EVA Related Heat Illness 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*	*3*	*3*	*2*	*3*

Comments and limitations:

1. **General comments.** This CLiFF characterizes heat illness that takes place during an EVA which might encompass a spectrum from heat cramps to heat exhaustion to heat stroke. Although astronauts performing an EVA may encounter an enormous range of external temperatures, the suit has been designed to closely control internal temperatures and prevent overheating despite heavy exertion. While the EMU (space suits) used during early spacewalks did not optimally control heat overload and caused complaints from astronauts, significant engineering advances in EMU design have nearly eliminated these problems. The exploration EMU will have 4 redundant systems designed to prevent heat overload even at maximum physical exertion levels. The best case is considered to be heat cramps or heat exhaustion responsive to stopping activity and hydration. The worst case is heat stroke (body core temperature > 40 degrees C).

2. **Incidence.** Given the lack of spaceflight data on heat injury during EVA (all reports are anecdotal) and the significant improvements in suit design, engineering data which calculates the risk of component failure leading to suit overheating was used to calculate incidence. The risk is extremely low, consistent with the 4 redundant components in the suit design that prevent

overheating. As long as one of these components continues to function, the crew should be able to work at maximum energy expenditure without experiencing heat illness. There is no other terrestrial analog that can be used to compute incidence. The best case/worst case probability is based on terrestrial studies showing the percentage of heat illnesses that progress to heat stroke. The clinical phase durations are based on terrestrial data showing the expected treatment times and hospitalization rates. RTDC and Loss of crew life probabilities are estimated based on data from wilderness medicine studies and hospitalization requirements. Untreated heat stroke can have mortality rates ranging from 6 to 100%. The probability density curve for incidence that was derived appears to be a reasonable representation of the engineering 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 is applicable during microgravity or surface EVA's.

6. **Limitations**

- Heat illness is significantly correlated if not entirely dependent on high environmental temperatures, humidity, and workload. On EVA these 3 factors are regulated by engineering systems and operational rules. Terrestrial literature therefore is inherently not accurate when evaluating the incidence of this condition.
- The incidence calculation is entirely determined by engineering risk analysis since there is inadequate spaceflight data to support calculation of incidence. All spaceflight data is anecdotal and was based on old suit designs.
- There are 4 redundant cooling systems within the xEMU specifically to reduce the risk of overheating during EVA to as close to 0 as possible. This medical condition is effectively mitigated by engineering design and may not require medical risk assessment.
- Treatment for heat illness involves rapid cooling and hydration. By default, a crew member overheating on EVA would be cooled to ambient ship temperatures and would rehydrate with normal oral intake. Untreated scenarios likely overestimate RTDC and Loss of crew life as the simple act of returning from EVA and initiating nominal activity would provide therapeutic benefit.

Reviewed by:

David C. Hilmers