Annex C – INFORMATION RELATED TO AV BLAST LANDMINE INJURIES

C.1 INTRODUCTION

This annex presents the medical aspects of anti-vehicular (AV) blast landmine injuries, which were taken into consideration in the development of the injury assessment method proposed in this report. The information contained in this annex is focused on the **physical** effects on military personnel inside vehicles when subjected to an AV blast landmine. The information contained in this annex does not take into account effects by other types of mines. The structure of this annex is the following:

- Section C.1 – Introduction
- Section C.2 – Injury Risk Assessment/Injury Scaling
- Section C.3 – AV Blast Mine Injuries and Their Consequences
- Section C.4 – Discussion & Conclusions

C.2 INJURY SCALING AND INJURY RISK ASSESSMENT

C.2.1 Injury Scaling

The injury assessment method proposed in this report (Chapter 3) implies the definition of injury criteria and tolerance levels. Injury criteria refer to parameters or functions of parameters that are related to injury (e.g. the measurements taken during a mine test like forces, moments, acceleration, etc.). Tolerance levels are the maximum acceptable values for each of the injury criterion. To establish injury tolerance levels for each body region of interest, the use of an injury scale was essential. Injury scaling is defined as the numerical classification of the type and severity of an injury. The three main types of injury scaling are [Radonić, 2004]:

- Anatomical scales: Described the injury in terms of anatomical location, type of injury and relative severity.
- Physiologic scales: Described the physiological status of the patient based on the functional change due to injury. This status may change over the duration of the injury's treatment period.
- Impairment, disability and societal loss scales: Rate the long-term consequences and in relation to this, the "quality of life".

Unlike the AP mine injuries [TR-HFM-089, 2004], no specific injury scales were available or developed to classify AV mine injuries. Therefore the HFM-090/TG-25 decided to use the Abbreviated Injury Scale (AIS) [AIS, 1990] to guide the definition of acceptable injury tolerance levels. The AIS is the most well known anatomical scale and has been universally accepted. It was first published in 1971 and has been revised four times (1976, 1980, 1985 and 1990). Although originally intended for impact injuries in motor vehicle accidents, the several updates in the AIS allow now its application for other injuries such as burns and non-penetrating injuries. The AIS was developed to provide researchers with a simple numerical method for ranking and comparing injuries by severity, and to standardize the terminology used to describe injuries. The AIS is based on anatomical injury and in this way, differs from other systems that depend on physiological parameters. The AIS scores injuries and not the consequences of the injuries. It is used as a measure of the severity of the injury itself (including the risk of fatal injuries) and not as a measure of impairments or disabilities that result from the injury. Figure C.1 presents the injury ranking as defined by the AIS [AIS, 1990].

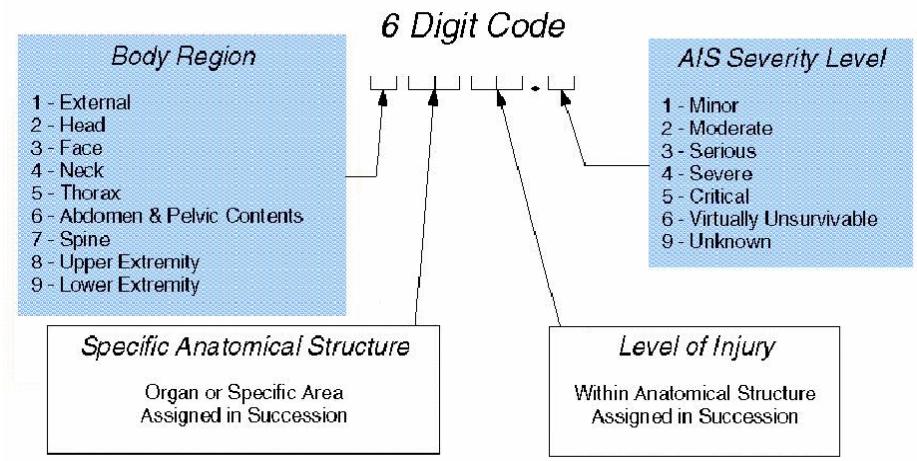

Figure C.1: AIS Coding Scheme [AIS, 1990].

