

Trauma – Minor Head 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	1	2	2	3	2	3

Comments and limitations:

1. General comments. This CLIFF characterizes the risk of minor head trauma during spaceflight. Minor head trauma includes concussions, post-concussion syndrome, and non-operative intracranial bleeds. Minor head trauma is generally considered to be a mild, transient traumatic brain injury (TBI). The symptoms can include headache, GI symptoms, visual changes, and altered sensorium. Persistent post-concussive symptoms, also called post-concussion syndrome, occurs when such symptoms last beyond the expected recovery period (weeks to months) after the initial injury. It is felt that during Artemis missions in which the vehicles are of much smaller size than ISS, the risk of significant head trauma in microgravity is extremely small. Thus, the terrestrial trauma evidence that is used to determine incidence will only be applied during surface operations. Ideally, this would only be applicable to non-EVA surface operations since the helmet of the EMU protects the head from 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. There have been a number cases of minor head trauma reported during spaceflight, but these were often poorly described, making it difficult to determine if these events met the case definitions. For purposes of this CLIFF the best case

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scenario is defined as head trauma resulting in a concussion that impacts mission objectives for less than 2 weeks (this includes concussive symptoms caused by non-surgical intracranial bleeds meeting the above criteria). The worst case scenario is head trauma resulting in post-concussive syndrome interfering with mission objectives or requiring medications for longer than 2 weeks.

2. Incidence. There are spaceflight reports of head trauma, but the descriptions are not detailed enough to determine whether they meet the case definitions of concussion or post-concussive syndrome. Terrestrial data was therefore used to calculate the incidence rate. The best source was felt to be a descriptive epidemiologic study by Marin (2014) of presentations to a hospital for TBI that were categorized as minor head trauma. This study used hospital visits nationwide for the years 2006 and 2010. The data from both years was combined to increase the sample size. The large sample size results in a small variance which may overestimate the confidence that we have as we apply this data to the spaceflight environment. As mentioned in the section above, the risk of head trauma is considered to be extremely low in microgravity 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 helmet will provide protection against minor head trauma. The best case/worst case probability split is based on terrestrial studies that when pooled showed a probability of post-concussive syndrome of 13% after mild TBI. It should be noted that the definition of TBI was not consistent across studies. The clinical phase durations, RTDC and Loss of crew life probabilities are supported by terrestrial evidence. RTDC used the need for hospitalization as a surrogate. The literature is not informative in differentiating between hospitalization rates in those who are treated and those untreated for either the best or worst cases. Thus, the RTDC probabilities are the same for TBC and UTBC and for TWC and UTWC. The Loss of crew life probability is the same for all scenarios because neither treatment, nor development of post-concussive syndrome affects the probability of Loss of crew life, according to the evidence base for these conditions. It should be noted that some of the probabilities are based on studies in pediatrics which may limit their usefulness in the astronaut population.

3. Clinical phase data. I am in agreement with the clinical phase durations 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 durations.

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 constrained by mission segment. The incidence is assumed to be zero during microgravity operations and is only applied during surface operations.

6. Limitations

- There are spaceflight reports of head trauma, but the descriptions are not detailed enough to determine whether they meet the case definitions of concussion or post-concussive syndrome. Terrestrial data was therefore used to calculate the incidence rate.

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- The overall confidence in the mean incidence value is probably overstated because of the large sample size of the Marin study which results in a very narrow probability distribution.
- 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 head trauma is based on terrestrial studies. However, it is felt that during Artemis missions in which the vehicles are of much smaller size than ISS, the risk of significant head 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 EMU helmet protects the head 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.
- The BC/WC probability split was based on reports in the general population. This applicability of this cohort to the astronaut corps is limited as it included patients older than 70 years. The mechanism of some of the head trauma described may be unlikely to occur during spaceflight.
- It should be noted that some of the probabilities are based on studies in pediatrics and college athletes which may limit their applicability to the astronaut population.
- The best case/worst case probability split is based on terrestrial studies that when pooled showed a probability of post-concussive syndrome of 13% after mild TBI. It should be noted that the definition of TBI was not consistent across studies.
- The literature is not informative in differentiating between hospitalization rates in those who are treated and those untreated for either the best or worst cases.
- There are few data in the literature regarding non-operative intracranial bleed as it is described in the best-case scenario. Thus, the data informing this CLiFF focus primarily on mild TBI (some of which includes intracranial bleed) and concussion for the best-case scenario. The worst-case scenario is informed by literature regarding post-concussive syndrome.
- The Loss of crew life probabilities for all scenarios are the same based on the assumption that the worst-case scenario (post-concussive syndrome) does not increase risk of mortality and the assumption that lack of treatment does not increase mortality (rather, lack of treatment extends the duration, which is reflected by increased durations for the untreated scenarios).
- Gomez et al, 1996 informed all Loss of crew life probabilities. This study was conducted in Spain, which may limit its generalizability to the astronaut corps.

Reviewed by:

David C. Hilmers