plan to overcome them.

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CHALLENGE NO. 1: OWNERSHIP

Responsibility for battlefield care delivery is distributed to the point where seemingly no one "owns" it. Unity of command is not established and thus no single senior military medical leader, directorate, division or command is uniquely focused on battlefield care, the quintessential mission of military medicine. This diffusion of responsibility is a result of multiple agencies, leaders, and units of the service medical departments each claiming bits and pieces, with no single entity responsible for patient outcomes forward of the combat hospital. Combat arms commanders "own" much of the battlefield casualty care assets in that medics, battalion physicians, physician assistants, flight medics, and associated equipment are assigned to their operational units, yet combat arms commanders are neither experts in nor do they have the resources to train their medical providers for forward medical care. Commanders rely on the service medical departments to provide the right personnel, medical training, equipment allocations, doctrine, and medical force mix in their units. In turn, although the institutional base trains and equips the combat medical force, it defers the responsibility of battlefield care delivery to line commanders. Although this division of responsibility may at first glance seem reasonable, the net negative effect of line commanders lacking expertise and medical leaders lacking operational control has been described.[3] The axiom "when everyone is responsible, no one is responsible" applies.

The concept of Tactical Combat Casualty Care (TCCC) evolved to fill this gap for line commanders. Originating from an article by Butler and Hagmann published in this journal in 1996,[4] TCCC created a conceptual framework focused on treating life-threatening battlefield injuries while taking into account tactical considerations. Navy physician and former SEAL, Dr. Frank Butler, spearheaded what has now emerged as the most significant battlefield medical advancement of the past decade. Before the advent of TCCC, combat medics were taught civilian-style first aid. Many of these techniques, based on civilian injury patterns such as motor vehicle accidents, were unhelpful or frankly dangerous when performed under fire.

The Committee on TCCC or CoTCCC is organized under the Joint Trauma System and is responsible for promulgating the tenants of TCCC. Its origins were nontraditional, reflecting a grassroots effort by a dedicated group of surgeons, emergency physicians, and experienced combat medics to incorporate new evidence and best practices into prehospital treatment guidelines. As a paradigm it is thoroughly grounded in the realities of the modern battlefield. The very existence of the CoTCCC, an organization born outside the traditional military medical establishment exposes a void in ownership and expertise in battlefield care. Although TCCC as a paradigm is sound, its adoption and implementation has been uneven. There remains considerable overlap of authorities and responsibilities between the services, the Geographic Combatant Commanders, and individual combat units with respect to training and equipping troops in battlefield trauma care. Previous recommendations by Assistant Secretary of Defense for Health Affairs to train all combatants and all physicians in TCCC, in particular, remain unimplemented throughout the Department of Defense (DoD). Newly recommended TCCC devices and medications are still being transitioned into use by combat forces largely based on the initiative of individual medical officers assigned to combat units.

In contrast to combat casualty care, other areas of the military medical establishment are led by flag-level officers. In the Army Medical Department, for example, brigadier generals lead veterinary medicine and warrior transition care. Dentistry and nursing are both led by major generals. Battlefield care would strongly benefit from similar centralized senior leadership. Establishing organizational ownership such as a battlefield medicine directorate, division, or command is the key first step.

CHALLENGE NO. 2: DATA AND METRICS

The services' medical departments repeatedly cite the reduction of case fatality rates to historically low levels as a major medical accomplishment during operations in Iraq and Afghanistan. Although seemingly positive, this statistic tells only part of the story. The case fatality rate, or the percentage of those injured who died, reflects multiple factors including weapons and tactics, protective equipment, and medical care.[5] In other words, the current data equally support the conclusion that the enemy's lack of regular combat units, artillery and armor (the major casualty producers in conventional warfare) and reliance instead on improvised explosive devices is plausibly just as responsible. Although many intended improvements have been made in military trauma systems, especially at the combat hospital and higher, there are few data to link specific actions to a direct and quantifiable relationship with lowered case fatality rates. Repeatedly citing "the lowest case fatality rate in the history of warfare" as an affirmation of military medicine's success over the past decade without a sober account of other contributory and confounding factors risks telegraphing the message that battlefield trauma systems are near perfected and no further significant improvements are required or even possible.

