USAARL-TECH-SR--2026-26

UNITED STATES ARMY AEROMEDICAL RESEARCH LABORATORY

Acute Thoracoabdominal Trauma and Incapacitation Injury Tolerance and Criteria Development Stakeholder Meeting Summary

Danielle Rhodes & B. Joseph McEntire

Notice

Qualified Requesters

Qualified requesters may obtain copies from the Defense Technical Information Center (DTIC), Fort Belvoir, Virginia 22060. Orders will be expedited if placed through the librarian or other person designated to request documents from DTIC.

Change of Address

Organizations receiving reports from the U.S. Army Aeromedical Research Laboratory on automatic mailing lists should confirm correct address when corresponding about laboratory reports.

Disposition

Destroy this document when it is no longer needed. Do not return it to the originator.

Disclaimer

The views, opinions, and/or findings contained in this report are those of the author(s) and should not be construed as an official Department of the Army position, policy, or decision, unless so designated by other official documentation. Citation of trade names in this report does not constitute an official Department of the Army endorsement or approval of the use of such commercial items.

REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

1. REPORT DATE *(DD-MM-YYYY)*	2. REPORT TYPE	3. DATES COVERED *(From - To)*
01-07-2026	Special Report	01-10-2024 - 31-10-2025

4. TITLE AND SUBTITLE

Acute Thoracoabdominal Trauma and Incapacitation Injury Tolerance and Criteria Development Stakeholder Meeting Summary

5a. CONTRACT NUMBER

5b. GRANT NUMBER

5c. PROGRAM ELEMENT NUMBER

0602115DHA

6. AUTHOR(S)

Rhodes, D.[1,2], & McEntire, B. J.[1]

5d. PROJECT NUMBER

462000

5e. TASK NUMBER

462A

5f. WORK UNIT NUMBER

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)

U.S. Army Aeromedical Research Laboratory
P.O. Box 620577
Fort Rucker, AL 36362

8. PERFORMING ORGANIZATION REPORT NUMBER

USAARL-TECH-SR--2026-26

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)

U.S. Army Medical Research and Development Command
Military Operational Medicine Research Program
810 Schreider Street
Fort Detrick, MD 21702

10. SPONSOR/MONITOR'S ACRONYM(S)

USAMRDC

11. SPONSOR/MONITOR'S REPORT NUMBER(S)

12. DISTRIBUTION/AVAILABILITY STATEMENT

DISTRIBUTION STATEMENT A. Approved for public release: distribution is unlimited.

13. SUPPLEMENTARY NOTES

[1]Chenega Services & Federal Solutions, LLC (CSFS), [2]U.S. Army Aeromedical Research Laboratory

14. ABSTRACT

A virtual stakeholder meeting was convened on April 23, 2025 to disseminate emerging results of the U.S. Army Medical Research and Development Command (USAMRDC) funded research on acute thoracoabdominal trauma and incapacitation injury tolerance and criteria development. Participants reviewed progress on biomechanical research aimed at developing injury risk curves for thoracoabdominal regions. Key findings highlighted the need for enhanced medical injury criteria to address emerging threats, such as lightweight body armor and high-velocity impacts. Presentations covered experimental methodologies, scaling techniques, and translational research challenges, and emphasized the importance of integrating physiological data. Stakeholders discussed future directions, including the development of new surrogates, injury grading schemes, and operational vignettes to inform military practices. The meeting underscored the importance of collaboration and innovation in advancing protective equipment standards for Warfighter survivability.

15. SUBJECT TERMS

behind armor blunt trauma (BABT), behind helmet blunt trauma (BHBT), acute thoracoabdominal trauma, human surrogates, medical injury criteria, injury scoring, incapacitation injury tolerance and criteria

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT	b. ABSTRACT	c. THIS PAGE			Amanda Hayes, MS
UNCLAS	UNCLAS	UNCLAS	SAR	8	19b. TELEPHONE NUMBER *(Include area code)* 334-255-6067

This page is intentionally blank.

