Trauma-Chest Injury (Blunt) CLIFF Peer Review

1. *Strength of evidence presented in CLIFF in modeling the characteristics and mission impact of this medical condition within the spaceflight environment?*

   Score: 2

   Grading Scale:

   4 - Confident

   3 - Somewhat confident

   2 – Neutral

   1 – Somewhat unconfident

   0 – Not confident

2. How confident are you that these data accurately represent the spaceflight environment?	*Tables 1, 2* *Composite Incidence and Level of Confidence*	*Table 3, 4 BC/WC* *Loss of Crew and probability*	*Table 4 - Clinical Phase 1, 2 durations* *Table 5 – CP 2 Loss of Crew*	*Table 4 – RTDC %* *Table 6 – RTDC Loss of Crew*	*Table 4 – Loss of Crew Life %* *Table 7 – Loss of Crew Life, Loss of Crew*	*Table 8 – TI*
Score	*2*	*2*	*2*	*2*	*2*	*3*

Comments and limitations:

1. **General comments.** This CLiFF characterizes blunt chest trauma that might occur during spaceflight. This version excludes penetrating chest trauma. A generally recognized metric that is used when grading the severity of chest trauma is the Acute Injury Scale (AIS). For thoracic (chest) injuries, injuries that have an AIS of 1 or greater include rib contusion or a single rib fracture and sternal contusions. Higher AIS scores are associated with more serious complications such as tension pneumothorax, hemothorax, flail chest, and adult respiratory distress syndrome (the subject of another CLiFF). A model has been developed for ISS based on terrestrial data and historical spaceflight reports of blunt chest trauma. However, it is felt that during Artemis missions in which the vehicles are of much smaller size than ISS, the risk of significant blunt chest trauma in microgravity is extremely small. Thus, the ISS modelling will only be applied during surface operations. Ideally, this would only be applied to non-EVA surface operations since the hard upper torso of the suit protects the chest from blunt trauma. However, the current version of IMPACT prevents us segmenting the mission into surface EVA or non-EVA operations. For now, this model will apply to all surface operations. There have been 6 reported cases of trunk injuries during spaceflight, but there was no delineation between abdominal and chest injuries. All the cases

reported were mild. The best case is considered to be mild or moderate blunt chest injury resulting in localized pain/discomfort and/or ecchymosis, requiring supportive treatment. The worst case is severe blunt chest trauma that causes damage of the internal chest organs with secondary complications (e.g hemothorax/mediastinum/pericardium, pneumo-thorax/mediastinum/pericardium, diaphragmatic rupture, rib fractures).

2. **Incidence.** There have been 6 reported events involving injuries to the trunk; however, the mechanism and location were not categorized. A model was developed by Lewandowski, et al in 2013 to estimate the incidence of blunt chest trauma for crewmembers on ISS. The model incorporates astronaut terrestrial data as well as the spaceflight experience to generate a risk of blunt chest trauma, broken down by AIS severity score (1 to 6, with higher numbers indicating greater severity). As mentioned in the section above, the risk of blunt chest trauma is considered extremely low in microgravity onboard small vehicles that will be used on Artemis missions, and as compared to a partial gravity environment, such as on the lunar or Martian surface. Since MPRAT currently only has the capability to segment the missions between EVA and non-EVA operations, this incidence will be applied to all surface operations, both on EVA and inside the habitat. This will likely lead to a slight overestimate as the EVA suit will provide protection against blunt chest trauma. The best case/worst case probabilities were based on the chest injury module by Lewandowski, which showed the best case scenario percentage is 93% (AIS < 3) and the worst case percentage is estimated at 7% (AIS ≥ 3). The clinical phase durations, RTDC and Loss of crew life probabilities are supported by terrestrial evidence and the case definitions, and I am in agreement with their calculation. CP2 times were based on terrestrial general population data. The best case RTDC and Loss of crew life were estimated as 0% by condition definition, and the untreated worst case RTDC was set at 100% based on the case definition (need for surgery). The probability density curve that was derived appears to be a reasonable representation of the data presented.

3. **Clinical phase data**. I am in agreement with the clinical phase 1 duration entered in this CLIFF. This data was compiled by a team of expert clinicians, and I was involved in the discussions leading to the calculation of the clinical phase duration. CP2 was supported by terrestrial evidence.

4. **Task impairment**. The analysis was performed and reviewed by a separate team of expert clinicians. I am aware of the methods that were used but did not directly participate in the discussions.

5. **Dependence on mission phase or duration of mission**. This medical condition is dependent on mission phase as it is only being considered during surface operations.

6. **Limitations**

- There have been 6 reported events involving injuries to the trunk; however, the mechanism and location were not categorized. Therefore, a chest injury model was used to estimate the incidence and BC/WC probabilities.
- This medical condition is constrained by mission segment. The incidence is assumed to be zero during microgravity operations and is only applied during surface operations.
- Estimates of the incidence of blunt chest trauma on ISS were based on modelling data. However, it is felt that during Artemis missions in which the vehicles are of much smaller size than ISS, the risk of significant abdominal trauma in microgravity is extremely small. Thus, the terrestrial trauma evidence will only be applied during surface operations. Ideally, this would only be applied to non-EVA surface operations since the hard upper torso of the suit protects the abdomen from blunt trauma. However, the current version of IMPACT

prevents us from segmenting the mission into surface EVA or non-EVA surface operations. For now, incidence data will apply to all surface operations but not to microgravity operations.

- It is possible that there will be overlap with ICL 116 Traumatic Hypovolemic Shock since chest trauma may be the cause of shock. It is also possible that it could overlap with the Respiratory Failure CLiFF.
- There have been no new cases of blunt chest trauma that have been reported during spaceflight since the Lewandowski paper was published, so the incidence may be lower than estimated in this paper.
- Terrestrial general population studies were used to estimate the Clinical Phase 2 durations and outcomes (RTDC and Loss of crew life) of chest injury in spaceflight. It is uncertain how chest injuries would manifest and respond to treatment in the microgravity and partial gravity environments of spaceflight.

Reviewed by:

David C. Hilmers