

Combat injury coding: A review and reconfiguration

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- BACKGROUND:** The current civilian Abbreviated Injury Scale (AIS), designed for automobile crash injuries, yields important information about civilian injuries. It has been recognized for some time, however, that both the AIS and AIS-based scores such as the Injury Severity Score (ISS) are inadequate for describing penetrating injuries, especially those sustained in combat. Existing injury coding systems do not adequately describe (they actually exclude) combat injuries such as the devastating multi-mechanistic injuries resulting from attacks with improvised explosive devices (IEDs).
- METHODS:** After quantifying the inapplicability of current coding systems, the Military Combat Injury Scale (MCIS), which includes injury descriptors that accurately characterize combat anatomic injury, and the Military Functional Incapacity Scale (MFIS), which indicates immediate tactical functional impairment, were developed by a large tri-service military and civilian group of combat trauma subject-matter experts. Assignment of MCIS severity levels was based on urgency, level of care needed, and risk of death from each individual injury. The MFIS was developed based on the casualty's ability to shoot, move, and communicate, and comprises four levels ranging from "Able to continue mission" to "Lost to military." Separate functional impairments were identified for injuries aboard ship. Preliminary evaluation of MCIS discrimination, calibration, and casualty disposition was performed on 992 combat-injured patients using two modeling processes.
- RESULTS:** Based on combat casualty data, the MCIS is a new, simpler, comprehensive severity scale with 269 codes (vs. 1999 in AIS) that specifically characterize and distinguish the many unique injuries encountered in combat. The MCIS integrates with the MFIS, which associates immediate combat functional impairment with minor and moderate-severity injuries. Predictive validation on combat datasets shows improved performance over AIS-based tools in addition to improved face, construct, and content validity and coding inter-rater reliability. Thus, the MCIS has greater relevance, accuracy, and precision for many military-specific applications.
- CONCLUSION:** Over a period of several years, the Military Combat Injury Scale and Military Functional Incapacity Scale were developed, tested and validated by teams of civilian and tri-service military expertise. MCIS shows significant promise in documenting the nature, severity and complexity of modern combat injury. (*J Trauma Acute Care Surg.* 2013;75:573–581. Copyright © 2013 by Lippincott Williams & Wilkins)
- KEY WORDS:** Combat; trauma; injury severity scoring; impairment.

Accurate, descriptive coding of anatomic injuries is a prerequisite to classifying injury by location and severity. When used in models that account for multiple injuries, physiology, or other factors, these codes are generally predictive of patient outcome in databases and thus form a basis for the evaluation of prehospital and trauma center/system care and case mix control, as well as case definition, clinical research, quality assurance/improvement, and resource allocation.^{1–4} In

the experience of the authors, existing injury coding systems do not adequately quantify the nature and severity of combat injury, which can involve unique combinations of blunt and penetrating injuries.

Although fewer than 50%⁵ of combat injuries require the casualty to be evacuated from theater, with the rest returning to duty, the former typically sustain multiple injuries from numerous mechanisms and of a complexity not found in civilian practice. Therefore, it came as no surprise that coding descriptions of these injuries and their databasing required a fresh look. Existing coding systems do not adequately describe penetrating combat injuries such as numerous and large soft tissue fragment wounds and the multiple injuries resulting from improvised explosive devices, which are predominant in modern warfare.⁶ The deficiencies in civilian systems relate to the descriptors (scores), the severity scales, and the modeling of multiple injuries.

A 4-year chronology of efforts, including the development of a military version of the Abbreviated Injury Scale (AIS), the AIS 2005–Military,⁷ failed to produce an alternative that could fully describe and appropriately assign severity to combat injuries or meet the needs of military injury databases. Thus, new tools were needed. Initially, we tried to modify the existing civilian injury scales but because the major problems

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of ad hoc coding and incomplete and inadequate descriptors remained, we began to develop a new replacement tool. The process was valuable in that it addressed some of the growing concerns with the AIS, which have been recognized by civilian trauma care professionals throughout the world.⁸⁻¹⁰

This article reviews the development of the Military Combat Injury Scale (MCIS), a severity scale that specifically characterizes the unique injuries encountered in combat, especially those caused by explosions, and its derivative, the Military Functional Incapacity Scale (MFIS), which indicates immediate, tactically relevant, functional impairment.

