Clinical Finding Form (CliFF)

Branch	Baseline

ICL116_Traumatic Hypovolemic Shock

The state of "shock" is defined as cellular and tissue hypoxia due to circulatory failure to meet cellular metabolic and oxygen requirements. Blood loss can cause depletion of intravascular volume and clinical decompensation, resulting in hypovolemic shock (Suresh, 2018). Blunt or penetrating trauma can often lead to significant blood loss, making traumatic hypovolemic shock one of the most common etiologies of shock. The general principal for treatment of hypovolemic shock is fluid repletion. Delayed treatment can often result in multi-organ failure. In addition to treating the underlying cause of hypovolemia (stopping the bleeding), traumatic hypovolemic shock should generally be managed initially with crystalloid solutions followed by blood products (Neal, 2012). In space, the greatest risk of severe trauma is present during extravehicular activities (EVAs) (McCuaig, 1992; Trunkey, 1986). Micrometeorites can cause penetrating traumas while many objects can potentially result in crush-type injuries during EVAs (Kirkpatrick, 2009).

INCIDENCE DATA INCLUDED IN THE MODEL

The model imports the following incidence information from the MEDPRAT Evidence Library Database: incidence data category, space adaption status, EVA status, incidence data type, incidence and occurrence distribution data and incidence data characteristics. Data category defines the type of data available for incidence calculations (i.e. raw data vs. adjusted data). Space adaptation identifies medical events that where onset occurs in the first 5-7 days of flight and does not reoccur. EVA-related incidence values identify medical events that occur only during an EVA. Incidence values types vary by data category and define the number of medical events per person-year (rates) or medical events per person at-risk (proportion) for each medical condition. Incidence values can be modified by crew characteristics such as gender sex and certain crew medical history characteristics. Modifying characteristics are noted below and incidence values are listed individually for each characteristic. Distributions are assigned to medical events incidence values and occurrences in the model. For each crewmember in a given trial, the incidence and number of occurrences of each medical condition are randomly selected from these probability distributions. Detailed descriptions of the distributions are included in the MEDPRAT Technical Description Document.

INCIDENCE DATA

SPACEFLIGHT LITERATURE

Current spaceflight reports on traumatic injury incidents in space are mainly minor injuries to the skin and mucous membranes (Gontcharov, 2005). (Johnston III, 2019) reported a total of 14 hospitalizations due to trauma between 1959 and 2018 among LSAH astronauts, none of which occurred during spaceflight. They also reported "circulatory medical event" incidence of 0.43 per 100 person-years. However, circulatory medical events included: dysrhythmia, coronary disease/angina, myocardial infarction, hypovolemic shock, and anaphylactic shock. There were no isolated incidents provided for traumatic hypovolemic shock. Musculoskeletal injuries and minor traumas in flight during the U.S. space program have been documented by (Scheuring, 2009). Traumatic and accidental deaths of astronauts in space have also been reported (Reynolds, 2018; Ushakov, 2017). However, there has not been a known report of traumatic hypovolemic shock among astronauts during spaceflight.

ANALOG LITERATURE

(Thomas, 2003) studied U.S. Navy submarine crew during periods of isolation as analogue population for long-term space missions. Similar to spaceflight incident reports, injury was one of the most commonly reported health incidents among this population. However, there were no documentation of severe traumatic hypovolemic shock not in the setting of battle injury.

TERRESTRIAL LITERATURE

(Ledingham, 1974) found that hemorrhage due to trauma makes up 21% of shock patients in a general hospital. Several more recent studies collected data on the etiologies of shock presenting to the ED. (Arendts, 2012) reported traumatic hypovolemic shock to be the cause of shock in 14% of patients. (Gitz Holler, 2019) is a population-based cohort study at a University Hospital in Denmark. They found 30% of shock patients presenting to the ED are due to hypovolemia and reported a hypovolemic shock incidence rate of 18.4/100,000 (Gitz Holler, 2019). According to additional data from (Ahrendts, 2012), approximately two-thirds of all hypovolemic shock episodes are due to major trauma. With these data, it can be estimated that traumatic hypovolemic shock has an incidence of approximately 12/100,000. Another study by (Standi, 2018) looked at 2017 Trauma Registry of German Trauma Society to identify cases of traumatic hypovolemic shock. 47,786 events occurred in 2017 when the national population of Germany was 82,657,002 according to World Bank data. Incidence can therefore be calculated as approximately 0.005 events/person-year. Combining these two, terrestrial incidence can be estimated at around 0.005-0.012 events/person-year. It is important, however, to note that incidence of trauma greatly varies between location and the outcome of trauma highly depends on the denominator population (age, health condition, etc.). Terrestrial data also does not translate well to spaceflight data due to major dissimilarities of environment and potential trauma etiologies.