Another problematic statistic is the died of wounds (DOW) rate or the percentage of those reaching medical care that later die. Remarkably, recent DOW rates exceed those of World War II and the Vietnam era.[5] Although startling, this does not necessarily reflect a decline in care. As evacuation becomes faster and prehospital care improves, the DOW rates will go up as more mortally injured casualties will reach the hospital alive. Conversely, if evacuation is delayed or medic care is poor, more will die in the field and reduce the DOW rate. Neither the DOW nor case fatality rates quantify the effect of medical care on survival nor do they provide insight into where specific improvements in combat casualty care can be made.

Another statistic which distorts the overall effectiveness of combat casualty care is the hospital survival rate. Surgical care in the combat hospitals and care in the subsequent evacuation chain back to the United States has advanced to such a degree that 98% making it there alive will go on to survive their wounds. By definition, it does not capture those with potentially survivable injuries who died in the field or died during prehospital evacuation. In other words, it does not speak to all of the casualties that succumb before hospitalization. What is needed is a metric that encompasses the full spectrum of care that includes the prehospital setting.

In contrast, the potentially preventable death rate illuminates where care can be improved along the entire chain of survival, from the point of injury to rehabilitation back in the United States. It is defined as deaths which could be avoided if optimal care could otherwise be delivered. The challenge of deriving this statistic comes from the complexity in determining if a death is potentially preventable. To accomplish this, specific clinical facts must be collected on each case and as we discuss shortly, prehospital data is often difficult to collect.

The potentially preventable death rate is derived by examination of autopsy and medical records by a multidisciplinary physician panel. One such review examined all the U.S. combat deaths in Iraq and Afghanistan from 2001 until 2011 and found up to 25% to be potentially preventable.[1] The vast majority of these (87%) died before reaching a surgeon or combat hospital. Many of the remaining 13% who died in the hospital were in profound shock on arrival and would have likely benefitted from aggressive prehospital resuscitation. It is important to recognize this figure, like the DOW rate, does not necessarily reflect inadequate care. All of these casualties were severely injured. Some would have required immediate, on-the-spot access to the most advanced care (e.g., the kind found only in premier trauma centers in the United States) to have any hope of survival and others died related to unavoidable delays because of on-going combat operations (e.g., hostile fire). However, many could have

survived with currently available prehospital medical interventions if only they were routinely and correctly employed. Unfortunately, we continue to know little about what care is provided before casualties reach the combat hospital.

The key goal is a coherent system to collect prehospital patient care information. We know very little about this phase of care.[6] Only 1 military unit we are aware of, the U.S. Army's 75th Ranger Regiment, has collected complete sets of casualty care data. The commander of the 75th Ranger Regiment has taken ownership of that unit's casualty response system. Using their Ranger Casualty Card and their unit casualty registry, they are able to determine what happened to every Ranger casualty during all phases of care. Ranger commanders routinely use this data to improve their casualty response systems. The Rangers are also the only unit in the U.S. military that can demonstrate no potentially preventable deaths in the prehospital setting after more than a decade of combat.[7]

Systematically examining potentially preventable deaths and prehospital care data gives a more accurate assessment of the entire continuum of care compared to other metrics. If collected and analyzed quickly, it also allows for the development of an agenda to improve casualty care in near real time. The Israeli Defense Force's medical corps has embraced the concept of eliminating preventable deaths as part of the next 10-year force build-up plan and emphasizes point-of-injury care (Dr. Elon Glassberg, personal communication, Trauma and Combat Casualty Care Branch, IDF, August 20, 2013).

