

Ebullism 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	2	3	3	3	3

Comments and limitations:

1. General comments. This CLIFF characterizes ebullism during spaceflight which occurs when human tissue is exposed to ambient pressures below 47 mmHg which is the vapor pressure of water at 36.1 deg C. Symptoms include bubbles in mucus membranes, swelling of the skin, and dissolved bubbles in the blood. This could occur because of low ambient pressures due to a leak in a pressurized compartment such as a station, vehicle, habitat, or EMU that is sufficiently rapid that the environmental system cannot compensate. The most likely scenario is that there is a large leak in the EMU during an EVA that causes a pressure drop to below 47 mmHg, and the crewmember is not able to return to the airlock prior to the onset of symptoms. Other scenarios that introduce a large leak inside a habitat, orbiting station, or vehicle such as Orion are unlikely to be survivable unless there is “lifeboat” available. In the latter case, the crew would be able to evacuate prior to the onset of symptoms. There have been no reports of this condition occurring during spaceflight outside of catastrophic spacecraft accidents. The best case is ebullism not requiring any respiratory support and not leading to mission-impacting long term neurologic deficits. The worst case is ebullism requiring prolonged respiratory support and/or resulting in mission-impacting neurologic deficits.

Ebullism CLIFF Peer Review

2. Incidence. There have been no cases of ebullism reported during manned spaceflight except for catastrophic accidents (i.e., Challenger and Columbia). The analog and terrestrial data is inadequate to replicate the environment and scenarios associated with a loss of cabin or EMU pressure. The incidence calculation is confined to EVA crewmembers because it is assumed that if there is a loss of cabin pressure sufficient to cause ebullism in a habitat or spacecraft, the condition is probably not survivable. Therefore, the incidence is calculated on a per-EVA basis for each crewmember who participates. The probability of loss of suit pressure then becomes an engineering assessment, and the EMU SPLAT suit leak analysis and PRA estimate for ISS were utilized. The probability of a suit leak large enough to result in ebullism (equivalent hole size of 1.1 cm) is estimated at approximately 0.00001 per EVA. Since there are no uncertainty estimates included, the incidence proportion is fixed rather than a probability distribution. This resulted in the incidence of ebullism per individual spacewalk of about once in every 98,000 EVA's. The best case/worst case probabilities of 33/67% were derived from case reports of ebullism during terrestrial activities and spaceflight. Out of 9 reports, there were 3 survivors without long-term neurologic effects. CP2 duration, RTDC and Loss of crew life probabilities are supported by terrestrial evidence. RTDC and Loss of crew life are estimated at 100% for UTWC. The composite probability density curve that was derived appears to be a reasonable representation of the data presented. The incidence is fixed; thus, there is no associated standard deviation.

3. Clinical phase data. I am in agreement with the clinical phase 1 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. The phase 2 duration was modified during the course of the review, and I am in agreement with the changes made.

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 mission phase dependent. It is postulated to occur only during a possible suit leak associated with EVA. The risk is considered to be zero during other mission phases since such a condition would be lethal to all crewmembers.

6. Limitations

- The EMU SPLAT suit leak analysis and PRA estimate were utilized. The probability of a large suit leak (hole size equivalent of 1.1 cm) is estimated at approximately 0.00001 per EVA. Since there are no uncertainty estimates included, the incidence proportion is fixed rather than a probability distribution.
- The condition dictates that the crew will need to return to a habitable volume and survive a return journey. As such, a catastrophic leak occurring in a lunar habitat, lunar lander, orbiting station, or Orion that leads to Loss of crew life is not considered. Only events that result in ebullism during EVA with a return to the airlock are considered. There may be circumstances in which emergency evacuation is survivable, but these are felt to be highly unlikely.
- The PRA that informed the incidence was for the ISS EMU. The incidence should be updated once a PRA has been completed for the exploration EMU. However, it is not expected that there will be significant differences in the results. This will remain a very rare event.

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Reviewed by:

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