OVERALL INCIDENCE SUMMARY

INCIDENCE

mean 0.004295 SD 0.001155

INCIDENCE SUMMARY

The Bayesian posterior distribution for the incidence rate given the astronaut data (14 events over 3255.814 person-years) under an uninformative prior is Gamma(shape=13.828, rate=3219.58) with mean 0.004295 and SD 0.001155. This incidence should only be applied for surface based operations as the incidence of trauma will be markedly lower in microgravity.

TABLE 1. INCIDENCE MODEL

Incidence Details

Incidence Type
UNK

Segment
Surface

Env. Exposure
NA

Sex
Any

Crowns
Any

Contacts
Any

Pregnancy
Any

Incidence Distribution

Occurrence Dist
Poisson

Incidence Dist.
Gamma

Mean
0.00429497

SD
0.001155

Gamma
(Shape): 13.828
(Rate): 3219.58

TABLE 2. INCIDENCE LEVEL OF CONFIDENCE (LOC)

Citation	Source	LOC Value
Gontcharov, 2005	Spaceflight	2
Johnston III, 2019	Analog	3
Thomas, 2003	Analog	2
Arendts, 2012	Terrestrial	1
Gitz Holler, 2019	Terrestrial	1
Ledingham, 1974	Terrestrial	1
Standi, 2018	Terrestrial	1

(Gontcharov, 2005) is a medical incidents report during the NASA-Mir orbital space programs but reported no incidents of traumatic hypovolemic shock so receives a LOC 2. (Johnston III, 2019) provided terrestrial data for trauma and circulatory medical conditions for spaceflight crew while not in spaceflight. Since it was not during spaceflight it is considered analog data and only receives a LOC of 3. (Thomas, 2003) is a analog population study for long-term space missions looking at health of US submarine crew during long periods of isolation. (De Backer, 2010) provided data on traumatic hypovolemic shock among patients presenting with shock in eight centers around the world. Cohort study (Gitz Holler, 2019) is a population-based study conducted in Denmark that provided data on the etiologies of shock presented to the ED. (Arendts, 2012) is an Australian study that also provided terrestrial data on etiologies of shock presenting to the ED. (Ledingham, 1974) is a older study looking at incidence of shock in the hospital. (Standi, 2018) calculated incidence of traumatic hypovolemic shock from Trauma Registry of the German Trauma Society. Due to dissimilarities between terrestrial trauma etiologies (e.g., gunshots) and potential causes of severe trauma in the spaceflight environment, they are a poor representation for incidence calculation, therefore receiving LOC of 1.

CREWMEMBER SELECTION/PREVENTION

DISQUALIFYING CONDITIONS

Refer to Medical Evaluation Documents (MED) Volume A, Medical Standards for ISS Crewmembers, International Space Station Program, Rev 3.4 (2016).

PREFLIGHT PREVENTATIVE MEASURES

Bone densitometry; Fitness assessments; EVA Medical Monitoring; Physical examinations; Body mass measurements; Pulmonary assessments

BEST CASE SCENARIO DEFINITION

Traumatic hypovolemic shock resulting in signs of end organ compromise that resolves with fluid resuscitation.

WORSE CASE SCENARIO DEFINITION

Traumatic hypovolemic shock resulting in signs of end organ compromise that fails to resolve with fluid resuscitation or requires blood transfusion.

CONDITIONS INCLUDED, BUT NOT EXPLICITLY STATED (CNES)

Acute Hypovolemia

BEST CASE/WORST CASE PROBABILITY COMMENTS

Current studies on outcomes of traumatic hypovolemic shock are all studies of the terrestrial population. A study reported 24% of hemorrhagic shock resulted in organ failure (Kauvar, 2006). Meta-analysis by (Owattanapanich, 2018) reported around 14.4% probability of multiple organ failure. A study by (Rau, 2016) looked at trauma patients receiving blood transfusion in the ED. Among these patients, they reported around 4% requiring massive transfusion. Astronauts are at a physiological disadvantage compared to patients on earth due to prolonged periods of weightlessness (Kirkpatrick, 2005). Conditions such as pneumothoraxes may also be exacerbated by the hypobaric stresses associated with EVA (Richardson, 1996). Additionally, cardiovascular adaptation associated with microgravity will most likely alter responses to hemorrhage and fluid resuscitation. It is therefore safe to estimate that probability of WC scenario will be 20%.

