

# TRAUMATIC BRAIN INJURY AWARENESS

## WRAIR PROTECTS YOUR SIX

Protecting your brain - the most important six inches on the battlefield

CENTER FOR MILITARY PSYCHIATRY AND NEUROSCIENCE



Blast Induced Neurotrauma and Neuroprotection



Sleep & Resilience



Team Performance and Mental Fitness



Military Psychiatry

Protecting the most important six microns between you and the threat of disease

CENTER FOR INFECTIOUS DISEASE RESEARCH

Vaccines & Entomology



Viral & Bacterial Diseases



Military HIV Research Program



Experimental Therapeutics & Emerging Infectious Diseases



## WHETHER YOU'RE AT HOME STATION OR SIX THOUSAND MILES AWAY

### WALTER REED ARMY INSTITUTE OF RESEARCH'S MISSION

Discover, design, and develop solutions for military relevant infectious disease and brain health threats through innovative research protecting and optimizing warfighter lethality.

#### LIKE AND FOLLOW WRAIR

- WRAIROfficial
- @WRAIR
- wrair.army.mil
- WalterReedArmyInstituteOfResearch

#### PROMOTED HASHTAGS

- #ArmyResilient #ForgeTheFuture
- #WRAIRProtectsYourSix #TBI
- #FarForwardBrainHealth
- #BrainAwareness #BrainHealth



WALTER REED ARMY INSTITUTE OF RESEARCH IS A SUBORDINATE COMMAND OF MRDC

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

# SUMMARY POINTS PAGE

## Neuroprotection

Novel methods to improve brain injury assessment, neuroprotection, and restoration

## Far-Forward Behavioral Health

Non-pharmacological and pharmacological solutions for immediate interventions supporting behavioral health and optimizing care