Brief Summary of Attempts to Apply Civilian Scoring Systems to Combat Injuries

AIS

Of the coding systems most often used to quantify anatomic injuries, the International Classification of Diseases (9th Revision, Clinical Modification [ICD-9-CM] and 10th Revision [ICD-10]) is an administrative coding taxonomy that has become an anatomic scoring system commonly used by injury researchers. It does not allow, however, for comprehensive quantification of combat injury severity. For this reason, the AIS is the most commonly used anatomic scoring system used by injury researchers. The AIS is a classification of each injury by body region according to its relative importance on a six-point ascending scale of severity. First developed in 1971 to characterize automobile occupant injury,¹¹ the AIS began with 73 codes for blunt injury. Its most recent update in 2008 contains 1,999 codes and requires specialized training to attain competence in, and maintain interrater reliability of, coding. Originally conceived as a scoring system for civilian blunt trauma, the AIS has been clearly documented as problematic in its ability to accurately describe civilian penetrating trauma and combat injuries.^{12,13} Although the AIS has been shown to correlate with morbidity and mortality in civilian injuries,^{14,15} it is (at best) an ordinal, not an interval, scale and is insufficiently sensitive to discern changes at the same severity level within and among body regions.¹⁶ Furthermore, it is an inconsistent system for coding combat injuries because the 10 AIS body regions are not anatomically correct, burns

and large soft tissue injuries are not adequately addressed, many codes are never or rarely used, frequently occurring combat injuries cannot be coded, the scale of severity is inconsistent between the defined body areas, and it excludes most bilateral injury to extremities.

The limitations of the AIS are multiplied in AIS-based models such as the Injury Severity Score (ISS).¹⁷ The ISS is the most commonly used model to describe both single and multiple injuries and is calculated using the three highest AIS scores in different body regions. Limitations of the ISS, amply described in the literature,^{12,18} greatly restrict its utility in combat injury assessment despite numerous modifications^{19,20} that attempt to compensate for its deficiencies.

Descriptors for penetrating injuries were added to the AIS in 1985, but these only consisted of low-kinetic-energy injuries treated in civilian settings. Subsequently, three of the authors (H.R.C., T.G., and M.M.L.), working with a military consensus panel and with the International Injury Scaling Committee of the Association for the Advancement of Automotive Medicine (AAAM), developed the AIS 2005–Military (since updated to AIS 2008–Military).⁷ Even this effort to more precisely describe the multiple penetrating and mixed mechanism injuries resulting from improvised explosive devices, which account for most of the injuries sustained in modern warfare,^{6,21,22} failed to capture the heterogeneity of multiple mechanisms and severity ranges of combat injury.

Quantification of Use of Existing Codes in Combat Injury Databases

Attempts to apply existing trauma scoring systems to combat injuries created frustration among military coders and resulted in inconsistent coding and failure to use a majority of codes. Before we began the process of creating a new, combat-specific system from scratch, we decided to analyze how the AIS is currently used in combat injury databases. The goal was to determine which AIS codes are used by military coders and which do not adequately describe the injuries. All AIS injury descriptors were reviewed, and frequency distributions were developed for each AIS code in three military databases. The analysis revealed that 65% to 82% of AIS codes were never

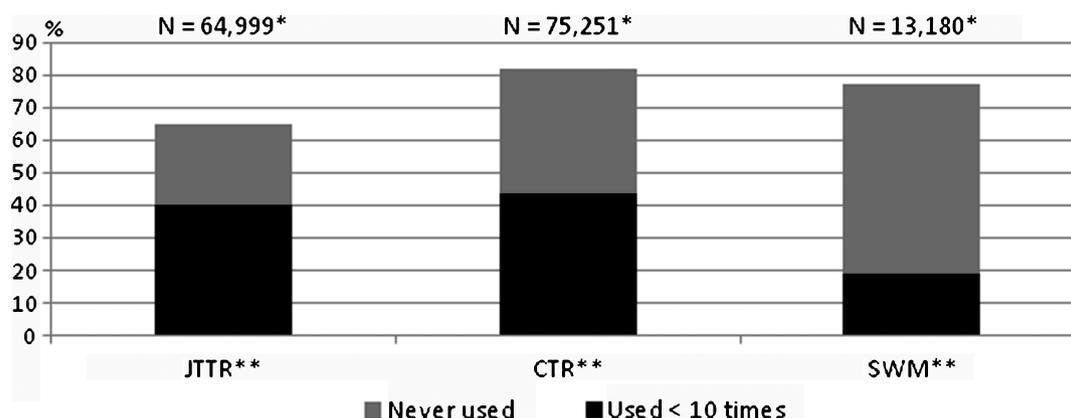


Figure 1. Percentage of AIS codes never or rarely used in military trauma registries.*AIS-codable injuries. **Military databases, use AIS 2008–Military (1,999); JTTR, Joint Theater Trauma Registry; CTR EMED, Navy-Marine Corps Combat Trauma Registry Expeditionary Medical Encounter database; SWM, Surface Wound Mapping™ database (deaths).

used or were used fewer than 10 times to describe the approximately 153,000 injuries in the databases (Fig. 1). Furthermore, codes that *are* used do not adequately characterize the complex multi-etiology, multimechanistic injuries that occur in combat, particularly from explosions. Moreover, analysis of data on 1.5 million civilian injury cases revealed that most AIS codes are not used to code noncombat trauma. Mapping problems between AIS versions have been observed,⁹ compounding the problems of accurate databasing using AIS. Thus, the inadequacies of the existing coding schema, plus vehicle and body armor engineers' need for a simple robust scale, prompted the development of MCIS.