A significant recent positive example of data driven combat casualty care improvement concerns the capabilities of medics staffing medical evacuation (medevac) helicopters. Medevac helicopters have traditionally been staffed by medics trained at the basic emergency medical technician level. Staffing civilian medical helicopters with advanced paramedics has been done since the 1980s and advocated for military medevac since the 1990s. A recent study comparing a National Guard medevac unit staffed with critical care-trained flight paramedics showed a 66% reduction in mortality compared to the standard flight medics.[8] After at least a decade of debate (and nearly 40 battlefield after-action reports recommending it but lacking detailed supporting data), a program was adopted by the Army in 2011 to train critical care paramedics for helicopter medevac. With better data collection in the prehospital setting, it is likely the decision cycle could be far reduced from the 11 years observed.

Changing the narrative of "unprecedented" survival rates to instead highlight the 25% potentially survivable death rate does place military medicine in a difficult strategic communications predicament. A fair and open accounting of the successes to date as well as where progress needs to be made is an imperative. In 1984, Dr. Ron Bellamy examining many of the same issues discussed here following analysis of Vietnam era casualty data noted, "A research program designed to improve health care delivery will have the greatest impact if its goals are chosen after a comprehensive review has been made in the ways of which the existing system fails."[9] A similar comprehensive review of combat casualty care in Iraq and Afghanistan is recommended.

CHALLENGE NO. 3: PREHOSPITAL AND TRAUMA EXPERTISE

If the prehospital setting is the area where nearly all potentially preventable deaths occur, then it is likely not coincidentally an area of limited organizational expertise. It would be natural to expect that the services, especially the ground forces, would invest heavily in clinical experts in far-forward combat casualty care. Paradoxically, the opposite appears true. The Army, for example, relies on the Professional Officers Filler System (PROFIS) to provide the bulk of forward medical officers. PROFIS is a cold-war era program whereby primary care physicians from the base hospital are tasked, often just before combat deployment, to serve at battalion surgeons responsible for the resuscitation of battle casualties in the battalion aid-station. This is reminiscent of how "Emergency Rooms (ERs)" were staffed in the 1960s and 1970s when junior physicians just out of training (or disinterested physicians from unrelated specialties) were rotated into the ER. Like the PROFIS physicians, these physicians had no in-depth training in resuscitation or emergency care, or worse, little interest in even learning it. Many of these PROFIS physicians, often inexperienced and unprepared, are placed into operational positions outside the scope of their training. This professionally unrewarding experience likely contributes to many leaving the military at the first available opportunity.[10]

The Korean and Vietnam Wars set the stage for the emergence of modern emergency medical services (EMS) systems in the late 1960s. These wartime experiences spurred the development of a robust "system of systems" comprised of emergency medical technicians, ambulances, communications, training programs, medical direction, and trauma centers that integrate prehospital and hospital trauma care. The investment paid off as trauma centers opened in nearly every major urban center and large swaths of the population are now served by effective and cohesive trauma care systems. Yet, the combat casualty on the battlefield today, like the accident victim in the 1960s ER, is likely attended to by a physician or physician assistant with no formal training in emergency medicine or trauma resuscitation. In the intervening years, ERs and the physicians that staff them have evolved into a sophisticated and specialized system of care, whereas the model for physician care in forward aid-stations remains largely stuck in the practices of the past century.

Since the 1980s, programs have emerged to train physician specialists in trauma surgery, emergency medicine and prehospital care. Without a major conflict since the emergence of these new specialties, there has simply not been a demonstrated need for them in the military until now. Nor

has there been a critical appraisal of how these relatively new specialties could be leveraged to optimize combat casualty care. For example, the DoD has only one relatively new prehospital training program capable of training 3 physicians per year. Today the U.S. Army has less than a dozen prehospital physician specialists and about the same number of trauma surgeons on active duty. By comparison, the Army has roughly the same number of radiation oncologists and nearly three times the number of pediatric psychiatrists and orthodontists. This is largely because medical specialty allocations are based on traditional peacetime beneficiary care needs. Refocusing on the wartime needs could populate key institutional and operational billets with a critical mass of trained prehospital and trauma specialists and drive further advances in battlefield care during peacetime.