TABLE 3.BEST/WORST CASE PROBABILITY LEVEL OF CONFIDENCE (LOC)

Citation	Source	LOC Value
Kauvar, 2006	Terrestrial	3
Owattanapanich, 2018	Terrestrial	3
Rau, 2016	Terrestrial	3

(Kauvar, 2006) is a review of traumatic hemorrhage outcome. It provided data on WC scenario probabilities in the terrestrial population, receiving a LOC of 3. (Owattanapanich, 2018) is a meta-analysis that provided data on outcomes of traumatic hemorrhagic shock including multiple organ dysfunction, receiving a LOC of 3. (Rau, 2016) is a study of trauma patients presenting to the ED who required blood transfusion. They provided data on necessity of massive transfusion, which is likely to be impossible during spaceflight, among these patients, receiving a LOC of 3.

TABLE 4. CLIFF TREATMENT & OUTCOME TABLE BY CLINICAL PHASE

Case Scenario	Composite Incidence	Condition Probability %	CP1: Diagnosis		CP2: Treatment			CP3: Condition End State				
			TI%	Duration	TI%	Duration		TI%	RTDC		LOCL	
			Preset	Preset	Preset	Min	Max	Preset	Min%	Max%	Min%	Max%
Treated Best Case (TBC)	0.004295 SD 0.001155	80 - 80	100	2	100	3	48	0	0	0	0	0
Treated Worst Case (TWC)		20 - 20	100	2	100	264	912	0	86	100	20	100
Untreated Best Case (UTBC)	N/A	N/A	N/A	2	100	24	48	0	20	86	10	20
Untreated Worst Case (UTWC)	N/A	N/A	N/A	2	100	264	912	100	100	100	80	100

TABLE 4 KEY

Composite Incidence: The same composite incidence will be used for both TBC and TWC. For EVA conditions: events per EVA (events/EVA). For space adaptation conditions: events per person (events/person). For non-spaceflight conditions: events per person year (events/py).

Condition Probability: The probability that CLiFF condition progresses to a worst case scenario. Best case scenario: 100%-Worst Case.

Clinical Phase General Comments:

- TI% = Task Impairment %. Task Impairment is the % of tasks that the crewmember is incapable of performing without impairment secondary to the medical condition.
- Durations are defined in hours.
- Removal to Definitive Care (RTDC): The probability the entire crew aborts the mission and returns to earth. This is considered as a condition end state result if any of the following criteria are met: 1) the potential for LOCL, 2) potential for significant permanent task impairment, or 3) potential for intractable pain.
- Loss of Crew Life (LOCL): The probability of death of affected crewmember due to medical condition.

Clinical Phase 1: Initial Assessment and Diagnosis:

- Covers only the initial assessment and diagnosis of the affected crewmember to define his or her medical condition. While the affected crewmember is being assessed, he or she is not able to perform any assigned tasks, thus Task Impairment (TI) during this phase is considered 100%. In the untreated case, there is no diagnosis performed, therefore Task Impairment and Duration will always be " not applicable."

Clinical Phase 2: Stabilization, Treatment, and Convalescence:

- The affected crewmember is receiving any appropriate initial or follow-on treatment for his or her medical condition to allow the crewmember to recover as much as he or she is able to recover in the spaceflight environment. Clinical phase 2 also encompasses relapses or recurrences of the same original medical condition in Clinical Phase 1. The duration of Clinical Phase 2 is expressed as minimum and maximum hours.

Clinical Phase 3: Condition End State:

- Reached once the affected crewmember has recovered from the medical condition as much as he or she is able to recover in the spaceflight environment amongst treated and untreated best and worst case scenarios. This may or may not be recovery from the given medical condition to the full extent possible. If this “recovered” state results in Removal to Definitive Care (RTDC) or Loss of Crew Life (LOCL) this will be noted in the condition end state results.

SCENARIO OVERVIEW COMMENTS

Immediate control of bleeding and fluid resuscitation are the two most important aspects for treatment of traumatic hypovolemic shock. In space, depending on the location of incident, medical care and ATLS capabilities will be different, therefore altering the probabilities of survival and outcome. In BC scenarios, mortality will be low since fluid resuscitation can be achieved in space. However, limitations including lack of blood storage or surgical capabilities exist in space. Although astronauts are equipped with many supplies to stabilize injured individuals, including IV fluid, TXA, and whole blood through "walking blood banks", surgery remains the major limitation. Therefore, in more severe situations such as the development of organ failure or the need of immediate surgery, RTDC will be warranted. Associated mortality will be high due to the limited medical capacity, time required to return back to earth, and the suited configuration during return to earth (limits capacity for respiratory and circulatory care).

