Identification of Candidate Military Health System mTBI Blast Injury Prevention Standards

Elizabeth Brokaw[1], Kassa Tizale[1], Ryan M. Byrne[1], Lisa Lalis[1], COL Raj K. Gupta (Ret.)[2], COL Matthew Scherer[2]

1 The MITRE Corporation. McLean, VA, 2 US Army Medical Research and Development Command, Fort Detrick, MD

Introduction

The DoW established the Military Health System (MHS) Blast Injury Prevention Standard Recommendation (BIPSR) Process to identify and objectively evaluate candidate blast injury prevention standards for determining their suitability for DoW. The standards play a critical role in preventing warfighter injuries by informing assessments of health hazards and survivability, and development of safe weapon systems, survivable vehicles, and effective protection systems.

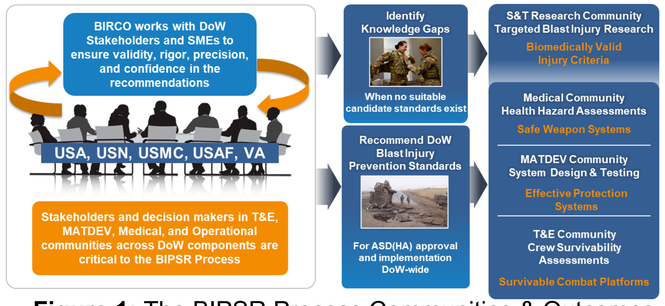

Figure 1: The BIPSR Process Communities & Outcomes

The BIPSR Process is the DoW's first unbiased, inclusive, stakeholder-driven process designed to identify and assess the suitability and applicability of existing candidate standards and to recommend standards that meet DoW Stakeholder needs with a suitable level of validity, rigor, precision, and confidence (Figure 1). The MHS BIPSR Process has two major objectives to:

1) Identify existing biomedically-valid candidate standards for immediate use by the DoW and,

2) Inform the research community of knowledge gaps where no suitable candidate standards exist.

Blast Injury Prevention Standards

A MHS Blast Injury Prevention Standard is a "biomedically-valid description of the physiologically- or biomechanically-based injury and performance response of a human to blast insults." Standards range from simple dose-response curves and injury thresholds to complex algorithms and computational models.

Over a series of initial meetings, BIPSR Process Stakeholders identified 14 BIPSR Blast Injury Types that affect different specific body regions.

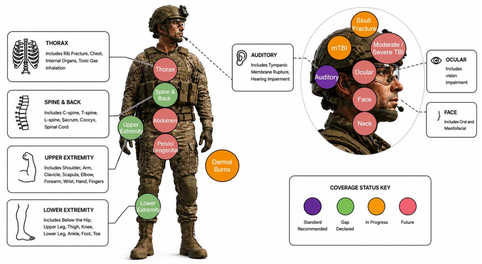

Figure 2: The BIPSR Process Injury Types

Methods

The BIPSR Process consists of six Pillars of activities for thorough information collection and candidate standard evaluation against the needs of the DoW. The BIPSR Process is initiated with the Review of Existing Capabilities.

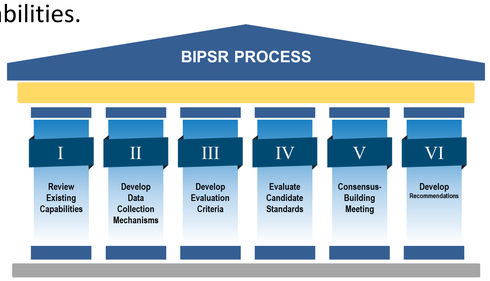

Figure 3: The BIPSR Process Pillars of Activities

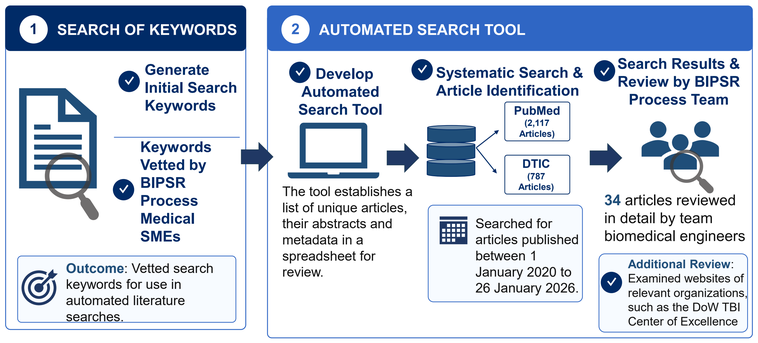

Figure 4: Steps in the Systematic Literature Review of the Review of Existing Capabilities (Pilar I)

Results

mTBI is common and can result from blast pressure exposure or blunt impact. mTBI is typically a diffuse brain injury with no visible lesions on standard imaging method, so diagnosis relies on clinical signs and symptoms.