METHODS

On November 17 and 18, 2008, a Military Injury Scoring Summit was convened at the US Army Institute of Surgical Research in San Antonio, Texas. The goals of the meeting were to (1) assess the accuracy and completeness of AIS 2008–Military in characterizing combat injury and (2) institute a process of midterm corrections and recalibrations informed by the knowledge gained during the previous several years of coding tens of thousands of patient visits, combat injuries, and deaths. To perform this work, a panel of triservice military and civilian experts representing the combat trauma community and specialties, many with recent combat experience, was formed. The panel was tasked with developing a new scoring system that would meet the following needs:

- To map the high-level specialty service scales (orthopedics, ophthalmology, neurosurgery, etc.) into one combat anatomic severity scale
- To correlate immediate combat functional incapacity with severity of injury
- To coordinate with existing efforts currently underway to develop survivability and tactical performance requirements for occupants of new military vehicles and platforms (including shipboard)
- To map the numerous experimental injury criteria used by the test and evaluation (T&E) community, particularly for explosions and based on different methodologies, into one common anatomic combat severity scale

The panel identified the requirements of a military-specific combat injury scale as follows:

- Adequately describes combat injury
- Is robust and simple to use
- Has face validity
- Includes immediate functional incapacity metrics that relate to mission sustainability
- Can service the needs of the research and development and T&E communities, particularly regarding explosion-related injury work
- Is transportable to animal models
- Maps to legacy databases and AIS and ICD coding systems

MCIS

At the request of operationally experienced military personnel, the group formulated a four-step approach to developing the MCIS: (1) determine combat injury-relevant body regions;

(2) define injury severity levels appropriate for military use; (3) tabulate injury descriptors from injuries actually seen in combat and related to specifics of early care (e.g., tourniquet application); and (4) generate a specific injury code for each injury or homogenous group of injuries. The panel considered many of the strengths of the existing structures and decided to continue using a system that was anatomically based and consensus derived. This process is described in the following sections.

1. Define Combat-Specific Body Regions

The group used the four anatomic regions of the body, plus one for multiple regions, as a starting point. Injuries to the clavicle, scapula, and pelvic girdle were grouped with the torso where they are anatomically located rather than in the upper and lower extremities where they are included for AIS and ISS. This rearrangement results in a more anatomically correct and militarily relevant set of body regions, as follows:

1. Head and neck: injuries to the head, face, and neck
2. Torso: injuries to the chest and abdomen, including the pelvic girdle and junctional areas such as the axilla and groin
3. Arms: injuries to the upper extremities
4. Legs: injuries to the lower extremities
5. Multiple: injuries not confined to one specific body region

Important military areas of concern, for example, junctional vascular nontourniquetable injuries, were specifically coded to facilitate their capture and analysis.

2. Define Combat-Relevant Severity Scales

Taking into account the fact that the science does not yet support an interval or decimal scale for severity, the expert panel scaled injury severity on a five-point scale based on increased risk of death over time. Medical resources and level of care required for each injury severity level were also considered when assigning severity (these will be linked to MCIS as part of another ongoing project). The panel began by separating out the minor and likely lethal injuries, as follows:

Severity 1. Minor

Minor or superficial injuries that can be treated in the theater of combat and the casualty likely returned to duty within 72 hours

Severity 5. Likely Lethal

Injuries that are likely not survivable in a military setting including catastrophic injuries and those from which the casualty is likely to die within minutes of wounding

The group then parsed out the three intermediate severity levels as follows:

Severity 2. Moderate

Injuries that do not need to be treated immediately and for which delaying treatment until the tactical situation allows would not likely result in an increase in morbidity or mortality

Severity 3. Serious

Serious injuries that would not result in shock or airway compromise but ideally should be treated within 6 hours of injury at a medical treatment facility (MTF) to avoid increasing risk of death or disability

Severity 4. Severe

Injuries that may result in shock or airway compromise; some casualties with injuries in this category will have increased risk or death or disability if not treated at an MTF within 6 hours.

Example injuries in each MCIS severity level and combat-relevant injury descriptors are given in Table 1.