TREATED BEST CASE (TBC) SCENARIO COMMENTS

Due to the normalization of vital signs achieved after fluid resuscitation and no need for surgery in BC scenarios, these patients will not require extensive treatment (assuming bleeding has been successfully stopped). This makes RTDC and LOCL due to hypovolemic shock unlikely to happen (any RTDC and LOCL would be attributed to the trauma itself or its complications), therefore estimated to be 0%. Treatment of hypovolemic shock usually starts with adequate control of bleeding and initial bolus of 1L of fluid (ATLS guideline, 10th edition). With good initial response to fluid resuscitation, maintenance fluid is generally still continued for a period of time.

TREATED WORST CASE SCENARIO (TWC) COMMENTS

22% mortality was reported by (Cole,2020) among patients with multiple organ dysfunction after traumatic injury. Hemorrhage accounts for approximately 30-40% of all trauma mortality (Sauaia, 1995). (Gitz Holler, 2019) reported a 7-day mortality rate of 19.2% and 90-day mortality of 36.8% among all patients with hypovolemic shock treated in the hospital. Data from meta-analysis by (Owattanapanich, 2018) revealed around 20% of mortality. If bleeding cannot be controlled successfully in time, patient will not be able to survive despite adequate fluid resuscitation. All patients will require longer periods of monitoring for severe hypovolemic shock. (Sisak, 2012) reported urgent surgery rate of 86% among trauma patients requiring blood transfusion. With limitations for treatment of severe trauma in space (Kirkpatrick, 2009), RTDC will have a maximum probability of 100%. Using terrestrial mortality data, it can be estimated that LOCL will be at least 20% (assuming bleeding can be managed and RTDC is prompt) with maximum of 100%. Treatment duration for traumatic hypovolemic shock is highly unpredictable with different forms of trauma and complexity of other potential associated complications. For example, (Bickell, 1994) reported an average of 11-14 days of hospitalization among hypotensive patients with penetrating torso injuries with the longest staying more than 38 days. Another study by (Duke, 2012) reported an mean of 13-18 days of hospital stay also with wide standard deviations.

UNTREATED BEST CASE (UTBC) SCENARIO COMMENTS

Without prompt treatment, hypovolemic shock is fatal. However, for minor bleeding in the category of class I hemorrhage, patients can often compensate within 24 hours without the need of fluid resuscitation (Hemodynamic instabilities do not usually occur until Class III hemorrhage) (ATLS guideline, 10th edition). Class II to Class IV hemorrhages, as mentioned above, would require fluid resuscitation and in most cases, blood transfusion in order to stabilize. Without treatment, if bleeding does not spontaneously stop, blood loss will continue and eventually lead to WC scenarios and death. Untreated BC scenarios can progress to WC scenarios. Therefore, maximum probability of RTDC can be estimated to be similar to the minimum RTDC probability of treated WC scenarios (86%). Similarly, for LOCL, maximum probability can be estimated to be that of minimum for treated WC scenarios (20%).

UNTREATED WORST CASE (UTWC) SCENARIO COMMENTS

Without treatment, WC scenario traumatic hypovolemic shocks will not survive. Therefore CP2 will not be meaningful under these circumstances, but are reflected as the TWC for maximum CP2 duration given the treatments that were not successful were being administered. LOCL could be estimated to be at least 80-100% when no treatment is administered and given the WC definition, RTDC would be required in every UTWC scenario.

TABLE 5. CLINICAL PHASE II DURATION LEVEL OF CONFIDENCE (LOC)

Citation	Source	LOC Value
Bickell, 1994	Terrestrial	3

Citation	Source	LOC Value
Duke, 2012	Terrestrial	2

(Bickell, 1994) provided data on the length of hospital stay among patients with penetrating torso injuries. (Duke, 2012) analyzed outcomes of patients with severe hemorrhage. Due to the wide variability of treatment duration, this section receives a LOC of 2.

TABLE 6. RTDC LEVEL OF CONFIDENCE (LOC)

Citation	Source	LOC Value
Kirkpatrick, 2009	spaceflight	3
Gitz Holler, 2019	Terrestrial	
Duke, 2012	Terrestrial	
Bickell, 1994	Terrestrial	
Sisak, 2012	Terrestrial	

(Kirkpatrick, 2009) outlined the limitations of medical treatments for trauma in space. (Gitz Holler, 2019) provided an overview of treatment requirements for traumatic hypovolemic shock. (Bickell, 1994) and (Duke, 2012) provided insight for treatment complexity for trauma patients, highlighting the importance of good clinical care to reduce mortality. (Sisak, 2012) is a study conducted at a single trauma center providing data on trauma patients requiring urgent surgery. With the evidence of need for early and extensive treatment, LOC is a 3.

