EVA Related Decompression Sickness 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: 3

   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	*3*	*3*	*3*	*3*	*2*	*3*

Comments and limitations:

1. **General comments.** The subject of this CLiFF is decompression sickness (DCS) during EVA's. DCS is caused by nitrogen, that is normally dissolved in tissues, becoming supersaturated during rapid lowering of environmental pressure, changing to the gaseous state and forming gas emboli. The risk for this is highest during the preparation for and execution of EVA's as the crewmembers enter the vacuum of space. While there have been no reported cases of DCS associated with EVA's during manned spaceflight, a significant amount of data has been compiled during vacuum chamber runs. The risk of DCS increases with higher workloads and length of the EVA. The best case is considered to be Type I DCS with mild to moderate pain in an isolated single joint that resolves spontaneously or with treatment. The worst case is severe joint pain, multiple joints with pain, or migrating joint pain, AND/OR Type II DCS with CNS (spotted vision, slurred speech, coordination difficulty, loss of sensation, headache, seizures, unconsciousness) or cardiopulmonary involvement (chest pain, cough, shortness of breath). Of note, this CLiFF only covers DCS that is related to EVA's.

2. **Incidence.** A probabilistic model developed at NASA utilizing data from hypobaric chamber runs informed the incidence distribution. This model used depressurization protocols and pressures

that are anticipated during Artemis missions. The composite incidence that was calculated closely resembles the model and the results of the chamber runs. The model assumed that EVA's will be 4 hours in length while CLiFFs assume that EVA's will be 6 hours in length. The additional EVA time may therefore result in an overestimate of the DCS incidence. The best case/worst case probabilities used data from the same study in which 5.6% of DCS events fulfilled the conditions of the worst-case definition. The clinical phase durations, RTDC and Loss of crew life probabilities are supported by data from analog and terrestrial studies, but there is a paucity of evidence to inform the untreated and worst-case scenarios. Therefore, worst case Loss of crew life probability is derived from subject matter opinion. The incidence 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 only applies during EVA operations.

6. **Limitations**

- The model assumed that EVA's will be 4 hours in length while CLiFFs assume that EVA's will be 6 hours in length. The additional EVA time may therefore result in an overestimate of the DCS incidence.
- The incidence distribution shape matches (and slightly exceeds) the uncertainty of the DCS model. The mean is slightly higher than the DCS prediction but matches it exactly at the mode (most-likely) value in the distribution. This was the distribution of best fit as determined by biostatistics.
- RTDC and Loss of crew life probabilities for the best-case scenarios were assumed to be 0%.
- The untreated scenarios (assuming that the crewmember can make it back to the vehicle) are not truly "untreated" since the change in pressure from the xEMU suit to the vehicle pressure would comprise partial treatment. This was taken into consideration for the various scenarios.
- Artemis Mission atmospheres are planned at the time of composition of this CLiFF but may change. Should that occur, the durations, RTDCs, and Loss of crew lifes would need to be reconsidered.
- Due to paucity of data the Loss of crew life for the worst-case untreated scenario was determined by subject matter expert opinion.

Reviewed by:

David C. Hilmers