3. Tabulate Combat-Relevant Injury Descriptors

More than 150,000 injury descriptions in the combat registries guided the tabulation of the initial MCIS injury descriptions. Information from coding meetings, coding quality reviews, case reviews, specific injury studies, and queries were used to confirm which additional injury descriptions should be added to the MCIS because they could not be adequately coded using AIS. The new injury descriptions were categorized as follows:

- Soft tissue injuries with loss of large areas of soft tissue or deep muscle

Descriptions for soft tissue injuries were expanded because in the combat registries, many soft tissue injuries exceed the upper bounds of measurement in AIS used to define “major” injuries (i.e., >10 cm² and into the subcutaneous tissue or >25 cm² if a penetrating injury or laceration and >100 cm² if an avulsion) and are therefore not adequately described. Thus, descriptors that account for the amount and depth of soft tissue loss, ranging from these “major” measurements up to soft tissue loss of an entire limb or region of the body were added.

- Penetrating injuries to the face involving one eye, the nose, and mouth or one or more areas of the face

Review of penetrating injuries to the face revealed that those involving one entire side of the face including one eye or those to the area surrounding the nose and mouth, with or without airway compromise, could not be adequately coded by existing systems (e.g., under the Whole Area Penetrating injury descriptions in AIS for Face, the descriptors are “with tissue loss >25 cm², AIS 2” or “massive destruction of whole face including both eyes, AIS 4”). Thus, appropriate injury descriptors were added in MCIS to account for these types of injuries.

- Second- and third-degree burns to the face, hands, feet, joints, and genitalia

Combat-related burns are complex and frequently occur with additional traumatic injuries; thus, their severity is not only based on total body surface area of the burn. Second- or third-degree burns to the face, hands, feet, joints, and genitalia require immediate specialized treatment. Therefore, additional injury descriptors were added to MCIS to identify these specific injuries.

- Avulsive loss of portions of the skull and brain

Combat wounds with skull penetration are often complex, and so avulsive loss of portions of the skull and brain, regardless of mechanism of injury, was added.

- Amputation, crush, and vessel injuries to which a tourniquet can or cannot be applied

Vessel and crush injury descriptions were created to indicate whether a tourniquet could be placed on the limb or whether the injury could be treated by compression (e.g., with a Combat Ready Clamp) based on injury location. Thus, specific numeric codes allow for identification of junctional, nontourniquetable

TABLE 1. Example Injuries Stratified by MCIS Severity and Body Region

MCIS	Head and Neck	Torso	Arms	Legs
1	Concussion, unspecified, no LOC or brief LOC (<5 min with full return to previous cognitive state)	Rib fracture, 1 or unspecified	Open wound of arm, minor, superficial, unilateral, or bilateral	Open wound of leg, minor, superficial, unilateral, or bilateral
2	Concussion with LOC ≥5 min or <1 h and/or incomplete return to previous cognitive state	Clavicle or scapula fracture, unilateral	Burns, second or third degree, hand, wrist, elbow or shoulder, unilateral	Open wound of leg, deep, extensive, into muscle, soft tissue loss of <25% of one leg, unilateral
3	Mandible fracture (except bilateral or parasymphysis, or mandible avulsion)	Open wound with loss of ≤10% muscle mass of trunk, buttocks, or pelvic girdle	Amputation or crush hands, bilateral Vessel injury below shoulder; able to place tourniquet	Open wound with soft tissue loss of ≥25% but <50% of one leg, single or multiple wounds
4	Mandible avulsion (includes complex, comminuted fractures of mandible and/or loss of portion of bone)	Open wound with loss of >10% muscle mass of trunk, buttocks, or pelvic girdle Iliac artery laceration or transection	Amputation or crush below shoulder or at or above elbow, able to place tourniquet or compress Vessel injury at shoulder (axillary artery); not able to place tourniquet	Vessel injury below groin; able to place tourniquet Vessel injury at groin; not able to place tourniquet
5	Penetrating or blast injury with destruction of bone and soft tissue of mouth and face, with airway compromise	Blast lung injury (overpressure), severe or multiple lobes or bilateral	Amputation or crush right shoulder (subclavian proximal axillary artery); not able to place tourniquet or compress	Amputation or crush left hip; not able to place tourniquet or compress

LOC, loss of consciousness.

injury. The treatment rendered for the injury is recorded in the combat registries. MCIS injury descriptors of amputation-related injuries indicate whether a tourniquet could be placed on the limb. Descriptors were also developed that address multiple amputations of the upper or lower limbs.

- Avulsion of the mandible

In combat, injuries to the mandible are often more severe than the comminuted, displaced fractures seen in civilian trauma. Avulsion of the mandible was added as an injury description to describe injuries in which portions of the mandible are shattered or missing.

- Combat stress injury

An injury description for acute stress reaction caused by combat was added to describe this injury, which is prevalent in the combat environment.