## Sustained Performance

Techniques to optimize cognitive functioning, attention and recuperative sleep

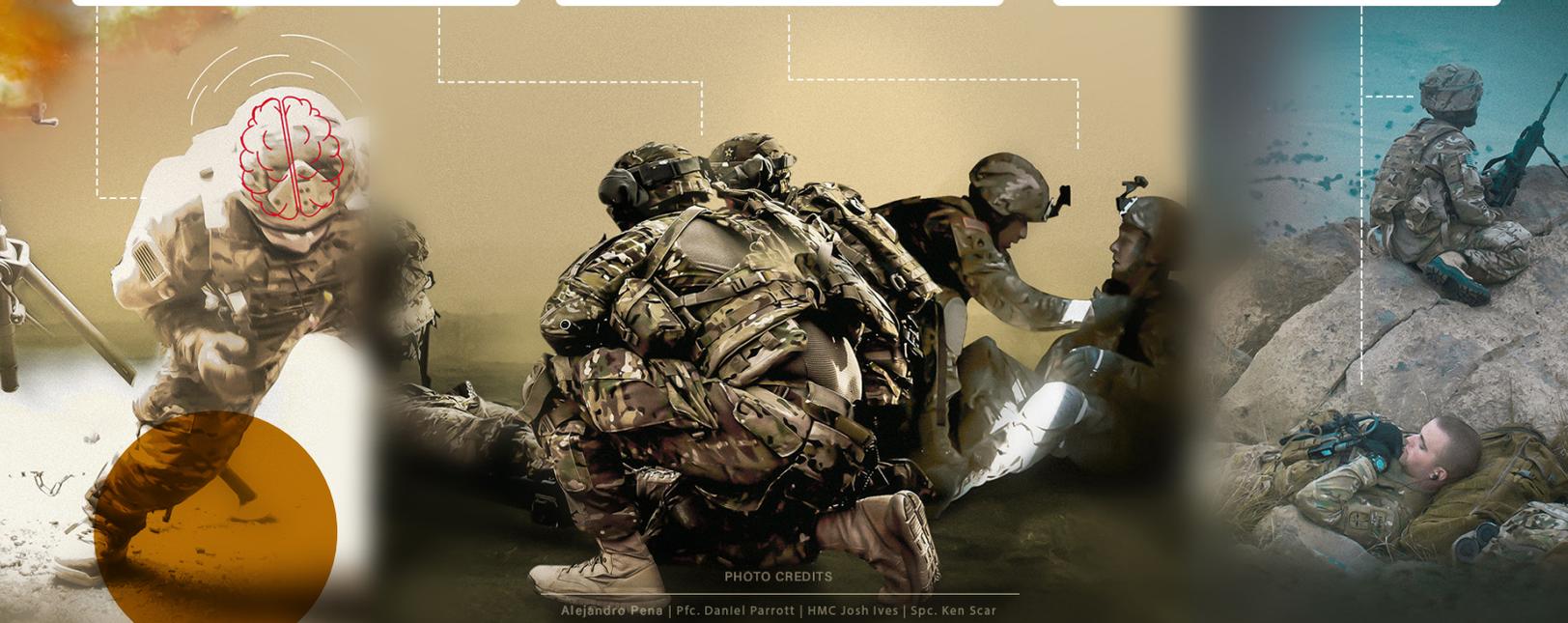


PHOTO CREDITS

Alejandro Pena | Pfc. Daniel Parrott | HMC Josh Ives | Spc. Ken Scar

## MILITARY TRAUMATIC BRAIN INJURIES

TBI is a major threat to Soldier readiness and currently lacks any FDA-approved drug treatment options. WRAIR is working to fill this capability gap by developing novel, ground-breaking solutions to mitigate TBI at the point-of-injury to reduce morbidity and mortality in a prolonged field care environment.

Fieldable diagnostic, preventive and treatment options are critical to Soldiers operating in the multi-domain environment. In addition to physical damage, TBI can meaningfully degrade mental capacity, including learning ability, decision making, attention span, memory, and emotion. Without these and other abilities or ready access to evacuation, the Warfighter is at serious risk in all phases of conflict.

### Types of traumatic brain injuries



Blast TBI



Concussion



Penetrating TBI



Polytrauma

# Military TBI : *by the numbers*

**84%**

FROM TRAINING, ACCIDENTS, ILLNESS AND NON-COMBAT ENVIRONMENTS



**16%**

DEPLOYMENT OR COMBAT ENVIRONMENTS

**383,947**

Warfighters have been diagnosed with a traumatic brain injury since 2000.

**80%**

of non-fatal traumatic brain injuries are diagnosed as concussion. Concussions can cause cognitive, physical, and emotional effects that may not fade with time. Critically, Soldiers are at greater risk of sustaining repeated concussions, which can result in second concussion syndrome, where the brain swells rapidly, leading to more serious symptoms.

**\$16 billion**

estimated total lifetime cost of severe TBIs sustained in Operation Iraqi Freedom and Operation Enduring Freedom through August 2005.

**\$32,760**

average cost per concussion case; this can exceed \$400,000 with more severe traumatic brain injury.

**LEAD CAUSE OF MORBIDITY AND MORTALITY**

## the terrible toll of TBI

### Concussion

- Headache
- Confusion
- Lightheadedness
- Dizziness
- Blurred vision
- Ringing in the ears
- Tiredness or sleepiness
- A bad taste in the mouth
- A change in sleep habits
- Behavior or mood changes
- Trouble with memory, concentration, attention, or thinking
- Loss of consciousness lasting a few seconds to minutes
- Sensitivity to light or sound
- Nausea or vomiting

### Moderate or Severe TBI

- Headache that gets worse or won't go away
- Repeated vomiting or nausea
- Slurred speech
- Convulsions or seizures
- An inability to wake up from sleep
- Enlargement of the pupil (dark center) of one or both eyes
- Numbness or tingling of arms or legs
- Loss of coordination
- Increased confusion, restlessness, or agitation
- Loss of consciousness lasting a few minutes to hours

## Table of contents

**SUMMARY POINTS**  
PAGE  
Page 1 to 2

**POINT OF INJURY**  
**CARE**  
Page 5 to 6

**CLINICAL PRACTICE**  
**GUIDELINES**  
Page 8

**PARTNERS**  
Page 11

**BIOMARKERS**  
Page 3 to 4

**PARTNERING TO**  
**PROVIDE SOLUTIONS**  
Page 7

**BREACHERS**  
**BRAIN**  
Page 9 to 10

# BIOMARKER DISCOVERY



## CHALLENGE

In combat or austere environments in which transportation to definitive care may be prolonged, innovative technology to diagnose more accurately the patient's TBI status has been a capability gap for multi-domain operations. Determining whether or not a Service Member needs a computed tomography (CT) scan to exclude intracranial hemorrhage or other ominous findings is a key military medical necessity.

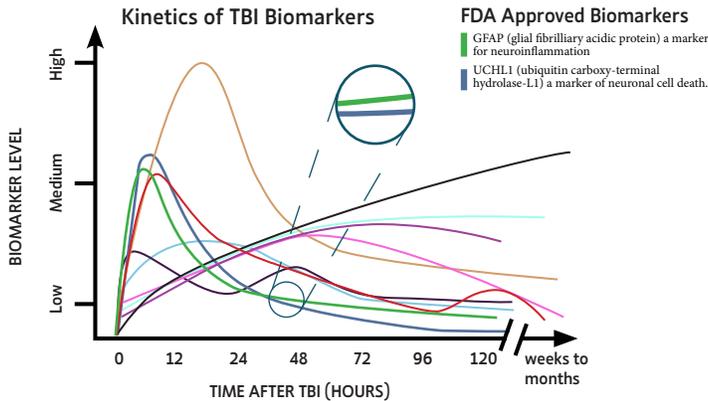


TBI increases risk for neurodegenerative pathologies such as dementia, Parkinson's disease, chronic traumatic encephalopathy, and Lou Gehrig's disease. When the brain is injured, molecules are released that can be measured in the blood and provide information on injury and treatment. WRAIR and the US Army Medical Material Development Activity (USAMMDA) worked with Banyan Biomarkers and Abbot Laboratories to develop the first tools that can identify these biomarkers.

