PROJECT CEREBRO: An evaluation of Blast Gauges in the Australian Defence Force

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Abstract

Background: Blast-related Traumatic Brain Injury (TBI) has been a frequent and prominent wound in recent conflicts. Helmet sensors or blast gauges have been proposed to monitor blast effects in troops exposed to Improvised Explosive Devices (IED).

Purpose: The findings of a trial of blast gauges in Australian troops deployed in Afghanistan are described.

Materials and methods: Three Blackbox Biometrics B3 Blast Gauge (BG) were issued to soldiers from September 2012 to December 2013, with data regularly downloaded by deployed personnel from DiggerWorks.

Results: A total of 1,474 blast events (with 68 suspected 'false' events) were recorded by the 4,513 sets issued. The trial identified and documented that personnel are exposed to potentially harmful blast effects in operational and non-operational combat related activities, with the latter being more frequent.

Conclusion: While soldier acceptance of the BGs was good, evaluation of their utility was limited by local operational factors. Further use of the BG system was recommended, including collaboration with allied nations to plan future research.

Keywords: Improvised explosive devices, blast gauges, helmet sensors, blast traumatic brain injury.

Introduction

Blast-related Traumatic Brain Injury (TBI) has been a frequent and prominent wound in the recent conflicts in Iraq and Afghanistan. By January 2014, 287,911 US servicemen and women had been medically diagnosed with TBI. Over 80% of these diagnoses were mild,[1] with the majority caused by blast injury from Improvised Explosive Devices (IED).[2] Concern over the prominence of blast-related TBI led the US Government to invest heavily in research on the subject,[3] which included investigating the use of helmet sensors or blast gauges. While trials of the devices have been underway for sometime,[4] there has been very limited publication of any research findings or data obtained.[5] This paper reports the findings of a blast gauge trial conducted by the Australian Defence Force (ADF).[6]

Method

In August 2012, the Chief of the Australian Army authorised a procurement and partnering arrangement with the United States Defense Advanced Research and Projects Agency (DARPA) to trial the Blackbox Biometrics B3 Blast Gauge (BG) with troops deployed on OPERATION SLIPPER to the Middle Eastern Area of Operations; the arrangement included the sharing of data with DARPA for ongoing research on TBI. The trial was conducted in Tarin Kowt, Afghanistan from September 2012 to December 2013 and involved two rotations of data retrieval by the organisation Diggerworks; a team of non-medical Army personnel within the Defence Material Organisation and the Defence Science and Technology Organisation who are tasked to provide the rapid trialling and implementation of combat systems. Approval for the trial was obtained from the Australian Defence Human Research Ethics Committee.

The objectives of the trial were multi-faceted and included:

a. Evaluation of the BG with regard to its fitness for purpose;
b. Utility and soldier acceptance;
c. Engagement with DARPA for data analysis and field support;
d. Assisting the immediate detection of mTBI while documenting severity and exposure to a combat related blast event;
e. Collecting scientific data for research into mTBI and the longer-term management of soldier health;

f. Assisting in reducing the risk of employing soldiers who may be unaware they have sustained an injury and thus support their medical treatment; and

g. Positioning the ADF and the Department of Veterans' Affairs with respect to potential claims for recognition of mTBI.

The B3 BG issued to Australian troops measures only pressure change, thus excluding the measurement of blunt force impact. Each set consists of three sealed plastic devices, colour-coded and labelled for wear on the head, chest and shoulder in standardised positions (Head - rear nape strap on helmet, Shoulder - non master side, Chest - on body armour). Each has a Light Emitting Diode indicator to provide real-time visual indication to the wearer of the potential severity of a blast exposure, as well as battery levels. A Green light indicates exposure to a pressure of 0-4 psi, Amber 4-16 psi and Red above 16 psi. The thresholds were chosen by the developers of the device at DARPA without extensive empirical medical data regarding mTBI, but with the premise that they could be changed in programmable software later when enough data was gathered. Data from individual blast events (where the energy is calculated from the explosion), from the blast gauges and from clinical information from the soldiers, with or without injuries, would be recorded and correlated leading to a better understanding of what levels tended to result in mTBI or worse.

Each microprocessor can record up to 12 individual blast events recorded separately with a date-time stamp. When an event triggers an indicator light, it stays illuminated until reset or another event is recorded of higher severity, whereupon the higher severity indicator light will show. The battery life of each device is 30-60 days. Data is downloaded via a USB port to a laptop computer.

Image 1: Blackbox Biometrics B3 Blast Gauge – front view. (Photograph courtesy of BlackBox Biometrics Inc.)

Image 2: Blackbox Biometrics B3 Blast Gauge- rear view with marker to indicate location on the body to place it: H for rear nape strap on helmet; S for shoulder, non-master side; and C for chest on body armour. (Photograph courtesy of BlackBox Biometrics Inc.)