TABLE 7. LOCL LEVEL OF CONFIDENCE (LOC)

Citation	Source	LOC Value
Cole, 2020	Terrestrial	2
Durham, 2003	Terrestrial	
Sauaia, 1995	Terrestrial	
Gitz Holler, 2019	Terrestrial	
Owattanapanich, 2018	Terrestrial	

(Cole, 2020) provided data on mortality of patients with traumatic injury who developed multiple organ dysfunction. (Kauvar, 2006) is a review of traumatic hemorrhage outcome. (Owattanapanich, 2018) is a meta-analysis that provided data on mortality among patients with traumatic hemorrhagic shock.

CAPABILITY RESOURCE TABLE (CRT) OVERVIEW

Capabilities and Resourcing Scope

Overview
Traumatic hypovolemic shock refers to life threatening end organ injury in the setting of acute blood loss from a traumatic injury suffered by a crew member. This is most likely to be a blunt injury in the spaceflight environment. In a microgravity environment, objects with large mass are weightless which allows them to be moved with relative ease but still exert a significant force. This puts crew members at risk of being struck, pinned or crushed between very 'massive' objects. In partial gravity blunt injury more closely mirrors the terrestrial environment with risk of fall from height, being struck or pinned, or heavy machinery accidents (including rovers and exploration vehicles). There have not been any life threatening traumatic injuries in flight to date however the management of a crew member in shock will be extremely difficult and mirror wartime injury management in austere environments. The best case scenario in this condition is defined as anemia or hypovolemia following a traumatic injury that responds to fluid resuscitation. The worst case is defined as hypovolemic shock following a traumatic injury, requiring blood products, nonresponsive to treatment, requiring surgery, or resulting in multiorgan failure from inadequate circulating volume and poor perfusion.

It is important to note here that we are excluding pneumothorax and cardiac tamponade, spinal shock, hypoxemia from pulmonary dysfunction, and blunt cardiac injury from this condition. These are separate but related issues with trauma and shock but do not pertain to hypovolemic or hemorrhagic shock.

CNES: Anemia, Acute Hypovolemia, Hemorrhagic Shock

Diagnostic Scope and Resourcing
In the best case scenario, diagnosis is dependent on the history and physical exam. A primary assessment with basic vital signs followed by a secondary trauma assessment of head to toe evaluation is necessary to identify injuries and location of blood loss. Irrigation and suction are needed to remove floating blood from wound sites to attempt to identify large bleeding vessels that can be ligated. Laboratory analysis is needed to trend hemoglobin and hematocrit counts. In terrestrial trauma centers, patients with significant injury or mechanism of injury that are hemodynamically stable receive CT scans to identify injuries however this is unavailable in flight. The unstable trauma patient is taken directly to the operating room for exploratory laparoscopy as a hybrid diagnostic and treatment phase which is even less practical in current mission parameters. Diagnostics are thus reliant on ultrasound imaging to identify injuries and guide management. We have agreed to include the Rapid Ultrasound for Shock and Hypotension (RUSH exam) as a necessary capability to consider other sources of shock and to do a more extensive ultrasonographic evaluation than the more traditional Extended Focused Assessment with Sonography in Trauma (E-FAST).

The worst case scenario CP1 mirrors that of the best case scenario as the difference between them is the response to treatment.

The diagnostic evaluation of the trauma patient in flight will be similar to injuries that occur in wilderness, wartime, or other austere environments. The diagnostic and treatment capabilities are limited to minimizing blood loss, resuscitation, and transfer to definitive care.

Clinical Phase 1 Duration and Rationale
This version of IMPACT presumes physician level knowledge, skill, and ability will be present on the mission. The CRT working group SME consensus duration is as follows:

CP1 BC (Treated or Untreated): 2
CP1 WC (Treated or Untreated): 2

The highest scope of practice for both the best and worst case scenario is 5 (attending physician) due to the necessity of careful identification of injuries with limited diagnostic resources in order to guide management.