## BIOMARKERS & THE DIAGNOSTIC PROCESS NOW



The GFAP and UCHL1 biomarkers are the only two biomarkers to receive FDA approval. WRAIR is working to identify other biomarkers for a more comprehensive approach to diagnosing TBI.



## BIOMARKERS TIMELINE

Banyan Biomarkers and WRAIR received the first DOD grant for TBI biomarkers. The initial approach focused on GFAP (glial fibrillary acidic protein), a marker for neuroinflammation, and UCHL1 (ubiquitin carboxy-terminal hydrolase-L1), a marker for neuronal cell death.

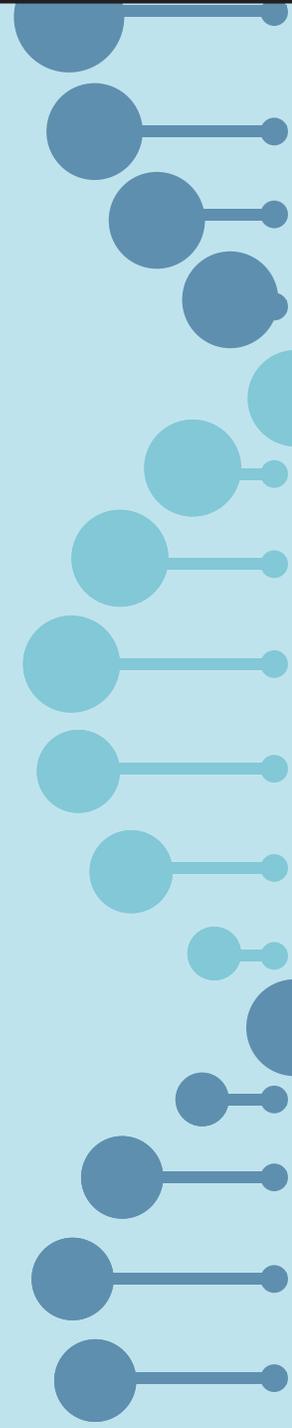
© 2002

Funding levels for TBI research were significantly increased by Congress due to growing concerns regarding the effects of repeated exposure to concussion in military and civilian sectors.

© 2007

WRAIR established the Laboratory Assay for TBI (LATBI) Program with USAMMDA to develop an acquisition strategy for diagnosing concussion on the battlefield.

© 2009





## BIOMARKER DEVELOPMENT AND FIELDING GOAL

### WHAT WE'RE DOING ABOUT IT

The LATBI program is focused on obtaining FDA approval for use of the biomarkers on the i-STAT Alinity. The i-STAT® system, which is already in use within the military as well as in hospitals globally, performs a number of common blood tests within minutes—at the bedside—and uses only two to three drops of blood. Integrating TBI biomarkers onto the i-STAT platform will provide far-forward solutions for objective, quantifiable diagnosis of TBI status following concussion occurring in training exercises and on the battlefield.



These blood-based biomarkers are the next step in the evolution of diagnosing and treating TBI. We are finding that not only are they more sensitive than CT in identifying TBI, but they may be more accurate than the current standard of magnetic resonance imaging (MRI).

- Geoffrey Manley, M.D., Ph.D., professor of neurosurgery at UCSF



### FORGING THE FUTURE

There is a need to identify additional biomarkers that can be used as part of a comprehensive approach to not only detect concussion, but also to detect bleeding deep in the brain and distinguish between severity levels across the entire spectrum of brain injury. TBI biomarker research efforts are also focused on identifying and validating novel biomarkers capable of indicating whether a drug has reached its target in the injured brain and is actually helping to repair brain damage.

The ultimate target is a lab-on-a-chip concept that integrates and automates laboratory assays on a small device that can be easily utilized by the Warfighter on the battlefield.



The government contracted Banyan Biomarkers to perform a pivotal, 2000 patient clinical trial to support a pre-market approval submission to the FDA.

2010

USAMRDC contracted Abbott Laboratories to transfer the biomarker assay technology to the highly portable i-STAT device.

2014

In February 2018, the FDA granted the de novo request to Banyan Biomarkers for the commercialization of an in vitro diagnostic blood test to aid in the evaluation of patients suspected of sustained concussion as part of its Breakthrough Devices Program.