4. Generate MCIS Coding Scheme

Using these new body regions, severity levels, and injury descriptors, a five-digit MCIS coding scheme was developed, and 269 codes were assigned. Digits 1 and 2 indicate injury severity and body region, respectively; Digit 3 indicates the type of tissue involved, and Digits 4 and 5 together indicate the specific injury when combined with Digits 1, 2, and 3 (Table 2). This coding scheme allows for injuries to the skull and brain to be identified separately from injuries to the face or neck and for injuries to the chest, abdomen, and pelvis to be separately identified despite being assigned to the same body region. The numbering scheme also allows for identification of unilateral or bilateral injuries, right or left for specific injuries, and easy identification of junctional area vascular injuries.

MCIS Coding of Soft Tissue Injuries

Soft tissue injuries are addressed with expanded codes in each body region in MCIS because many of the injuries seen in combat involve loss of large areas of soft tissue. Skin and soft tissue injuries, in addition to any underlying injuries,

are assigned a separate severity code in MCIS. Soft tissue loss for the limbs and torso, as well as scalp, face, and neck are assessed, and one code (or two for limb injuries) is assigned for each body region. This new rule was instituted to account for soft tissue loss associated with multisystem, multimechanism injuries. In both ICD-9-CM and AIS Update 2008, open wounds are not coded when underlying injuries are present. For example, in a casualty with peppering across the posterior and lateral areas of the back and buttocks extending into deep muscle and involving loss of muscle mass, MCIS code 42207, *open wound with loss of >10% of muscle mass of trunk, buttocks, or pelvic girdle* (MCIS Severity 4), is assigned. In AIS 2008–Military, the same injury would be coded as 416004.2, *penetrating injury of thorax with tissue loss >100 cm²* (AIS Severity 2), which greatly underestimates the actual severity of the injury. In ICD-9-CM, the injury would be assigned the code for open wound of the trunk, which specifies an injury to the skin and soft tissue only, with no indication of underlying injury.

MFIS

At the request of the T&E and operational communities, the MFIS was developed to correlate maximum MCIS severity with immediate functional impairment. This relationship makes the MFIS applicable across all Army Military Occupational Specialties. Members of the Committee on Tactical Combat Casualty Care determined that immediate functional impairment/incapacity should be defined as impairment in the casualty's ability to shoot (load, aim, or fire a weapon system), move (walk, run, crawl, enter/exit/drive a vehicle), and communicate (comprehend, receive, or send verbal or nonverbal orders). These are the essential, operationally relevant functions that determine whether the casualty can contribute to the sustainability of the mission. The MFIS was structured as an ascending scale of functional impairment with four levels, as shown in Table 3.

MFIS levels of incapacity were linked directly to MCIS injury severity under the following general construct:

TABLE 2. MCIS Coding Definitions and Example

Definitions				
1	2	3	4	5
Injury Severity	Body Region	Type of Tissue	Specific Injury	
1, Minor	1, Head and neck	1, Whole area	Specific injury related to body region and type of tissue, when combined with Digits 1, 2, and 3	
2, Moderate	2, Torso	2, Skin		
3, Serious	3, Arms	3, Muscles, tendons, ligaments, and joints		
4, Severe	4, Legs	4, Nerves and spinal cord		
5, Likely Lethal	5, Multiple	5, Bone		
		6, Vessels		
		7, Organs of the head, face, neck, and chest		
		8, Organs of the abdomen		
		9, Organs of the pelvis		
		10, Other		
Example: A 5-cm laceration of the liver, MCIS 32812				
3	2	8	1	2
Serious	Torso	Organ of the abdomen	Liver	Laceration

- **MCIS Severity 1 injuries**
 - Are not associated with immediate functional incapacity, and casualties are able to continue with the mission
 - Treatment can be delayed until the tactical situation allows without any impact on outcome, and casualties with these injuries are likely to return to duty within 72 hours
- **MCIS Severity 2 injuries**
 - Likely result in immediate functional impairment with the potential for the casualty to contribute to the mission
 - Treatment can be delayed until the tactical situation allows without any impact on outcome
- **MCIS Severity 3, 4, or 5 injuries**
 - Require medical treatment
 - Casualties who sustain one or more of these injuries are lost to the mission or to the military

Reliability and Validity Testing

Several standard tests were used to evaluate MCIS, i.e., face and content validity, coder interrater reliability, and construct validity. In addition, two injury models were used to assess predictive and external validity when multiple injuries are involved.

Face and Content Validity

Face and content validity were assessed by circulating drafts of MCIS and MFIS to several hundred personnel and stakeholders, who vetted and contributed to approximately 10 iterations. These personnel included combat-seasoned clinicians including point-of-wounding care providers; care providers through all echelons of care; Committee on Tactical Combat Casualty Care members; experts in burn, toxic gas inhalation, and other combat-specific injuries; registry managers, coders, and injury modelers; and military end users including ground and shipboard forces as well as US Army design and live-fire T&E engineers involved in the management of the Joint Light Tactical Vehicle program. For each

injury description, each panel member contributed input, and severity was assigned based on majority agreement after roundtable discussion (a methodology that was used to develop AIS during the past 40 years).