Treatment Scope and Resourcing

In the best case scenario, treatment is dependent on stopping blood loss and resuscitation with crystalloid. Hemostasis of external bleeding occurs with direct pressure with procoagulant impregnated gauze and vessel ligation. Pelvic fracture or injury is stabilized with pelvic compression when appropriate. Modern approaches to hemorrhagic shock limit crystalloid resuscitation due to alteration of pH, coagulation cascades, and worse clinical outcomes. In this CRT we have limited IV crystalloid fluids to 2L. External rewarming occurs to limit hypothermia as part of the trauma triad. Txa has been included however the authors acknowledge this is a controversial choice in the patient not in hemorrhagic shock. We agreed that intravenous Txa was indicated given our lack of any other treatment options for significant abdominal or thoracic trauma and its safety profile when given to healthy patients within 3 hours of injury. There are currently ongoing studies of Txa use in this population (i.e. the patient with significant trauma that is not in shock) that may guide this capability in the future. Treatment of other sources of bleeding such as long bone fracture, hollow or solid viscous injury, or thoracic injury was excluded from this condition as it is included in other conditions.

In the worst case scenario the early phases of treatment are the same as the best case scenario. This is because the defining feature between the two is response to crystalloid resuscitation. As such, management focuses on limiting external blood loss, initiation of <2L crystalloid fluid, and Txa administration. A crew member still in hemorrhagic shock after limited crystalloid resuscitation then requires blood transfusion. There are several operational approaches to the management of blood transfusion in flight that are many ways beyond the scope of the CRT project however we recommend the 'floating blood bank' as discussed by Nowak et al. 2019. This mirrors a 'walking blood bank' used in military services and includes blood type and reactivity as a parameter for crew selection. The advantages are primarily delivery of whole blood products and limited need for other equipment. Blood product donation limits are a 1-2 pints per crew member. Lyophilized blood is an alternative option but costs mass and volume.

As with other critical care level conditions in the condition list, the likelihood of LOCL in this condition is high particularly in the WC scenario as the capabilities necessary to treat this condition at the terrestrial gold standard would require extensive infrastructure and personnel that at this time are unrealistic. The future of spaceflight will eventually require surgical capabilities however they are outside the scope of our defined reference mission.

Communications and Support Needs

In both the best and worst case scenarios continuous AV communication is necessary if available given the significant risk of loss of life and limb to a crew member suffering from significant trauma.

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IMM CLIFF RECONCILATION COMMENTS

BC and WC scenario definitions were changed in this CLiFF to be more specific and compatible with potential situations in space. IMM CLiFF reported 19-100% probability of best case scenarios. However, they only accounted for those 19% who required "massive transfusion" within the first 24 hours. With further evidence provided by current terrestrial incidence of development of severe complications such as organ transfusion, we conservatively report a 80% chance of BC scenarios. The reported LOCL and RTDC probabilities are similar to this CLiFF.

LIMITATIONS SUMMARY

There is currently no documented incident of traumatic hypovolemic shock during spaceflight34. There is also no suitable analog population as etiologies of trauma are dissimilar in military or terrestrial environments. However, using the Johnston paper, which reports trauma of astronauts outside of their spaceflight duties, has been used as a surrogate. This may include injuries from elderly astronaut falls, may include hospitalizations that did not result in traumatic hypovolemic shock and may also include injuries that are only possible terrestrially (e.g. gunshot wounds). Therefore, this is likely overestimating the incidence, and therefore should only be applied for surface based operations (partial G) as the incidence of trauma will be markedly lower in microgravity. Similarly, for WC/BC scenarios, due to the fundamental differences between possibilities in space and on earth, probability data is most likely not transferable. Additionally, according to current ATLS guideline, those with Class II hemorrhage or above would most likely require blood transfusion. Current treatment guidelines also recommend repleting intravascular volume with blood products as soon as possible following all traumatic hypovolemic shocks. However, in space, blood products are unlikely to be readily available, and therefore crews would rely heavily on IVF for hypovolemia treatment. Therefore, treatment data from terrestrial literature are not ideal representations of scenarios that could happen during spaceflight. It is also difficult to assign treatment durations, RTDC, and LOCL for untreated scenarios as the presence of continued blood loss would greatly alter the need for treatments and outcome.

TABLE 8. TASK IMPAIRMENT CALCULATION BASED ON AFFECTED HUMAN SYSTEMS TASK CATEGORIES (HSTC)