2018



# INNOVATIVE DRUG DELIVERY FOR BATTLEFIELD POINT OF INJURY CARE

## THE CHALLENGES

According to the Joint Theater Trauma Registry, approximately 80% of reported TBI casualties are due to concussion, and 20% represent severe TBI. Moreover, second only to hemorrhage, severe penetrating TBI represents our most significant debilitating and life-threatening trauma. There are currently no FDA-approved drug therapies for TBI.

Treating the brain is extremely challenging; unlike other organs, the brain is isolated from the rest of the body by the blood-brain barrier, effectively preventing many drugs from entering the brain.

### WHAT IS NEEDED?

- Point-of-injury drug delivery systems capable of safely providing therapies directly to the injured brain
- Interventions that are capable of targeting multiple aspects of TBI to promote repair and recovery in a prolonged field care environment
- Kit-ready, user-friendly, fieldable solutions capable of withstanding extreme conditions and can be safely and effectively utilized by combat medics and support personnel.



## WHAT WE'RE DOING ABOUT IT

### INTRANASAL DRUG DELIVERY

Intranasal drug delivery offers a convenient route of delivery for TBI therapeutics. We are working on developing and testing of intranasal delivery devices that can accurately and reliably deliver TBI drugs that can be easily administered by combat medics and Soldiers for treating concussion.

### NANOPARTICLE-MEDIATED PRECISION DRUG DELIVERY

WRAIR is working with the University of California San Diego to develop a nanoparticle delivery system capable of delivering the payload directly to the injured brain where the drugs are released only upon reaching their designated target. This facilitates getting the drugs to where they are most needed and minimizes adverse side effects. These brain-specific nanoparticles have a broad safety profile and are simple to administer. The formulation is stable at room temperature, which makes this candidate suitable for transport, storage, and deployment in far-forward military operations.

### BIODEGRADABLE HYDROGEL DRUG DELIVERY

WRAIR is collaborating with Clemson University to develop a biodegradable hydrogel scaffold to protect the injured brain following severe open-head or penetrating TBI. The hydrogel is being designed to seal the wounded environment and to facilitate the controlled, continuous release of potent hemostatic agents to stop intracerebral hemorrhage, antimicrobials to prevent infection, and anti-inflammatory drugs to prevent brain swelling and brain herniation. The proposed hydrogel delivery system is stable, cost-effective, highly malleable, and easily transportable. This drug delivery system is capable of carrying multiple therapeutics and could revolutionize point-of-injury care for TBI occurring on the battlefield.

# TBI THERAPEUTIC STRATEGIES AIMED AT IMPROVING COMBAT CASUALTY CARE

## PRESERVING/RESTORING BRAIN HEALTH



Identifying underlying mechanisms of brain injury as biomarker and therapeutic targets for TBI



Intranasal (nose spray) and intratympanic (ear drops) drug delivery for concussion



Mitochondrial targeted therapeutics to improve brain bio-energetics for acute post-injury care of TBI



Next generation biomarker-guided drug development to treat neuroinflammation, infection, and sepsis following TBI



Point-of-Injury therapeutics targeting acetylcholine (learning & memory) receptors to improve cognitive outcome following TBI



Nanoparticle-mediated precision drug delivery vehicle for TBI



Biodegradable hydrogel drug delivery system that can seal an open-head wound, stop the bleed, and prevent brain swelling and herniation for severe TBI



## FORGING THE FUTURE

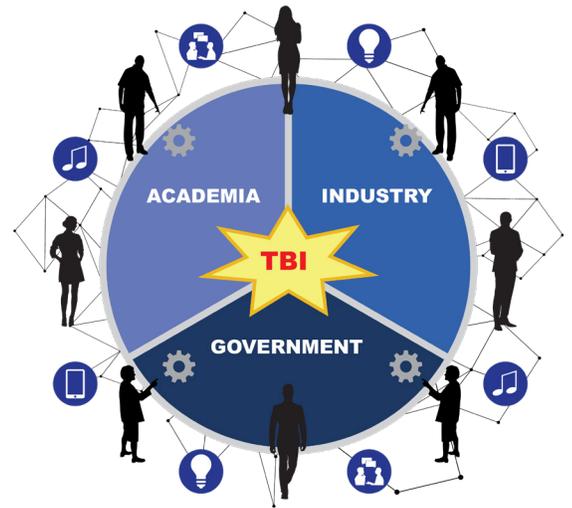
WRAIR's preclinical TBI neuroprotection research is critical for informing the TBI Drug Treatment Program at USAMMDA in working to deliver an FDA licensed drug.



# PARTNERING TO PROVIDE SOLUTIONS AT THE VELOCITY OF RELEVANCE

## THE PROBLEM

There are no FDA-approved drugs available for treating TBI. In part, this is because most of the drugs selected for clinical testing came from preclinical studies conducted using a single TBI model, with the bulk of preclinical data often coming from individual labs. A more robust preclinical approach was needed to address the comprehensive and complex injuries caused by TBI.