Coder Interrater Reliability

Interrater reliability of MCIS coding was tested using three coders with extensive civilian and combat trauma registry experience. Two of the coders had more than 10 years of experience with civilian trauma registries using ICD-9-CM and AIS before their combat registry experience. One coder had fewer than 2 years' experience with ICD-9-CM and AIS Military. All coders received 2 hours of training in MCIS coding. Each coder independently assigned MCIS injury codes to a sample data set of 278 combat injury descriptions abstracted from autopsy reports and casualty records from the Navy-Marine Corps Combat Trauma Registry Expeditionary Medical Encounter (CTR EMED) data set (see Supplemental Digital Contents 1 and 2, <http://links.lww.com/TA/A300> and <http://links.lww.com/TA/A301>). Their coding was compared with MCIS coding of the same injuries performed by an expert coder and coding instructor with more than 25 years of experience (M.M.L.).

Construct Validity

Construct validity was evaluated by comparing mortality and disposition outcomes for each MCIS severity level and number of injuries within each severity level on 1,000 combat casualties in the CTR EMED coded using MCIS at the time the preliminary analysis was performed. Outcome data were not available for 8 patients; the remaining 992 in the sample consisted of 152 fatalities (15%) and 840 survivors (85%).

Modeling of Multiple Injuries

Most combat injuries are caused by multimechanistic forces involving explosive devices or high-energy projectiles.

TABLE 3. MCIS Severity and Associated MFIS Incapacity Level

MCIS		Associated	MFIS	
Severity	Description		Level	Description
1 Minor	Superficial injuries that can be treated in theater Minimal or no immediate significant functional impairment. Likely to return to duty within 72 h	1	1	Able to continue mission
2 Moderate	No increased risk of death if treatment delayed because of tactical situation Likely immediate functional impairment Likely able to contribute to sustaining mission	2	2	Able to contribute to sustaining mission
3 Serious	No shock or airway compromise Ideally should be treated within 6 h of injury at an MTF Functionally impaired; lost to mission	3 / 4	3	Lost to mission
4 Severe	Some injuries have increased risk of death because of shock or airway compromise if not treated at an MTF within 6 h of injury Functionally impaired; lost to mission or military		4	Lost to military
5 Likely Lethal	Injuries likely resulting in death immediately or within minutes Lost to active-duty military	4 / 5	4	Lost to military

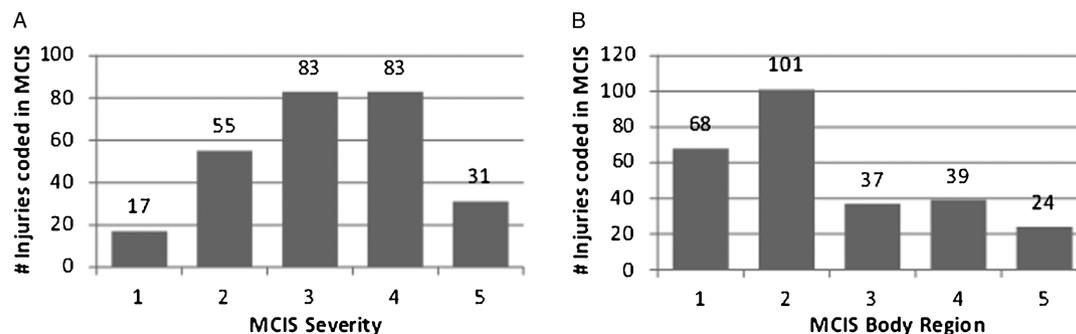


Figure 2. MCIS codes (n = 269). Breakdown by severity (A) and body region (B). MCIS body regions: 1, head and neck; 2, torso; 3, arms; 4, legs; 5, multiple.

The research team performed an extensive review of all possible modeling methods for combining multiple mechanisms/multiple injuries and developed a model that is the subject of a follow-on publication. For preliminary evaluation for predictive and external validities, two models were chosen that would enable external comparisons between MCIS and AIS-based models, with a focus on scale performance instead of on more complex multimechanism modeling. The first model provided a direct comparison of the two rating scales using patient maximum score levels. The AIS and MCIS ratings for each casualty's most severe injury were mortality predictors in a logistic regression equation. The second model was chosen to contrast the scales' performance with a composite measure typical of those used in civilian trauma mortality models, the New Injury Severity Score (NISS, used in preference to ISS because NISS allows for multiple injuries in a single body region to be counted and because it compared better than ISS on multiple screening tests of AIS and MCIS).