An overall parameter for damage to parts of the body (the Injury Severity Score, ISS) can be calculated using the AIS code. The ISS score summarises the damage for the whole body in global terms. The ISS is the sum of the squares of three of the highest AIS codes in each of the most severely injured body parts. Recently, a modification of the ISS that both improves accuracy and simplifies scoring has been discussed in literature [Osler, 1997]. The NISS is the sum of the squares of the AIS scores of a patient's three most severe injuries, regardless of body region. The NISS avoids some shortcomings of the ISS, which leaves some injuries out of the scoring process altogether, such as when a patient sustains multiple injuries to a single body region, in which cases only the single worst injury contributes to the ISS. Also the ISS often ignores some more severe injuries in one body region in favor of less severe injuries to some other body region or regions, such as when multiple body regions are injured. Shortcomings of both, ISS and NISS are that it was designed for blunt trauma only, and it does not take into account physiologic variables. The (N)ISS score ranges from 1 to 75. Any injury code AIS 6 is automatically assigned an (N)ISS score of 75. This implies that 75 means a fatal injury whereas lower values indicate a less serious effect, ranging from critical to minor, in a way similar to that in the AIS code order. The corresponding estimates for survivability go from "highly unlikely" to "full recovery beyond any doubt".

C.2.2 Injury Risk Assessment

Injuries having an AIS score below 3 are generally not life-threatening and are usually not associated with long-term impairment. In order to reduce, as much as possible, the risk of life-threatening as well as disabling injuries, the injury tolerance levels for the pass/fail limits to qualify the protection level were defined by STANAG 4569 based on the research by the HFM-090/TG-25. It has been decided that a 10% risk of AIS 2+ (AIS 2 or more) is acceptable. This guideline was followed, as much as possible, for the determination of the injury tolerance levels. The injury risk assessment for the STANAG 4569 consists of full scale testing using anthropomorphic test devices measuring the injury parameters and comparing the results to the tolerance levels. The procedure is described in the main text of the report, whereas the test protocol is presented in Annex I.

C.3 AV BLAST MINE INJURIES AND THEIR CONSEQUENCES

The analysis of vehicle mine incidents [Medin, 1998; Radonić, 2004] is necessary in understanding the effects on the human body of blast mine detonations under vehicles. However, information is often classified, not/hardly available, or not detailed enough. Information on direct blast injuries caused by AP mines is easier available, because the number of AP mines and therefore the number of incidents is

considerably larger. Besides more civil than military are involved in AP mines incidents, which makes the medical information more accessible for these direct blast injuries. In contrast with antipersonnel (AP) mine strikes [TR-HFM-089, 2004], antivehicular (AV) mine strikes are not associated with specific injury patterns. Depending on a large number of factors, an AV mine blast may result in a full spectrum of physiological effects ranging for example, from a minor scratch to a fatal injury, and may injure all parts of the body. Based on a limited amount of information, coming from incident reports and full-scale testing experience, the lower extremity, the spine, the head and the auditory and non-auditory internal organs/systems (susceptible to overpressure effects), were identified as the most vulnerable body regions to AV blast landmine strikes.

C.3.1 Injuries, Recovery and Impairment

The following tables give examples of injuries that may be sustained by vehicle occupants subjected to an AV blast mine, for the most expected vulnerable body regions: lower leg, spine, head, neck and non-auditory organs. The information is presented here to have an indication of the injuries, recovery and impairment. For each of the injury, the time for recovery is estimated and level of risk of impairment after recovery is indicated. The estimated time for recovery and risk of impairment is in general very sensitive to a number of factors. The information contained in the following tables represents the most expected scenario for a relatively young person in good physical condition.

The term 'recovery' refers here to the healing and 'impairment' refers to the after-effects and/or limitations caused by the injury. For example, the recovery period for a calcaneus fracture is usually short (3 months), but the risk of impairment associated with this injury is high. Because of the pain, the patient may be not able to walk or run normally anymore.

Table C.1: Lower Leg Injuries

Examples of Injuries	AIS	Recovery	Risk of Impairment
Ankle sprain	1	2 to 3 months	Low
Simple fracture of the tibia	2	3 months	Low
Simple or comminuted fracture of the talus	2	3 months or +	Medium
Simple or comminuted fracture of the calcaneus	2	3 months or +	Medium – High
Open fracture of the tibia	3	3 months or +	Low – Medium
Fracture of the fibula with affected artery or nerve	3	3 months or +	Medium – High
Traumatic amputation	4	3 months or +	High

Table C.2: Cervical and Thoraco-Lumbar Spine Injuries

Examples of Injuries	AIS	Recovery	Risk of Impairment
Sprain	1	2 to 3 weeks	Low
Disk hernia	2	1 to 3 months	Low – Medium
Stable vertebrae fracture	2	1.5 to 4 months	Low – Medium
Spinal cord simple contusion (with or without fracture)	3	3 months or +	Medium – High
Uncompleted spinal cord syndrome	4	3 months or +	High
Completed spinal cord syndrome	5	6 months or +	High
Unstable vertebrae fracture	5	3 months or +	Medium – High