Operation Brain Trauma Therapy (OBTT) was established as a partnership between government, academic and industry partners to screen the most promising drugs for TBI across multiple preclinical TBI models. The primary research sites include: University of Pittsburgh, Miami Medical University, WRAIR, Virginia Commonwealth University, Banyan Biomarkers, University of South Florida, and Messina University (Italy). In addition to taking a rigorous preclinical approach, OBTT was the first to incorporate blood-based biomarkers into its preclinical studies.

## accomplishments



To date, OBTT has screened 12 of the most promising drugs for TBI across multiple preclinical studies. The results have shown correlations between TBI biomarkers and different types/severities of brain injury, which provided further validation to support the recent FDA approval of utilizing TBI blood-based biomarkers as an aid to diagnosing concussion.



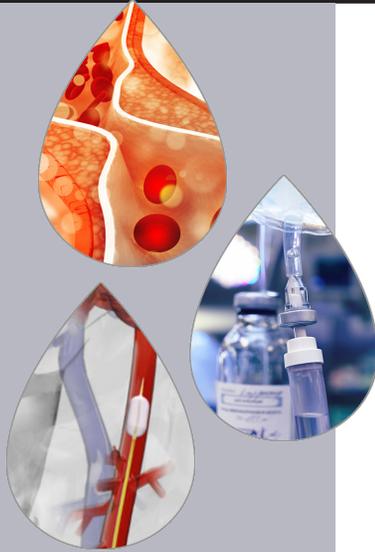
Even more importantly, OBTT has shown that TBI biomarkers correlate with improved outcomes and reduced brain injury, which indicates these biomarkers may be useful in validating therapeutic efficacy of TBI drugs undergoing clinical testing. The OBTT provides an outstanding example of how leveraging partnerships can accelerate the velocity of relevance to identify a drug that will help Soldiers exposed to TBI in training or on the battlefield.



## FORGING THE FUTURE

The USAMRDC-led acquisition program is using innovative adaptive Phase 2 clinical trial designs to rapidly advance the development of the most promising TBI therapies through a partnership with TRACK-TBI NET. TRACK-TBI NET is a multi-faceted Phase 2 TBI clinical trial network that builds on the well-established infrastructure of its foundation: the longitudinal, observational TRACK-TBI study. This institutional and public-private partnership is comprised of 18 clinical enrollment/study sites, 7 cores, and a contract research organization, for a total of nearly 50 collaborating institutions, corporations, and philanthropic organizations.

# CLINICAL PRACTICE GUIDELINES FOR ACUTE TBI CARE



## THE CHALLENGES

- Brain Swelling
- Bleeding Inside the Skull
- Blood Clotting In The Brain



- » Importantly, over 96% of TBIs occur in conjunction with extremity trauma, increasing the complexity of brain injuries that require tailored medical solutions in the context of the associated TBI/polytrauma. For example, there is controversy whether current resuscitation and treatment strategies for extremity trauma are safe for use in TBI patients.
- » WRAIR scientists are actively engaged with military medical experts in order develop safe and effective neurotherapeutic resuscitation protocols for TBI/polytrauma. The primary focus of this work is to experimentally replicate these complex brain injuries to assess various medical solutions to polytraumatic injuries, including testing prehospital resuscitation strategies, resuscitative endovascular balloon occlusion of the aorta (REBOA), and prophylactic administration of heparinoids for mitigating deep vein thrombosis in trauma patients, all of which target the development of standards of care for trauma patients.

## THE SOLUTIONS

### PREHOSPITAL RESUSCITATION FLUIDS AND TARGETS:

Tranexamic acid (TXA) is a pro-thrombotic resuscitation product that stops the bleed during the acute post-injury phase. However, TXA may also increase clotting in the brain, resulting in impeded blood flow and oxygen delivery to damaged areas. WRAIR is collaborating with the Safar Center for Resuscitation (UPITT Medical University) to test the effects of TXA and other resuscitative agents to help establish optimal neurotherapeutic protocols.

### RESTORING BLOOD FLOW:

Prophylactic use of heparinoids is a standard-of-care procedure to prevent deep vein thrombosis following trauma but may be contraindicated in the presence of TBI with intracerebral hemorrhage. WRAIR is working with the Department of Neurosurgery, Uniformed Services University, to determine how soon heparinoid therapy may be safely initiated following severe TBI.

Importantly, while not direct solutions for TBI, these procedures may provide some measure of indirect neuroprotective effects for TBI including stopping brain bleed (TXA), mitigating blood clots and restoring blood flow and oxygen delivery (heparinoids), and triggering the release of molecules that potentiate anti-inflammatory effects in the brain (both).