CHALLENGE NO. 4: RESEARCH AND DEVELOPMENT

Current research and development (R&D) efforts are focused on material "things" and our current medical combat development efforts are primarily focused on rearranging existing paradigms for doctrine, manpower, and equipment. Less attention is paid to training, leadership, and organization, yet the current literature shows these areas have made the most significant documented improvements in survival. Several examples illustrate the potential for capitalization: (1) The U.S. Army Rangers, with their command led casualty response system, are able to document no potentially preventable prehospital deaths after more than a decade of combat.[7] (2) Staffing a forward battalion aid-station with emergency medicine trained providers showed a 30% reduction in deaths,[11] and (3) adopting current civilian air ambulance standards during helicopter evacuation in Afghanistan showed a 66% reduction in the risk of dying.[8] The training level and capabilities of the providers in the examples above exceeded the existing doctrinal model and the benefits were tangible. The solution lay with people, not technology. Using a sports analogy, the DoD is spending billions of dollars trying to perfect golf clubs, golf balls, and golf shoes, and virtually no research dollars on how to train the best golfers.

Prehospital care experts should direct and advise key research and development efforts, and set research priorities focused on improving prehospital casualty survival. Traditional measures of research program success (grants awarded, article published, and abstracts presented) should be shifted in favor of measurable solutions to specific battlefield problems (reducing preventable death, improving procedural success, reducing secondary injury, etc.).

To be sure, advanced technology can pave the way for enhanced combat casualty care. Examples of recent tools placed in the hands of medics and battalion medical officers include tourniquets, junctional hemorrhage control devices, and intraosseous needles. Yet, many of these so-called "new" tools and concepts have existed for decades or even centuries. With the exception of the hemostatic dressing, no new technology has been put into the medic's aid bag today that did not exist before the war (or even a century ago). The proposition is to balance the investment between things and people to optimize care on the battlefield.

CHALLENGE NO. 5: HOSPITAL CULTURE

The delivery of health care in fixed facilities is military medicine's largest mission and dwarfs all others. At a cost of nearly 60 billion dollars, the Military Health System (MHS) represents one of the most expensive components of the overall defense budget and is under constant scrutiny from Pentagon leaders. Former Assistant Secretary of Defense for Health Affairs, Dr. Sue Bailey's quote, "We are an HMO that goes to war" sums up a continuing concept regarding military medicine's primary focus on beneficiary care at fixed facilities. Indeed, when physicians are tasked to deploy from hospitals in the United States to the combat zone, a regulation calls them "fillers" and hospital personnel officers colloquially refer to the loss of skilled physicians as an "the operational tax."[10]

Regarding the combat medics' role, the traditional conceptual framework for some medical leaders starts not at the point of injury but rather in the combat hospital (or forward surgical team): "get the casualty to the hospital and we will take care of them." This is a legacy of the cold war when the combination of massive casualties and limited far-forward capability meant few meaningful interventions were possible until the casualty reached a combat hospital.[12] Today, we know the actions or inactions of the ground medic, flight medic, or junior battalion medical officer can mean the difference between delivering a salvageable casualty or a corpse to the combat hospital. We expect medics to perform lifesaving treatment under the most difficult of circumstances but invest minimal institutional effort toward training them to a high level or insisting they train alongside physicians and nurses in our fixed military hospitals during peacetime.