Summary

A virtual stakeholder meeting was convened on April 23, 2025, to disseminate emerging results of the U.S. Army Medical Research and Development Command (USAMRDC) funded research on acute thoracoabdominal trauma and incapacitation injury tolerance and criteria development. Participants reviewed progress on biomechanical research aimed at developing injury risk curves for thoracoabdominal regions. Key findings highlighted the need for enhanced medical injury criteria to address emerging threats, such as lightweight body armor and high-velocity impacts. Presentations covered experimental methodologies, scaling techniques, and translational research challenges, and emphasized the importance of integrating physiological data. Stakeholders discussed future directions, including the development of new surrogates, injury grading schemes, and operational vignettes to inform military practices. The meeting underscored the importance of collaboration and innovation in advancing protective equipment standards for Warfighter survivability.

This page is intentionally blank.

Table of Contents

This page is intentionally blank.

Background

A virtual stakeholder meeting was convened on April 23, 2025, to disseminate emerging results of the U.S. Army Medical Research and Development Command (USAMRDC) funded research on acute thoracoabdominal trauma and incapacitation injury tolerance and criteria development. This meeting was held virtually due to government travel restrictions imposed in early 2025. The agenda for this virtual meeting is provided in Table 1. Summaries of the presentations and discussions are provided in the results section of this paper.

Table 1. Agenda for the Med-BABT Stakeholder Update Meeting

Time	Duration (min)	Topic	Presenter
0900	10	Welcome and Introduction	Mr. McEntire/ Dr. Piehler
0910	20	Medical (Med)-Behind Armor Blunt Trauma (BABT) Overview	Mr. McEntire
0930	15	Research Plan	Dr. Yoganandan
0945	15	Lung Injury Criteria	Dr. Yoganandan
1000	15	Heart Injury Criteria	Dr. Salzar
1015	15	Liver Injury Criteria	Dr. Bass
1030	10	Break	N/A
1040	15	Soft Tissue Contusion	Dr. Salzar
1055	15	New Lung Injury Mechanism and Implications	Dr. Bass
1110	15	Preliminary Human BABT Injury Risk Curves and Enhanced Medical Injury Criteria (EMIC)	Dr. Yoganandan
1125	10	Data Management, Reports and Dissemination, and Path Forward	Mr. McEntire
1135	15	Discussions and Input from Stakeholders	Team
1150	10	Wrap Up	Mr. McEntire

This space is intentionally blank.

Participants

Invited Organizations:

U.S. Special Operations Command (USSOCOM)
U.S. Army Aeromedical Research Laboratory (USAARL)
Defense Health Agency (DHA) Public Health (PH)
Uniformed Services University (USU)
Henry M. Jackson Foundation
Office of Naval Research
National Intrepid Center of Excellence (NICoE)
USAMRDC, Military Operational Medicine Research Program (MOMRP)
National Institute of Justice
Joint Base San Antonio
Walter Reed Army Institute of Research (WRAIR)
Medical Capability Development Integration Directorate (MED-CDID)
DHA Research and Engineering (DHA R&E)
U.S. Army Office of the Surgeon General (OSTG)
U.S. Navy (USN)
Armed Forces Medical Examiner System (AFMES)
Blast Injury Research Coordinating Office (BIRCO)
Maneuver Center of Excellence – Capability Development Integration Directorate (MCOE-CDID)

Presenters:

USAARL
Wayne State University (WSU)
Medical College of Wisconsin (MCW)
University of Virginia (UVA)

Contractors:

Leidos Staff

This space is intentionally blank.

Results

Welcome

Dr. Piehler opened the meeting with welcoming remarks and appreciation for everyone's interest and time. Mr. McEntire facilitated brief introductions from the meeting participants and then transitioned to providing a programmatic overview.