## FORGING THE FUTURE



Translating preclinical research into clinical practice guidelines for the acute management of TBI from the point-of-injury through hospital care



# BREACHER'S BRAIN

## THE CHALLENGE

Breacher's brain is a symptom complex associated with chronic exposure to repetitive low-level blast. It compromises the ability of Warfighters to make split-second decisions that may have life or death consequences. Subjective symptoms include, but are not limited to, headache, fatigue, slowed thought process and an increase in memory difficulties. It is similar to sports concussion.

## THE SOLUTION

WRAIR scientists are measuring blast overpressure and its subsequent effects on human performance. DOD personnel are adjusting how they train based on feedback from WRAIR scientists.

## THE FUTURE

WRAIR and USAMMDA are partnering to develop a blast gauge dosimeter that identifies for military leaders and medical personnel when a Soldier has experienced cognitive decline.

## PRODUCTS



**LEADERSHIP TOOL:** a real-time Soldier assessment tool that predicts the effect of blast on human performance

**MEDICAL TOOL:** blast overpressure exposure is stored in Soldiers' medical records and accessed by treating physicians



## ACOUSTIC INSULT

Breacher's brain symptomology can occur in training environments that produce low blast overpressure. For example, hand-grenade pits provide adequate blast overpressure protection and yet the acoustic insult is high. We have incorporated sound pressure measurement into our program to better understand the acoustic insult on Warfighters and its effects on their performance.



## DOD REQUIREMENT TO STUDY BLAST

Federal laws contained in recent **National Defense Authorization Acts** have directed the Department of Defense to study blast exposure and demonstrate that it can be stored in a Service Member's medical record.

**NDA 2018, Sec. 734.** Longitudinal medical study on blast pressure exposure of members of the Armed Forces.

**NDA 2019, Sec. 253.** Review of guidance on blast exposure during training.

**NDA 2020, SEC. 716.** Inclusion of blast exposure history in medical records of members of the Armed Forces.





## PERSONAL PROTECTIVE EQUIPMENT

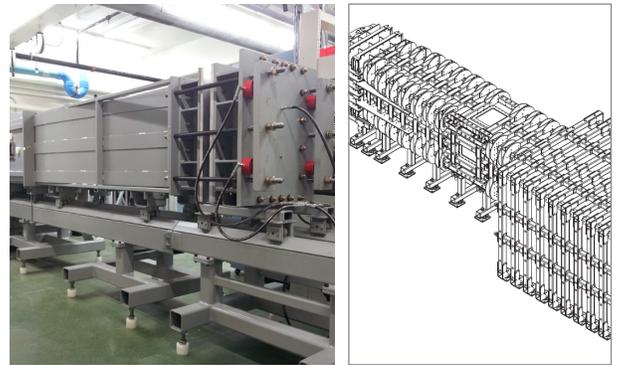
### THE CHALLENGE

Personal protective equipment (PPE) protects the Warfighter from blunt injury caused by fragment debris and other flying projectiles from an explosive blast. However, PPE is not designed to protect against the overpressure after an explosion. The ability of PPE to protect the Warfighter from overpressure is largely unknown. The challenge is determining whether that overpressure has injured the Soldier wearing the equipment. This measure will determine whether the equipment is safe.

### THE SOLUTION

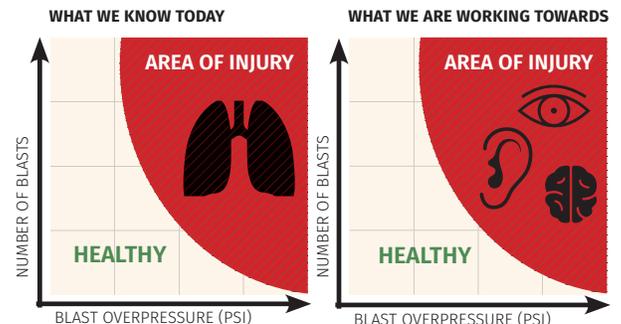
#### from Lab to Soldier

#### DETERMINING INJURY RISK CRITERIA



The Advanced Blast Simulator (ABS) provides a high fidelity re-creation of a blast to define injury criteria and improve Soldier readiness.

We are establishing the survivability and injury risk curves for health hazard assessment of personal protective equipment. In addition, we are defining biomechanical parameters underlying the effective protection of Soldiers from the vital organ injuries resulting from blast.



## DID YOU KNOW

# Blast IS A WHOLE BODY INJURY?



Eyes of Soldiers are at a high risk of being wounded by explosions. Although Soldiers are issued protective goggles, ocular injuries nevertheless can occur largely due to blast wave penetration. As a result, more than half of Soldiers wounded by blast have vision deficits. Using the Advanced Blast Simulator, we are learning that the eye, especially the retina, is highly susceptible to injury from low-intensity repetitive blast exposures. Our results provide a step towards identifying safe thresholds for blast exposure, as a means to prevent potential loss of sight.