In their defense, military medical leaders face a unique set of challenges combat arms commanders do not face. Combat arms commanders focus on preparing for war. When not deployed or in a recovery or support cycle, they are focused on training and preparing for the next mission. Conversely, the MHS is expected to perform its mission of delivering high quality health care to military beneficiaries in its fixed facilities every day and be prepared to go to war at a moment's notice. Historically, the overwhelming pressures of providing beneficiary care in clinics and hospitals have conspired to redirect resources away from maintaining or improving battlefield care skills during peacetime.[13] Future efforts should be devoted to breaking free from this seemingly intractable constraint.

A WAY FORWARD

If history is any guide, making significant interwar advancements in battlefield medical care will be very difficult. As the current conflicts end, repeating the narrative of low case fatality and high survival rates, without a comprehensive and

TABLE I. Summary of Challenges and Recommendations

(1) Ownership
Establish a High-Level Battlefield Care Directorate, Division or Command Responsible for Improving and Synchronizing Battlefield Care Delivery
(2) Metrics and Data
Develop Methods to Collect Comprehensive Combat Casualty Care Data From the Point of Injury and During Evacuation
Develop a Systematic and Ongoing Method to Analyze Potentially Salvageable Combat Deaths and Use That Analysis to Drive Improvements in Equipment, Training, and Doctrine in Near Real Time
(3) Prehospital and Trauma Expertise
Systematically Train and Develop a Cadre of "Combat Medical Specialists"
Leverage Civilian Models of Prehospital Care (Advanced Medics, Flight Paramedics, EMS-Trained Physicians) to Improve Battlefield Care
(4) Research and Development
Focus R&D Efforts on Training, Leadership, and Doctrine, as well as Material Solutions
Use Metrics and Data to Drive R&D Efforts and Priorities
Leverage Prehospital Care Physician Specialists to Set Research Priorities
(5) Hospital Culture
Embrace Wartime Combat Casualty Care as the Core Mission of Military Medicine
Make the Elimination of Potentially Salvageable Combat Deaths an Organizational Goal
More Closely Align the Culture of Military Medicine With the Warfighter

sober review of both successes and where improvements can be made, risks impeding the ability to truly learn the lessons that will improve the survival of Soldiers, Sailors, Airmen, and Marines in the next conflict.

As a call to action, the following steps offer a potential way forward to overcome the challenges described above (Table I): (1) Adopt the IDF or similar model of combat casualty care focus and make an institutional commitment to eliminating potentially preventable death. Allow careful study of these deaths to drive the training, research, and development agenda. (2) Leadership of battlefield care must be established at the most senior level and the service medical departments held accountable for improving it. (3) Data and metrics must be obtained from the point of injury and throughout the continuum of care, and this information should drive evidence-based decisions. (4) Commit to training physician, nursing, and allied health providers to become "combat medical specialists" and placing them in key operational and institutional positions to leverage improvements in training, doctrine, research and development. (5) Research funds should be directed towards solving prehospital clinical problems and balanced to include research on training, organization, and leadership, not just material solutions. (6) The current paradigm of military medicine needs to evolve from an organizational culture chiefly focused on full-time beneficiary care in fixed facilities and part-time combat casualty care, the "HMO that goes war," toward an organizational culture that treats battlefield care delivery as its essential core mission. This need not lessen the importance or scope of beneficiary care and if agilely executed, could enhance the prestige and cache of the beneficiary mission.

Addressing leadership, strategy, metrics, workforce, and patient outcomes is common methodology for promoting excellence in hospital-based health care. The same methodology could be used to improve care forward of the hospital. Such a program would require a significant realignment of resources and priorities within military medicine that would challenge existing bureaucratic and leadership hierarchies. Acting on what we have learned to prepare for the next conflict in a resource constrained interwar period will challenge our medical leaders. Civilians can operate peacetime hospital systems, perhaps even more efficiently than the military. Yet ultimately, going to war is the unique mission of military medicine that distinguishes us from civilian health care and justifies our cost to the nation. If military medicine cannot demonstrate ownership of and expertise in its quintessential mission, prehospital, and battlefield trauma care, we must ask ourselves why military medicine exists.

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