Med-BABT Overview

The USAMRDC funded research program on acute thoracoabdominal trauma and incapacitation consists of two parts, an extramural effort and an intramural effort. The extramural portion was the focus subject of this stakeholder meeting. The extramural effort consists of an Other Transaction Agreement (OTA) award through the Medical Technology Enterprise Consortium (MTEC) to the MCW with two academic partners, the UVA and WSU. The objective of this extramural effort is to develop region specific thoracoabdominal injury risk curves for incapacitation and lethality when struck by blunt impacts that are representative of insults caused by localized body armor deformation when defeating kinetic threats. This injury mechanism is commonly referred to as behind armor blunt trauma (BABT) and is a body armor performance requirement for both soft and rigid armor systems. The legacy BABT performance threshold for body armor systems is to not exceed a maximum armor deformation distance of 44 millimeters (mm) as measured in the residual deformation of a Roma Plastilina # 1 (RP1), a commercially available clay surrogate.

Current military body armor is designed to defeat specific ballistic threats without exceeding the 44 mm back face deformation (BFD) threshold. However, this armor is recognized to be heavy and exasperates fatigue. Increased ballistic threats are anticipated in future near-peer conflicts. Advances in material science have demonstrated materials with increased ballistic tolerance and reduced weight, but with increased BFD deformations. Additionally, the Army has relaxed the 44 mm BFD to 58 mm with the intent to increase design optimization by the industry. However, the injury risk associated with this BFD requirement change is not understood.

Research Plan

The objective of this MTEC BABT effort is to develop region specific injury risk curves to help foster optimization of future body armor design and development efforts. Prior efforts to investigate BFD risk with live fire rounds and armor protected specimens, while interesting, have been unsuccessful because the resulting armor deformation is influenced by armor type and projectile parameters, and the insult kinematics acting on the specimen are unknown. The approach proposed by the MTEC BABT consortium is to apply direct blunt impacts onto unprotected specimen (without armor) with a blunt instrumented projectile propelled by compressed gas. The impact surface of the original projectile indenter (ID1) was based on observed armor deformations during live fire tests. Feedback received at a prior stakeholder meeting requested additional research be conducted with a second indenter (ID2) with an impact surface contour that better represents the deformation shape observed with soft armor systems. The projectile indenter was instrumented with a tri-axial accelerometer with a known mass and velocity to calculate the applied dynamics and kinematics of the impact. The information

provided by the instrumented indenters offer the researchers opportunity to consider numerous insult metrics during injury risk curve development.

The three universities proposed to conduct research with three surrogate types, human cadaver, deceased swine, and live swine under approved research protocols. The deceased specimen provides structural correlation data between the surrogate types while the live swine provides incapacitation and injury data for living tissue exposed to similar loading conditions.

Presentation Summaries

Lung injury criteria – MCW.

Dr. Yoganandan presented progress on reproducing BFD injuries to the lungs to develop lung injury risk curves. An overview of the process to establish injury criteria for the lung was presented. Images of BFD injuries produced by live fire were compared to injuries produced by direct blunt impacts to specimens with ID1 and ID2. The comparison concluded that the direct blunt impacts reproduced similar injuries to the live fire. The test model developed allowed investigators to determine the mechanism of injury while measuring metrics that could not be measured in the field. The team assessed a variety of biomechanical metrics such as viscous criterion, impulse, impulse density, deflection, force, energy, and loading rate to develop lung injury risk curves. Of these, the viscous criterion and impulse were considered for the injury risk curve analysis and presented. It was noted that indenter shape produced similar curves. The presentation concluded by reviewing preliminary lung BABT injury risk curves at different severities

Heart injury criteria – UVA.

Dr. Salzar presented progress on reproducing BFD injuries to the heart for heart injury risk curve development. Similarities with the MCW laboratory and the additional sensors used were noted. The research team conducted tests using ID1 and ID2 and measured blood pressure of the specimen post-impact. Impacts were focused on specific intervals of normal sinus rhythm to assess the risk of an insult occurring during different waves. Heart impact during the T-wave will induce ventricular fibrillation and therefore was avoided. Difficulties to develop body armor, especially lightweight body armor, that would protect against ventricular fibrillation were noted. With this risk known, outcomes for heart impact during other intervals of normal cardiac sinus rhythm are being investigated.