Predictive and External Validities

Predictive and external validities were assessed using death, survivor, and total misclassification rates. Statistical evaluation of discrimination and calibration were performed by comparing the area under the receiver operating characteristic (ROC) curve (AUC), the Hosmer-Lemeshow (H-L) statistic,²³ and the Akaike information criterion (AIC).²⁴ Validity tests were performed using medical record data coded in both AIS 2008–Military and MCIS on the sample of 992 combat casualties coded in both systems at the time of the preliminary analysis.

RESULTS

MCIS Severity Code Distribution and Use

The association of MCIS severity levels with MFIS functional incapacity is shown in Table 3. Distribution of the 269 MCIS codes by severity and body region is shown in Figure 2. Of the 269 MCIS codes, 51 (19%) are for injuries that absolutely cannot be coded using AIS 2005 Update 2008. This breaks down by body region as follows: head and neck (9 injuries), torso (5), arms (16), legs (12), and multiple (9). A majority (83%) of the 269 MCIS codes were used to code the 992 cases in this analysis.

Reliability and Validity

Face and content validities were ensured by developing the MCIS and MFIS with a large panel of subject-matter experts (SMEs) including triservice, military combat surgeons and specialists with recent experience in Iraq and Afghanistan, and vetting by numerous specialists and committees, which resulted in relevant injury severity and incapacitation scales for contemporary combat injuries. Interrater reliability assessment showed that the results of all three coders matched 91% to 93.5% of the expert-assigned MCIS codes, which is a much higher rate of interrater reliability than for AIS coding of civilian injuries (reported in the 65–75% range before the further growth and complexity of AIS since 2000).²⁵

The construct validity assessment revealed highly statistically significant associations showing monotonic increasing severity and injury number correlations with disposition. Table 4 shows disposition data for maximum MCIS in 992 combat casualties, and Table 5 shows disposition by maximal injury severity and number of injuries, with a larger percentage of patients requiring evacuation and fewer remaining in theater as severity increases, which is especially relevant in the combat environment.

The comparisons of discrimination and calibration created parallel models for the MCIS and AIS measurement systems. One model used the maximum injury severity as the predictor (single rating). The second model used the sum of the squares of the three most severe injuries as the predictor (rating composite). The model evaluation criteria were the AIC, the H-L statistic, and misclassification rates.

TABLE 4. Distribution of Maximum MCIS Severity Scores, Combat Casualties

Maximum MCIS	RIT	Evac	Fatal	Total
1	40	9	0	49
2	80	106	0	186
3	9	177	3	189
4	0	392	88	480
5	0	27	61	88
Total	129	711	152	992

Evac, evacuated out of theater; RIT, remained in theater.

The AIC values in Table 6 were computed from the SPSS output values reported for $-2 \log$ likelihood using the general AIC formula $AIC = -2LL + 2k$, where $k = 2$ for all models. The correction for small sample size was omitted because it would have had little effect on the table values given the sample size.

Results of the predictive and external validity assessments using maximum score and NISS (composite) model for both MCIS and AIS are shown in Table 6. The MCIS had lower AICs in composite ratings (the smaller the AIC, the closer the model is to the hypothetical true model), equivalent AUCs, and lower total death misclassification rates in both the single and composite ratings.

The AIC strongly favored MCIS in the composite injury model. The single-rating models were equivalent by this criterion (Table 6). The MCIS H-L statistic was smaller than the AIS H-L statistic for both models. The misclassification rate was lower for the MCIS model in both comparisons because substantial gains in the accuracy of forecasting fatalities more than offset minor losses in the accuracy of forecasting survival.

DISCUSSION

The 2008 Military Injury Scoring Summit resulted in the formation of an expert panel that developed the MCIS to more accurately characterize combat injury and the MFIS to quantify immediate postinjury functional capacity. The MCIS was developed de novo in a process that entailed (1) designating five combat-relevant body regions, (2) defining combat-relevant injury severity along a five-point ordinal scale, (3) adding injury descriptions to address the spectrum of injuries seen in combat, and (4) establishing a system to code each injury

TABLE 5. Outcome in Relation to Maximal Injury Severity and Number of Injuries

Maximum MCIS	Outcome	No. Injuries	SD	n
1	Evac	1.89	1.05	9 (18%)
	RIT	1.92	1.21	40 (82%)
	Total	1.91	1.17	49
2	Evac	4.64	3.58	106 (57%)
	RIT	2.64	1.69	80 (43%)
	Total	3.78	3.08	186
3	Fatal	7.67	3.79	3 (1%)
	Evac	5.44	3.86	177 (94%)
	RIT	4.78	2.59	9 (5%)
	Total	5.44	3.80	189
4	Fatal	13.25	8.15	88 (18%)
	Evac	9.63	6.12	392 (82%)
	Total	10.29	6.68	480
5	Fatal	12.97	7.50	61 (69%)
	Evac	12.85	7.50	27 (31%)
	Total	12.93	7.46	88
Total	Fatal	13.03	7.84	152 (15%)
	Evac	7.87	5.86	711 (72%)
	RIT	2.57	1.76	129 (13%)
	Total	7.97	6.49	992

Evac, evacuated out of theater; RIT, remained in theater.

