Wrist fracture 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*	*4*	*3*	*2*	*3*

Comments and limitations:

1. **General comments.** As defined in this medical condition, wrist fracture includes a fracture of the distal radius or ulna, or fracture of any of the carpal bones (scaphoid, lunate, triquetrum, trapezoid, trapezium, capitate, hamate, and pisiform). Distal radius fractures are the most common type of wrist fracture on earth, and one of the most common fractures in adults. Potential mechanisms of injury for wrist fracture in space include impact from an outstretched hand during intra-vehicular translation, hyperflexion or a direct blow to the wrist such as while stowing equipment, or excessive forces exerted such as doing a repair during an EVA. There have been no fractures of any type reported during past missions in microgravity or during lunar operations. The risk of a fracture during normal crew operations in microgravity is considered to be so close to zero that it was not studied in this CLIFF. Since there are no good terrestrial analogues for calculating the risk of a wrist fracture during a lunar surface EVA, a model that was developed to predict wrist fractures on lunar and Martian surface EVA's was utilized to predict incidences. **It should be noted that the incidences that were calculated in this CLIFF used data for lunar EVA's and NOT Martian EVA's. Similarly, this CLIFF should not be used to calculate the risk of wrist fractures on non-EVA surface operations on either Mars or the moon.**

2. **Incidence.** The incidence mean, variance and distribution curves were derived from a prediction model and apply only to lunar EVA operations. As the risk of fracture for men and women is different, there are two separate curves with corresponding means and variances. There is no terrestrial data that could be applied to verify this model. Consequently, the results are the best that can be provided without further refinement to the fracture model. There were no good data sources for best or worst case untreated conditions. The loss of crew life was therefore left at 0% although intuitively it is felt by the editors that there is a finite risk of death from sepsis or compartment syndrome.

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 CLIFF is only applicable to lunar surface EVA's. For now, the risk of fracture during other phases of a lunar mission will be considered to be zero.

6. **Limitations**

- The risk of non-EVA lunar surface operations is presumed to be lower than the risk during EVA's, but higher than during the microgravity phase of a mission. Non-EVA surface operations fracture risk should be considered separately as more conditions are added to the medical condition list.
- IMPACT users should be careful not to use this model to predict fracture risk on a planetary mission profile as it only applies to surface lunar EVA operations.
- Analog articles examining wrist fracture in the context of fragility fractures/osteopenia/osteoporosis were disregarded by the student effort as not applicable. However, fractures that occur in spaceflight would be most similar to these types of fractures terrestrially. This is a limitation of the search.
- Searches for incidence did not consistently use the same mesh words. For instance, distal radius fractures were included for terrestrial incidence data, but not for spaceflight or analogue incidence searches. It is *appropriate* to include distal radius/ulna fractures in the searches, but they should be included for all searches. Of note, distal radius fractures are extremely common, terrestrially. This could artificially inflate the terrestrial incidence value. Students documented concerns about inconsistency in the terrestrial data studies. Scaphoid fracture was used as a surrogate in many cases (which is the most common carpal bone fracture, but not as common as distal radius fracture).
- Duration, RTDC, and Loss of crew life were based on distal radius and scaphoid fractures only and did not include the other bones of the wrist.
- The RTDC surrogate chosen was "ORIF / Permanent disability incidence." This does disregard the possibility of compartment syndrome as an RTDC surrogate.
- The literature search was unable to identify any duration, RTDC of Loss of crew life data for *untreated* wrist fractures. Thus, the duration and RTDC for *untreated* scenarios is using *treated* data, i.e. the duration and RTDC %, and Loss of crew life % for *treated* and untreated scenarios will be identical. The paucity of data for untreated scenarios remains a limitation in this effort.

- Loss of crew life probability was determined to be 0% for both best and worst-case scenarios. However, in the worst-case scenario this does not include the complication of compartment syndrome, which could cause a finite probability of death. It seems intuitive that the risk of death from an untreated WC fracture such as comminuted or open, that isn't treated could be greater than zero from infection, sepsis, or compartment syndrome. There was no data available for the untreated scenario, so the treated probability was used (0%). Thus, Loss of crew life may underestimate the true probability of Loss of crew life in the model, especially in the worst case, untreated scenario.

Reviewed by:

David C. Hilmers