Clinical Phase 2: Treatment												
	Affected HSTCs											
	Cognitive - Simple	Cognitive - Complex	Communications	Inter-personal Skills	Vision	Hearing	Cardio-pulmonary	Dentition	GI	GU		
Treated Best Case (TBC)	223	664	113	89	854	44	145	5	13	6		
Untreated Best Case (UTBC)	223	664	113	89	854	44	145	5	13	6		
Treated Worst Case (TWC)	223	664	113	89	854	44	145	5	13	6		
Untreated Worst Case (UTWC)	223	664	113	89	854	44	145	5	13	6		
	Affected HSTCs (Continued)								TI Calculation			TI Score
	Hand (Dom)	Hand (Any)	Upper Extremity	Lower Extremity	Ambul & Standing (g)	Translation & Stabilization (microgravity)	Don/Doff Equipment	Pressure Ops	Total Tasks Impaired By Condition	Total Human System Category Tasks Full Mission	TI Decimal	TI %
Treated Best Case (TBC)	132	564	414	22	196	34	34	211	3763	3763	1	100
Untreated Best Case (UTBC)	132	564	414	22	196	34	34	211	3763	3763	1	100
Treated Worst Case (TWC)	132	564	414	22	196	34	34	211	3763	3763	1	100
Untreated Worst Case (UTWC)	132	564	414	22	196	34	34	211	3763	3763	1	100

Clinical Phase 3: Condition End State												
	Affected HSTCs											
	Cognitive - Simple	Cognitive - Complex	Communications	Inter-personal Skills	Vision	Hearing	Cardio-pulmonary	Dentition	GI	GU		
Treated Best Case (TBC)												
Untreated Best Case (UTBC)												
Treated Worst Case (TWC)												
Untreated Worst Case (UTWC)	223	664	113	89	854	44	145	5	13	6		
	Affected HSTCs (Continued)								TI Calculation			TI Score

	Hand (Dom)	Hand (Any)	Upper Extremity	Lower Extremity	Ambul & Standing (g)	Translation & Stabilization (microgravity)	Don/Doff Equipment	Pressure Ops	Total Tasks Impaired By Condition	Total Human System Category Tasks Full Mission	TI Decimal	TI %
Treated Best Case (TBC)									0	3763	0	0
Untreated Best Case (UTBC)									0	3763	0	0
Treated Worst Case (TWC)									0	3763	0	0
Untreated Worst Case (UTWC)	132	564	414	22	196	34	34	211	3763	3763	1	100

TABLE 8 KEY

Human System Task Category (HSTC) Definitions: Cognitive-Simple: Tasks requiring simple cognitive involvement (low levels of attention, following simple checklists, and not requiring extensive decision making) in conjunction with inputs from other systems. Cognitive-Complex: Tasks requiring complex cognitive involvement (requiring constant attention, frequent interpretation of outside stimuli to inform real-time situations) in conjunction with inputs from other systems. Communication: Tasks requiring primarily communication, via hearing and speaking. Interpersonal Skills: Tasks requiring interpersonal, social interaction between crew including complex technical tasks that require extended crew interaction. Vision: Tasks in which visual information is required. Hearing: Tasks in which primarily auditory information is required, excluding communication, e.g. hearing alarms, medical auscultation, OOHAs. Cardiopulmonary: Tasks requiring greater-than-baseline cardiopulmonary effort, e.g. physically strenuous activities. Dentition: Tasks requiring use of teeth for mastication. GI (Gastrointestinal): Tasks requring use of the alimentary sytem, e.g. solids/liquids consumption and solids excretion. GU (Genitourinary): Tasks requiring use of the male/female genitourinary systems. Hand (Dominant): Tasks performed using primarily the hand, requiring use of the dominant hand (piloting, medical procedures, dental procedures). Hand (Any): Tasks performed using primarily the hand(s), with no preference for dominance, with equivalent bilateral effectiveness. Upper Extremity: Tasks requiring specific use of the upper extremities, excluding hands. Lower Extremity: Tasks requiring specific use of the lower extremities (excluding ambulation and standing in the presence of gravity), e.g. using exercise equipment. Ambulation and Standing (g): Tasks requiring use of both lower extremities to accomplish ambulation or standing in the presence of gravity. Translation and Stabilization (microgravity): Tasks requiring use of either the upper or lower extremities to accomplish translational movement and stabilization (securing oneself to remain stationary) in the setting of microgravity. Don/Doff Equipment: Tasks requiring the donning of personal equipment (including pressure suit, exercise harness, EVA equipment, etc). Pressure Ops: EVA/contingency tasks performed while pressurized in a suit.

Criteria for Assignment of Conditions to HSTCs (any of the following):

1) Is affected crew member physically incapable of performing the human system task category, without impairment, with the condition?
2) Would the treatment (e.g. medications) impair the crewmember's ability to perform the human system task category? (Does not apply to UTx)
3) Does the condition have a high likelihood of causing a significant aeromedical contraindication with an associated human system task category
4) Would performing tasks in an associated task category worsen the condition? (If so, it is affected).
5) Does pain associated with the condition impair any further human system categories?