Dr. Salzar presented images and data from two exemplar cases and concluded with preliminary injury risk curves, one representing apnea and the second representing lethality. Energy was found to be the best predictor of risk. Future work is focusing on elucidating the severity of impacting different intervals of normal sinus rhythm to develop a better idea of injury risk.

Liver injury criteria – WSU.

Dr. Bass presented progress on reproducing BFD injuries to the liver and noted liver injuries diagnosed with necropsy and radiology. The research team conducted tests using ID1 and ID2. Images of BFD injuries to the liver at varying severities of injury were presented. Using criteria from the American Association for the Surgery of Trauma (AAST), each group graded injury severity ranging from grade I (minor) to a grade IV (severe). Testing indicated a higher energy was associated with more severe laceration and extravasation in the peritoneal cavity. The injuries are often associated with lung contusion resulting from the impact to the lower right quadrant of the ribs.

The data presented provides preliminary new injury criteria for the liver. Moving forward, a new indenter will be implemented. The next steps for the team include refining injury assessments across groups, coordinating injury assessment with polytrauma, assessing geometric scaling for the indenter, and investigating other scaling effects for ID1 and ID2.

Soft tissue injury – UVA.

Dr. Salzar presented an overview of soft tissue contusion formation from simulated BABT impacts. Soft tissue contusions were investigated through launching an indenter into the muscle of the inner thigh region. Targeted impact energies ranged from 50 to 270 Joules. Post-test observations revealed decreased mobility, inflammation, hematoma, edema, scarring, and tissue necrosis that was dependent on the severity of the impact. Results from this work highlighted that soft tissue contusion occurring as a contact injury under body armor should not be discounted. Post-presentation discussion introduced the topic of deep tissue bruising causing more severe injuries like calcification combined with scarring. Although there is uncertainty regarding the impact of these injuries and how long calcification could last, it was expected that results of the sustained injuries could last for years.

New lung injury mechanisms and implications – WSU.

Dr. Bass presented an overview of possible new mechanisms of lung injury associated with blunt impacts that exceed the speed of sound. During this test series, researchers discovered that at higher speeds, an impact to the right lung resulted in injuries to both lungs. This result deviated from lower speed impacts that resulted in lung injuries occurring close to the site of impact. The proposed hypothesis on the differences between sustained lung injuries was that higher speed impacts resulted in shock damage. Lung shock increases with higher chest wall acceleration and results in pulmonary bleeding into alveolar sacs, which was observed in the higher speed blunt impacts. Introducing a new mechanism of lung injury (i.e., shock injury) results in competing injury criteria for a single impact location. Competing injury criteria highlights the importances of considering multiple injury mechanisms to be included for a robust thoracic BABT injury assessment.

Preliminary human BABT injury risk curves and Enhanced Medical Injury Criteria (EMIC) – MCW.

Dr. Yoganandan presented a summary of preliminary human injury risk curves and preliminary injury criteria was presented. The importance of a regional approach to thoracic injury risk curves was highlighted as different regions had different responses to blunt forces. For this reason, it was suggested that different metrics for different regions might be required for generating the most accurate injury risk curves. Some of the metrics being investigated are energy, energy density, velocity, momentum, blunt criterion, viscous criterion, loading rate, and others. Additionally, injury scoring was highlighted as an important factor in this research. The injury probabilities for a single region change based on the level of injury severity is being assessed. Understanding injury probabilities is an important factor regarding body armor assessment methodology development. Different injury risk curves will be required based on the level of protection that is desired.

Data management, reports and dissemination, recommendations and path forward.

Mr. McEntire presented the path forward for the data generated by the three academic centers. He indicated that all data produced by MCW, UVA, and WSU are government-owned and delivered to USAARL for storage and additional use. Outside organizations can request data and be provided with access under a data sharing agreement. He provided an overview of the approval process for presentations, publications, and posters, noting all materials undergo technical and editorial, operational security, and public affairs reviews. Any materials involving animals or cadavers also go to the USAMRDC for review. Mr. McEntire highlighted that the performers have 28 open manuscript articles to date and an additional 20-30 posters, presentations, and abstracts.