Hearing loss is “the most prevalent service-connected disability among American Veterans”. We are addressing this by identifying changes to inner ear DNA after blast overpressure exposure. This work provides pivotal clues toward identifying the genes that are involved in blast-induced hearing loss.



Biomarker levels change as a result of blast insult, but the central nervous system is uniquely vulnerable to explosive blast overpressure. The use of blood-based biomarkers has the potential to aid TBI diagnosis and prognosis for Service Members.

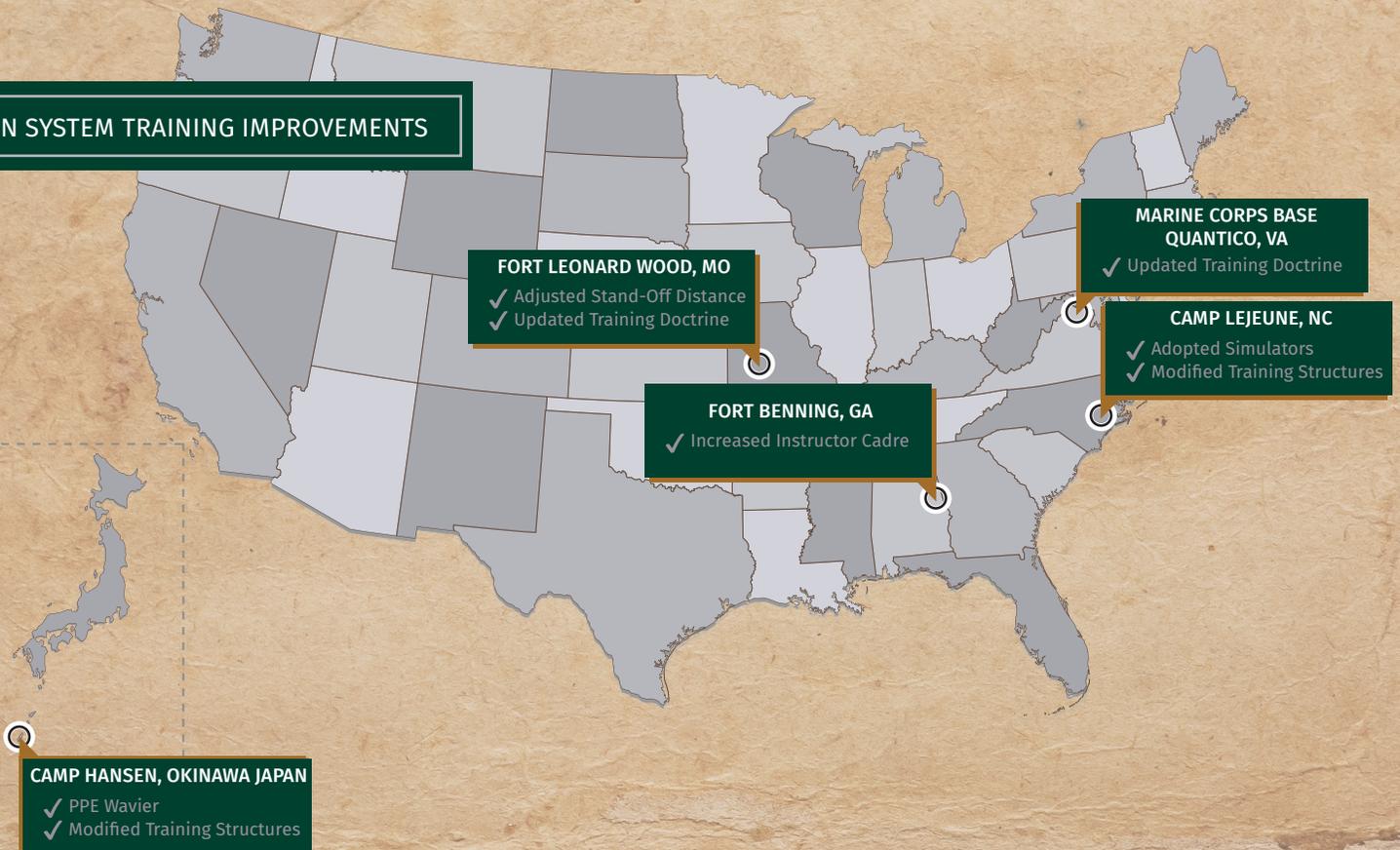


Training with explosives and heavy weapon systems exposes Soldiers to repeat low-level blast. It is important to know the health risks associated with prolonged exposure. Too much may temporarily alter brain function at a molecular level. In our simulator we can replicate blast exposures that are relevant to Warfighters and then measure subsequent functional impairment and protein expression changes to better understand the deleterious effects of repeat low-level blast.