To date the BIPSR Process team identified 19 injury criteria as potential candidate mTBI blast injury prevention standards, including four criteria focused on military blast pressure exposure and 15 blunt impact injury criteria mainly from the sports and vehicle crash safety domains.

Despite substantial research, challenges remain in characterizing the relationship between blast exposures and mTBI, such as:

- Individual tolerance can significantly affect injury thresholds.
- Limitations in translating findings between exposure domains (e.g., car crashes to sports).

Candidate Standards

BLAST PRESSURE CANDIDATE STANDARDS (4)

1	4 psi Peak Overpressure	4 psi is the risk management threshold for blast overpressure exposure. This threshold is based on community use of TP No. 51-070-0217 "Pressure Limits to Provide Protection from Eardrum Rupture" and confirmation of associated of exposures >4psi with symptoms (CATMS1) TAB B 2022.
2	Impulse	HFM-338 RTG recommends cumulative impulse over a single day of 219 kPa*•ms (31.7 psi*•ms) to limit the risk of adverse brain health effects. (NATO, 2026).
3	Generalized Blast Exposure Value (GBEV)	HFM-338 RTG recommends GBEV, a self-reported exposure metric with 200k-400k as threshold for blast exposure to limit the risk of adverse brain health effects. GBEV uses the Blast Exposure Threshold Survey (BETS), a 5–8 min weapon exposure frequency survey.
4	Blast Ordnance and Occupational Exposure Measure (BOOM)	10-minute survey developed by National Intrepid Center of Excellence (NICoE) to capture career blast exposure designed for use in clinical settings. BOOM leverages and expands on BETS exposure categories.

BLAST IMPACT CANDIDATE STANDARDS (15)

1	Head Injury Criterion (HIC)	Linear acceleration criterion with duration of the integral initially set to 36ms, but 15ms is now more commonly used. A HIC15 threshold of 390 is used in car crash safety standards and a value of 151 is associated with mild injury (Pfister 2009). Used by NHTSA, FAA, OSHA.
2	Generalized Acceleration Model for Brain Injury Threshold (GAMBIT)	Combined linear and angular acceleration model developed for automotive impacts based on the maximum shear stress/strain theory.
3	Head Impact Power (HIP)	A cumulative version of GAMBIT, which also considers mass and inertia. It is a measure of the rate of energy transfer to the head during an impact, combining linear acceleration, rotational acceleration, and impact duration.
4	Kleiven's Linear Combination	Linear and angular acceleration-based criteria combining HIC36 and maximum magnitude angular velocity.
5	Head Impact Telemetry severity profile (HITsp)	A non-dimensional head impact severity measure that combines peak linear and angular acceleration with impact location to produce a single impact metric to predict sport related concussion.
6	Principle Component Score (PCS)	Linear and angular acceleration criteria based on sports (football) data. It combines HIC, Gadd Severity Index, maximum linear acceleration, and maximum angular acceleration.
7	Power Rotational Head Injury Criterion (PRHIC)	Angular acceleration criteria leveraging head impact power (HIP).
8	Rotational Injury Criterion	Angular Acceleration criteria based on HIC36.
9	Kinematic Rotational Brain Injury Criterion	Angular acceleration and angular velocity criteria focused on modeling diffuse axonal injury.
10	Brain Injury Criterion	Angular velocity criteria based on computational modeling findings that strain can be predicted based on angular velocity in three dimensions. Experimental data established threshold x,y,z value of 66.2, 59.1, 44.2 rad s−1. Used by NHTSA.
11	Rotational Velocity Change Index (RVCI)	Angular velocity criteria in three dimensions for pedestrian impact events determined from FE models with time duration less than or equal to 10ms.
12	DAMAGE	Angular acceleration three degree of freedom second order lumped mass system model.
13	Convolution of Impulse Response for Brain Injury Criterion (CIBIC)	Angular acceleration model like DAMAGE.
14	Brain Angle Metric (BAM)	Angular acceleration three degree of freedom lumped parameter model developed with football, and navy sled tests.
15	Combined Probability of Concussion	Football head impact logistic function combining translational and rotational acceleration.

Next Steps

- Interview subject matter experts and post a request for information on SAM.gov to identify additional candidate standards, their capabilities, and limitations.
- Interview DoW Stakeholders for MHS mTBI Blast Injury Prevention Standard intended uses and requested functionalities.
- Work with DoW Stakeholders and Subject Matter Experts to evaluate candidate standards for immediate use by the DoW and identify critical knowledge gaps for future research.

We welcome your participation in the BIPSR Process! Contact: BIPSR_Process@mitre.org

To learn more, visit: http://blastinjuryresearch.health.mil