Table C.3: Head Injuries

Examples of Injuries	AIS	Recovery	Risk of Impairment
Skull fracture	2	4 to 6 weeks	Low
Brain concussion	2	1 month	Low
Brain contusion	3	3 months	Low – Medium
Complex or open skull fracture	4	3 months or +	Medium
Intracerebral haemorrhage	4	3 months or +	Medium – High
Brainstem contusion	5	3 months or +	High

Table C.4: Auditory and Non-Auditory Overpressure Injuries

Examples of Injuries	AIS	Recovery	Risk of Impairment
Eardrum rupture	1	4 to 6 weeks	Low
Dislocation or rupture of the ossicles (malleus, incus and stapes)	1	1 to 3 months or +	Medium – High
Damage of hair cells of the cochlea	1	1 to 3 months or +	Medium – High
Trachea minor ecchymosis	2	1 month	Low – Medium
Bowel major contusion	3 – 4	2 to 3 months	Medium
Rupture of spleen	3	1 to 3 months	Low – Medium
Unilateral blast lung (1 lung affected)	3	4 to 6 weeks	Medium
Rupture of liver	4	2 to 3 month or +	High
Bilateral blast lung (2 lungs affected)	4	4 to 6 weeks or +	Medium – High
Hemothorax	?	4 to 6 weeks or +	Medium – High
Penumothorax	?	4 to 6 weeks or +	Medium
Bowel contusion with perforation	5	2 to 3 months	Medium – High

C.3.2 Parameters that Influence the Injury Severity

The extent of damage to the different body regions is related to different human factors like:

- Anthropomorphic data;
- Gender, age; and
- Physical state.

According to [Radonić, 2004] the extent of damage and the localization of the wounds are in direct relation with the type of landmines, the distance between occupant and mine, the strength of explosive charge, the brunt of airwave and the thermal activity. When a vehicle is subjected to a blast landmine, the following factors are believed to be the most influent on the severity of injuries sustained by the occupants:

- Distance between mine and occupant;
- Type of vehicle (including type of protection); and
- Loading conditions.

The severity of the effects of the mine on vehicle occupants is directly correlated with the impact of the mine on the vehicle itself. The mine protection system will then deal with these factors in order to reduce the impact of the mine on the vehicle and thus, on the occupants. The following paragraphs present some examples for these three latter factors.

C.3.3 Distance between Mine and Occupant

The report by Medin et al. [Medin, 1998] describing a blast mine incident on an armoured personnel carrier (APC) in Bosnia, in 1996, shows the important effect of the distance between mine and occupants, on the severity of injuries. Figure C.2 shows the vehicle with the nine passengers (commander, gunner, driver and six rear passengers) and the mine location (red circle). The commander (C), the driver (D) and the passenger Rf did not sustain any physical injury. The gunner (G) and the passengers Lf, Rc and Rr sustained lower extremity injuries. The passengers who were the closest to the mine (Lc and Lr) sustained the most severe lower leg injuries, which unfortunately resulted in surgical amputation for both of them after the incident, (Lc lost both lower legs).

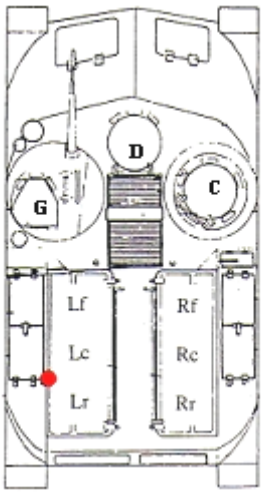

Figure C.2: APC Subjected to AV Blast Landmines (Modified from [Medin, 1998]).

C.3.4 Type of Vehicle

The type of vehicle, by its specific geometry, will of course have an influence of the distance between occupants and mine. The vehicle structure solidity (including the type of protection) will affect the extent of damage on the vehicle and thus, on the occupant inside. Figure C.3 shows unprotected light-armored and logistic vehicles both subjected to an equivalent blast mine threat detonated under the front wheel. The light-armored vehicle, being more robust and having a stronger structure, was more resistant than the logistic vehicle. The conditions of the vehicles after detonation (shown on Figure C.3) give a good idea of the impact that may have been transmitted to the vehicle occupants. In these cases, it is expected that the occupants of the logistic vehicle would not survive the blast whereas the probability of survivability is expected to be much higher for the occupants inside the light-armored vehicle.