A primary blast injury is the direct result of blast overpressure on the whole-body. This blast wave propagation of energy can injure gas-filled organs (e.g., lungs) and also interrupt soft tissue healing. At the cellular level, blast overpressure decreases the number of white blood cells which are needed to protect the body from infections.

## WEAPON SYSTEM TRAINING IMPROVEMENTS



### CAMP HANSEN, OKINAWA JAPAN

- ✓ PPE Wavier
- ✓ Modified Training Structures

### FORT LEONARD WOOD, MO

- ✓ Adjusted Stand-Off Distance
- ✓ Updated Training Doctrine

### FORT BENNING, GA

- ✓ Increased Instructor Cadre

### MARINE CORPS BASE QUANTICO, VA

- ✓ Updated Training Doctrine

### CAMP LEJEUNE, NC

- ✓ Adopted Simulators
- ✓ Modified Training Structures

## KEY PARTNERSHIPS

Our robust partnerships, especially our MIL-MIL partnerships, provide a competitive advantage and help build strategic depth during all phases of MDO.

### U.S. GOVERNMENT

- ARDEC
- ARL
- BHSAI
- CCDC
- CCCRP
- ERDC
- ERT
- FBI/ERT
- MCSC
- MEDVAMC
- NHRC
- NIDCD/NIH
- NMRC
- NRL
- NSRDEC
- PEO
- RDECOM
- TSRL
- USAARL
- USAISR
- USAMRICD
- USAMMDA
- VA
- WRIISC
- WRNMMC/NICOE

### ACADEMIA

- CLEMSON UNIV.
- GEORGIA TECH RESEARCH INST.
- JOHNS HOPKINS APPLIED PHYSICS LAB
- JOHNS HOPKINS UNIV. SCHOOL OF MEDICINE/LIEBER INST.
- MASSACHUSETTS INST. OF TECHNOLOGY
- MESSINA UNIV.
- MIAMI MEDICAL UNIV.
- MOUNT SINAI, ICAHN SCHOOL OF MEDICINE
- NEW JERSEY INST. OF TECHNOLOGY
- OAK RIDGE INST. FOR SCIENCE AND EDUCATION
- PENNSYLVANIA STATE UNIV.
- UNIV. OF CALIFORNIA/SAN DIEGO
- UNIV. OF CALIFORNIA/SAN FRANCISCO
- UNIFORMED SERVICES UNIV. OF THE HEALTH SCIENCES
- UNIV. OF FLORIDA
- UNIV. OF KENTUCKY
- UNIV. OF MARYLAND SCHOOL OF MEDICINE
- UNIV. OF MICHIGAN
- UNIV. OF OREGON
- UNIV. OF PITTSBURGH
- UNIV. OF SOUTHERN FLORIDA
- UNIV. OF SYDNEY
- U.S. AIR FORCE ACADEMY
- U.S. MILITARY ACADEMY
- VIRGINIA COMMONWEALTH UNIV.
- VIRGINIA TECH UNIV.

### FIELD RESEARCH PARTNERS

- CAMP HANSEN, OKINAWA (III MEF EOTG)
- CAMP LEJEUNE, NC (II MEF EOTG)
- CAMP PENDLETON, CA (I MEF EOTG)
- CHICAGO SWAT
- DEPT. OF ENERGY, OAK RIDGE, TN
- FORCED ENTRY TACTICAL TRAINING
- FT. BENNING, GA, SFARTEC
- FT. JACKSON, SC, 171<sup>ST</sup> INFANTRY
- FT. LEONARD WOOD, MO, 35<sup>TH</sup> ENGINEERS
- FT. SILL, OK, 428<sup>TH</sup> FIELD ARTILLERY
- JB ELMENDORF-RICHARDSON, AK
- LAS VEGAS SWAT
- MARINE CORPS BASE QUANTICO, VA (MOE)
- NATIONAL CAPITAL BREACHERS GROUP
- NAVY EOD-MOU TEU 1&2
- PORTLAND SERT
- TACFLOW ACADEMY
- TACTICAL ENERGETIC ENTRY
- WASHINGTON COUNTY SHERIFFS

### FOREIGN GOVERNMENT & MILITARY

- AUSTRALIAN MILITARY
- DRDC
- INMAS-DRDO
- NEW ZEALAND MILITARY

### INDUSTRY

- 13-THERAPEUTICS
- ABBOTT
- ANTHROTRONIX, INC
- APPLIED RESEARCH ASSOCIATES
- BANYAN BIOMARKERS
- BLACKBOX BIOMETRICS, INC
- DYNFX, LLC
- KALOCYTE
- KURVE TECHNOLOGY
- L3 COMMUNICATIONS
- LPATH, INC.
- NYRADA
- RUBICON BIOTECHNOLOGY
- SYNCTHINK

THIS IS A SUBSET OF WRAIR'S MORE THAN 400 PARTNERSHIPS