Mr. McEntire discussed that his role in the project was to ensure transition of findings to Service Members and programs in the military. He overviewed the path forward, noting discussions regarding an amendment for option year three which will need additional funding. There are plans to convene a medical review panel to ascertain the interpretation of the injuries. Mr. McEntire noted that for successful transition of the injury criteria for future body armor test programs, a new surrogate is required. Once surrogates are identified, they will need to be evaluated for bio-fidelity.

Mr. McEntire reviewed current and anticipated challenges. Funding continues to be an issue, but the team is consistently submitting applications for additional funding, and the MTEC has added additional tasks which resulted in an extension of the period of performance. The team is facing uncertainty regarding the future of the program due to the separation of the DHA and the U.S. Army.

The presentation was concluded with an overview of recommendations from the fiscal year (FY) 23 stakeholders meeting. Mr. McEntire highlighted that the team added an ID2 and plans to add an ID3 in option year three to address the comment on testing various impactor geometries. A tethered impactor has been added to option year three. For FY26 and FY27, government validation efforts are planned to test and validate injury risk curves (IRCs) against modern body armor plates and projectiles/BFD data to live fire. To address the need to include

other injury severity scores, a medical review panel is planned with the Joint Trauma System to develop operational vignettes and a military relevant grading scheme. Mr. McEntire noted no action has been taken to address a comment regarding expanding the research scope to include oblique impact, but this is a potential new task for the program. Last, the team is unable to consider finite element models (FEM) for tissue properties because modeling is outside the scope of work for the effort and cost prohibitive.

Discussions and Input from Stakeholders

A USN researcher acknowledged the difficulty of obtaining funding. For cost savings, he recommended that the team postpone efforts addressing oblique impact and development of work with the third indenter.

An Army representative noted that a new lightweight body armor has been developed and is moving forward to the Army Futures Command. The new body armor is lighter weight but retains the 58 mm of BFD requirement. Mr. McEntire noted that the injuries produced and observed under this ongoing research are not common operationally due to the legacy armor system performance. However, the newly developed armor may perform differently from the legacy system, and it is important to study to inform medical practice moving forward.

A concern was raised about moving forward with new body armor when the BABT consortium studies are underway. The Army representative explained that the Vice Chief of Staff of the Army requested new body armor with a substantial weight reduction. He noted the new body armor is still reliable and will protect against the most common battlefield threats. Mr. McEntire ensured that the comment was not lost and noted his job was to keep developers informed about their findings so that informed decisions can be made on the performance requirements and integrated into the acquisition cycle.

Dr. Thuvan Piehler inquired about when the new body armor will be available. It was noted the contract has been awarded and the body armor will be acquired soon. Dr. Piehler requested Mr. McEntire reach out to obtain the new body armor, noting the program will have the research and testing capabilities in FY26.

Mr. McEntire noted a challenge being faced by introducing new thoracoabdominal injury criteria is that the body armor industry already has a familiarity and comfort with the existing BABT test protocol. As stated previously, a new surrogate will likely be needed for testing the next generation of body armor and convincing the industry to adapt to this change will be difficult.

A senior administrator inquired if the teams have integrated the results for different injury thresholds. Mr. McEntire stated that injuries are likely to correlate across regions; however, the three universities are still in the process of collecting data. Once all data has been processed and analyzed, it will be merged and integrated into a final report. The administrator noted that it would be important for stakeholders to understand so that combat medics know what to expect for different levels of injury.

BABT Wrap-Up

Mr. McEntire and Dr. Piehler thanked presenters and participants. They noted there will likely be an in-person meeting in fall 2025 to allow for more direct and in-depth conversations.

U.S. ARMY AEROMEDICAL RESEARCH LABORATORY

FORT RUCKER, ALABAMA

Optimizing

HUMAN PROTECTION AND PERFORMANCE

since 1962

U.S. ARMY

FCC

MRDC