Light Armoured Vehicle – Before the test

Light Armoured Vehicle – After the tests

Light Logistic Vehicle – Before the test

Light Logistic Vehicle – After the test

Figure C.3: Light-Armoured and Logistic Vehicles Subjected to Similar Mine Threat (Pictures courtesy of DRDC).

In the study of Radonić et al. [Radonić, 2004], AV mine strike incidents occurring during the war of Croatia between 1991 and 1995, were analyzed. The vehicles involved in these incidents were light vehicles (lorries, cars, buses, etc.) and six of the seven mine types reported were blast landmines. Of the 464 victims, 42 (9%) were injured and 12 (29%) of the injured victims died. The major cause of death was brain injuries and the most frequent injured body region was the leg. Leg traumatic amputation, leg fracture (especially calcaneus),

eyes injuries and brain injuries (with skull fracture) were the most reported injuries. The severity and types of injuries reported in the study of Radonić would not be necessarily the same expected if heavier vehicles would have been subjected to the same threats. For example, in the vehicle mine incident described by Medin, six of the nine vehicle occupants were injured and none of them died. The injured occupants suffer lower extremity injuries, but none of them suffered traumatic amputation, eye or brain injuries.

Open and closed vehicles subjected to blast mines will not necessarily result is the same severity and type of injuries. In the case of an open vehicle, the occupants are more exposed to detonation products, heat and blast wave. Also, the occupants of an open vehicle may be ejected. The ejection may result in multiple injuries to the whole body when falling on the ground, especially skull, brain and neck injuries. Also fractures to the pelvis and femur have been documented [Medin, 1998]. The severity of the injuries will depend on the height of the fall.

C.3.5 Loading Conditions

The impact of the mine on the vehicle depends on the loading conditions, which are not only related to the mine itself. The following parameters will influence the severity of the loading conditions on the vehicle and its occupants:

- Explosive mass and type;
- Type of soil;
- Depth of burial; and
- Mine location with respect to the vehicle.

More information on this topic can be found in the STANAG 4569 minutes and reports.

C.4 DISCUSSION AND CONCLUSIONS

Antitank blast landmines result in multiple injury mechanisms causing physical injuries to the whole body. The definition of an injury assessment method for protection against AV mines was an important challenge due to the limited information available on AV mine incidents and injuries. However, based on full-scale testing experience and on few incident reports, it was possible to develop a satisfying assessment method. This method includes injury criteria and tolerance levels that were established to protect, as much as possible, against life-threatening and disabling injuries. The Abbreviated Injury Scale (AIS) was the tool used to establish acceptable injury tolerance levels.

Injuries sustained by the vehicle occupants may range from AIS 1 to 6, depending on human, mine and vehicle factors. The Abbreviated Injury Scale has its advantages and limitations. The most important advantage of using the AIS is for its simplicity. Being applicable to individual body regions, the AIS does not reflect the global conditions of a casualty suffering of multiple injuries. Injuries having an AIS score below 3 are generally not life-threatening and are usually not associated with long-term impairment, but they are some exceptions. Ear and lower extremity injuries are examples of AIS 1 (ear) and AIS 2 (leg) injuries resulting in long-term impairment. Ear injuries (even the ones resulting in hearing loss) have a score of AIS 1 and are of course very incapacitating, and represent a considerable loss of quality of life. Calcaneus fracture, having an AIS score of 2, is very painful and is often associated with infection. These complications may result in an amputation of the leg below the knee, which strongly affect the patient quality of life. Finally, different types of fractures may have the same AIS score, but not the same consequence. For example, intra-articular (outside the joint) represent more chances of long-term impairment (loss of joint mobility) than extra-articular (in the joint) fractures. Even if the AIS does not always reflect long-term consequences of injuries, it was believed the best approach for the HFM-090/ TG-25 to establish NATO evaluation standards for AV blast landmine protection testing.

As other war injuries, mine injuries are unclean because the explosive brunt carries ground particles, dirt, bacteria, remnants of clothing, metal fragments, etc., besides the inside of the vehicle is never clean. The type of injuries occurring due to the mine blast under the vehicle can require complex and expensive treatments and often result in disability and long-term impairment.

Based on incident reports of Medin and Radonić, it is clear that whatever the type of vehicle striking a mine, the lower leg is the most vulnerable body region, being in direct contact with the vehicle structure. Although usually not lethal, lower leg injuries are very incapacitating because they can result in surgical amputation of the leg. For this reason, the HFM-090/TG-25 participating countries are presently putting a considerable effort on the optimization of the lower leg injury assessment method (see Annex E).

C.5 REFERENCES

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