TABLE 6. AIS-MCIS Rating Scale Comparisons

Criteria	Single Rating (Maximum Score)		Rating Composite (NISS)	
	AIS 2008	MCIS	AIS	MCIS
Statistical				
AIC	600.78	603.62	595.05	575.94
H-L statistic				
χ^2	8.00	0.61	32.05	15.34
Degrees of freedom	3	3	8	7
P value	0.046	0.895	0	0.032
AUC	0.86	0.83	0.89	0.87
Classification				
Death misclassification*	88.8%	59.9%	74.3%	67.1%
Survivor misclassification rate**	0.2%	3.2%	4.0%	2.0%
Total misclassification	13.8%	11.9%	14.8%	12.0%

*1-sensitivity

**1-specificity

description. The initiative thus addresses the shortcomings of AIS in terms of descriptive scoring and scaling, and responds to user needs for simplicity and robustness.

So that the MCIS may be related to civilian and archival combat databases, it has been mapped to AIS 2008-Military, AIS 2005 Update 2008, AIS 1998, and ICD-9-CM and will be mapped to ICD-10-CM when it becomes available.

The MCIS was developed with consultation from multiple specialties and in recognition of databases being developed by the specialties (including orthopedic, ophthalmologic, neurosurgical, and craniofacial) with a higher level of granularity than is required for use of a general trauma database. The existence of these data sets greatly facilitated the ability to reduce the number of codes for general injury description to approximately 13% of those in AIS. This level of reduction had become necessary because of the complexity of AIS, which has grown from 75 codes to almost 2000 during the past decades. The AIS is largely unused by most injury database stakeholders, and is no longer required by the American College of Surgeons National Trauma Data Bank.

The reduced number of codes and rationalization of the body areas are likely largely responsible for the coder interrater reliability observed in comparing the MCIS with AIS. The laborious input from multiple personnel and professionals within the military also account for the construct validity shown in Tables 4 and 5.

Predictive and external validities were tested on a random sample of 992 combat casualties in the Naval Health Research Center database. These initial validity comparisons were encouraging but highlighted some issues. Specifically, nine MCIS 1 injury patients evacuated from theater had concussions and were evacuated at physician discretion, and a significant number (20%) of MCIS 5 patients who lived had significant head injuries but were still alive at the time of latest evaluation that we used, that is, 30 days after injury. The scale compression associated with moving from the six-point AIS to the five-point MCIS produced models that performed as well by statistical criteria and better in terms of overall predictive accuracy.

The NISS composite MCIS was the best model overall in this analysis. The AIC indicated that the data provided almost no support for the remaining three models relative to the MCIS composite model. However, the classification criteria arguably are the most important for medical care logistics and vehicle occupant vulnerability simulations, which must accurately distinguish fatalities from survivors. Overall, the MCIS models performed this task more effectively than the AIS models. The MCIS-based models are being tested on combat casualty data from more than 5,000 patients in the combat trauma registries under the Office of Naval Research (ONR)-funded Human Injury and Treatment (HIT) program.

The MCIS has been linked to measurable military criteria for crew safety requirements for future military vehicle design and development. New military vehicles are being designed to prevent or mitigate incapacitating injuries from underbelly or underwheel explosions. Incapacitating injuries are defined as those which (1) prevent the occupant from exiting the vehicle without assistance and seeking medical care at the buddy or unit level; (2) are irreversible, such as loss of life, limb, or eyesight, or those that result in permanent disability; and (3) prevent the casualty from returning to duty. Each injury criterion developed for use by the civilian automotive crash community has been reviewed, and its applicability to military vehicle crash investigation has been determined. MCIS risk curves have been developed. Because the MCIS and MFIS are based on combat injury severity and functional incapacitation, when linked to crash injury criteria, incapacitating injuries can be identified, and military vehicle design can be modified to mitigate or possibly prevent them. These efforts are similar to those undertaken by the civilian automotive community during the past four decades.

The mapping of MCIS to existing injury taxonomies and trauma scores to enable comparisons will permit linkage of test, injury, and measurable military criteria for crew safety requirements for future military vehicle and ship development.

SUMMARY

During a period of 5 years, several hundred individuals involved in the assessment, treatment, and databasing of combat injury or the scientific application of injury severity tools worked to complete a combat injury scale that is firmly founded on the injuries sustained in modern combat. For the first time, such an injury scale and simple models derived from it were evaluated on combat injury databases. They are shown to exhibit superior performance using standardized testing for biologic and biometric models and thus have great promise for many military-specific and civilian counterterrorist applications.

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