TASK IMPAIRMENT COMMENTS

CP2: No comment. CP3: No comment.

EVIDENCE COLLECTION PROCESS

Mesh terms that most closely resembled the best-case and worst-case scenarios, and associated Conditions Included but Not Explicitly Stated (CNES), were utilized to build incidence, duration, RTDC, and LOCL searches by best- and worst-case.

Incidence:

Databases searched for spaceflight and analog incidence data included: PubMed, Google Scholar, NASA Technical Reports Server (NTRS) public search, Defense Technical Information Center (DTIC), and Barratt MR, Baker E, Pool SL. Principles of Clinical Medicine for Space Flight. New York, NY: Springer; 2019. 2nd Edition. Databases searched for terrestrial incidence included: DynaMed, PubMed, and Google Scholar.

Duration, RTDC, LOCL:

Databases searched for duration, RTDC, and LOCL included: Dynamed, Cochrane, PubMed, and Google Scholar. Note, that if duration, RTDC, or LOCL data was found in a DynaMed search, the other search engines were not included. Relevant articles were selected and reviewed. If applicable, the article was included in the CLiFF.

LEVEL OF CONFIDENCE (LOC) SCORING

Articles obtained to update the evidence behind this CLiFF were scored by ExMC editors, based on their applicability to the Exploration Spaceflight environment using the following grading scale:

4 – Confident
3 – Somewhat confident
2 – Neutral
1 – Somewhat unconfident
0 – Not confident

The following considerations factor into the grading scale above:

• How closely does the paper describe the medical condition as defined by the IMPACT 1.0 Condiltion List (relevance)?
• How closely does the population included resemble the astronaut population?
• Quality of the paper (number of subjects, methods, etc.)
• How much does the editor trust the source of the evidence?
• How closely does the editor think that the data represents the exploration spaceflight environment?
• Other considerations, at the discretion of the editor, supported in the comments for LOE scoring.

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ACRONYMS

ACRONYM	PHRASE
AAOMS	American Association of Oral and Maxillofacial Surgeons
AMA	American Medical Association
ARCL	All Remaining Conditions List
ARS	Acute Radiation Sickness
BHP	Behavioral Health and Performance
CAC	Coronary Artery Calcium
CHS	Crew Health and Safety
CL	Condition List
CliFF	Clinical Finding Form
CMO	Crew Medical Officer
COMFORT	Clinical Outcome Metrics for Optimization of Robust Training
CP1	Clinical Phase 1
CP2	Clinical Phase 2
CP3	Clinical Phase 3
CRL	Clinical Resource Level
CRT	Capability Resource Table
CST	Clinical Science Team
DCS	Decompression Syndrome
DRM	Design Reference Mission
ED	Emergency Medicine Doctor
EL	Evidence Library
EMCL	Exploration Medical Condition List
EMT	Emergency Medical Technician
EVA	Extravehicular Activity
EXMC	Exploration Medical Capability
HRP	Human Research Program
ICD	International Classification of Disease
ICL 1.0	IMPACT 1.0 Medical Conditions List
ICU	Intensive Care Unit
IMCL	iMED Condition List
iMED	Integrated Medical Evidence Database
IMM	Integrated Medical Model
IMPACT-MD	Impact Medical Database
IP	Incidence Proportion
IR	Incidence Rate
ISS	International Space Station
IV	Intravenous
JSC	Johnson Space Center
LEO	Low-Earth orbit

LEVA	Lunar Extravehicular Activity
LOCL	Loss of Crew Life
LOM	Loss of Mission
LSAH	Lifetime Surveillance of Astronaut Health
LSO	Lunar Surface Operations
MCL	Master Condition List
MEVA	Medical Extravehicular Activity
NASA	National Aeronautics and Space Administration
N/A	Not Applicable
NP	Nurse Practitioner
OBGYN	Obstetrics and Gynecology
OR	Occurrence Rate
PA	Physician Assistant
PDQ	Pain Disability Questionnaire
PFCL	Proposed Future Conditions List
PPE	Personal Protective Equipment
PTRS	Project Technical Requirements Specification
PRL	Pharmaceutical Resource Level
QTL	Quality Time Lost
RCL	Removed Conditions List
REP	Rochester Epidemiology Study
RTDC	Removal to Definitive Care
SANS	Spaceflight-Associated Neuro-ocular Syndrome
SAS	Space Adaptation Syndrome
SEVA	Spaceflight Extravehicular Activity
SME	Subject Matter Expert
SoP	Standard Operating Procedure
SPE	Solar Particle Event
TBD	To Be Determined
TI	Task Impairment