Image 3: Blackbox Biometrics B3 Blast Gauge showing activation of Red Indicator Light. (Photograph courtesy of BlackBox Biometrics Inc.)

Results

Immediately after the start of the trial, there was a major change in the force posture and subsequent operations conducted by Australian troops, which resulted in a significant reduction in exposure to the risk of blast events. Thus, the data presented from blast events is almost all related to training activities (e.g. firing mortars and detonating explosive charges to breach doors) and not operation related events. Table One contains data retrieved during the trial. A total of 1,474 blast events (with 68 suspected 'false' events) were recorded by the 4,513 sets issued to troops.

Following a blast event, the device was used to aid commanders in rapidly identifying those believed to be most at risk of mTBI, including those who may have been unaware they were impacted, and to prioritise their screening by medical personnel. Soldiers referred to medical services underwent a clinical assessment, including a Military Acute Concussion Evaluation (MACE).[7] Clinical findings were documented, but as the trial management personnel were non-medical, they were not able to access this information. Post-deployment correlation of blast gauge data and clinical records is being conducted on de-identified records by medical personnel for inclusion in the joint Australian and United States research data pool at DARPA. Of those personnel who sustained training related blast exposure, only a small number reported symptoms, such as headache, when later assessed by medical personnel.

Number of Blast Gauges issued	4513 sets
Number of operational files retrieved	10,195 (~ 3400 sets)
Number of events recorded	2417
Number of Red events recorded	36
Number of Amber events recorded	2381
Number of Blast Gauges with events recorded	923
Average time in Monitor Mode (number of hours spent active on the user)	172 hours
Average time in Monitor Mode before battery went flat	340 hours
Percentage of devices with flat battery before 60 days usage	5%
Number of status light checks per issue period (Issue period approximately 60 days)	1.9
Time in Monitor Mode between status light check (personnel were directed to check status before and after every mission, or at least once per day)	89 hours

Table 1: Trial Data Retrieval Findings

Three operational events were recorded. One involved an IED strike on a Bushmaster protected mobility vehicle. Although impact injuries did occur, the details of which were not released for publication, the soldier did not record any blast exposure on his BG, probably due to protection from the blast wave by the vehicle's reinforced hull. Two separate dismounted (i.e. on foot patrol) IED events occurred. In the first, blast data was successfully recorded by gauge 1, however gauges 2 and 3 were destroyed. In the second, no data was recorded, probably due to dissipation of the blast wave across intervening terrain. Unfortunately, medical data about the events was not recorded for a range of reasons including operational priorities and a lack of understanding of reporting requirements for the trial.

False events were determined by study personnel co-located with troops in the field when no blast event was directly observed, when events were correlated with periods of inactivity and when recorded pressure graph profiles were not consistent with a blast event.

Discussion

The study was limited by the small number of operational blast events that were recorded. However, the study proved the ability to capture blast dose data in the field and the capability of the devices to assist in the prioritisation of medical assessment for personnel at risk of mTBI. While it is recognised that there is a large variation in tolerance of forces to the head, including blast pressure, and that a particular blast dose would have variable effects on a general population of soldiers, information from blast gauges such as that collected in this study can nevertheless inform research, clinical decision-making and procedures in the field.

The BGs functioned according to their specification with soldier acceptance reported as being good, although compliance with daily testing was not achieved uniformly across the trial. A small number of the shoulder BGs were lost due to incompatibility with pack straps and a small number of chest BGs were crushed during firing from the prone position or crawling. Evaluation of their utility was complicated by: the time delays experienced between an event and a medic obtaining the data for analysis; soldiers not presenting with a positive blast gauge reading because they were not experiencing any symptoms; a lack of awareness of BG capabilities by medics; an incompatibility with existing Standing Orders on TBI management; and lastly, insufficient situational data being recorded about a blast event.

The trial identified and documented that personnel are exposed to potentially harmful blast effects in operational and non-operational combat related activities, with the latter being much more frequent. It also demonstrated that existing ADF proximity-based mTBI assessment Standing Orders that determine who requires formal screening for TBI when a vehicle is struck by an IED, do not account

for all the variables in a blast event and that such practices have the potential to over-load medical services. In contrast, the trial identified that wearing a BG provides the means to quantify blast exposure individually. Finally, the exact medical meaning of an Amber or Red BG threshold and the relationship to mTBI has yet to be determined due to insufficient data being collected. This has been acknowledged as requiring further research at DARPA, with whom there is an on-going relationship, to correlate the pooled clinical evidence with the blast data. As a result, the objective of positioning the ADF and the Department of Veterans' Affairs with respect to potential claims for recognition of mTBI cannot be met at the present time.

The trial report recommended troops deployed on OPERATION SLIPPER should continue to use the BG system and that focused trial activities using the equipment should occur concurrently in Australia. Furthermore, it recommended exploring mTBI research opportunities with allied nations and the potential establishment of a multi-agency work group to organise and plan future research to inform medical policy development.

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