Clinical Finding Form (CliFF)

Branch: Baseline

ICL20_Burn - Chemical Skin

There are countless chemicals used in everyday functions that can cause caustic skin injury. This number continues to climb and as the industry synthesizes new formulations with novel properties. Chemical burns are a common household as well as work related injury and can vary between minor and life altering. Astronaut crew members are required to perform countless tasks while in flight from maintenance, to engineering, to scientific research and thus are also exposed chemicals that may have a number of cutaneous and systemic effects. Both acidic and alkaline chemicals can cause significant injury and threaten crew function, require medical evacuation, or even result in LOCL. Risk of chemical skin burn among crew members is dependent on engineering and crew functions during flight and may vary widely depending on the generation or stage of the mission.

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

Spaceflight literature is limited. There are several instances of thermal burns in flight but no reported instances of chemical burns on review of available literature

ANALOG LITERATURE

No analog literature used to determine incidence of condition. Barillo et al, 2004 was a retrospective study at Booke Army Medical Center over 50 years and was combination of multiple retrospective chart reviews of chemical burns among service members. Both weaponized chemical exposure and accidental chemical exposure resulted in burns. This study provides incidence of chemical burns as a fraction of all burn related injuries but does not provide total visits and incidence cannot be calculated among all comers. A large majority of these injuries were from white phosphorous burns during the Vietnam war and less applicable to an astronaut population. This literature was not used in incidence calculations

TERRESTRIAL LITERATURE

Koh, DH et al. 2017 is a retrospective review of chemical burns in South Korea and incidence of chemical burns per 10,000 person years over a 4 year time frame. This South Korean National Health Insurance Service Sample Cohort is a dataset of 1 million people specifically designed to represent the population of South Korea. This study provides location of burns and specifically designates which involve primarily skin which is important to limiting cross over with the condition "Burn - Chemical Eye". Incidence reported combining both NHI and Workmen's Comp data is 1.09/10,000 patient years. There are several other studies including Hall et al 2018, Eldad et al 1998, Herbert et al 1989 are all terrestrial studies that give prevalence of chemical burns as a percentage of all burn visits rather than true incidence. These studies were not included due to inability to calculate overall incidence.

OVERALL INCIDENCE SUMMARY

INCIDENCE

Mean=1.09E-4; SD= 5.587E-6

INCIDENCE SUMMARY

Incidence for chemical burn is based on terrestrial data of chemical burns among all comers. There is no spaceflight data available and military data

is limited and primarily focused on chemical weapon injuries. The incidence of chemical burn is going to be entirely dependent on the chemicals used on the DRM and may vary widely from the proposed incidence here. The Bayesian posterior distribution for the incidence rate given the evidence data (Koh 2017) under an uninformative prior is Gamma(shape=380.62, rate=3491959) with mean 1.09E-4 and SD 5.587E-6. The full incidence is defined in terms of the sum of the rates from the national health insurance and workmen's comp as they represent two distinct contributions to total events of chemical skin burns (work-related and otherwise).

TABLE 1. INCIDENCE MODEL

Incidence Details

Incidence Type
General

Segment
All

Env. Exposure
NA

Sex
Any

Crowns
Any

Contacts
Any

Pregnancy
Any

Incidence Distribution

Occurrence Dist
Poisson

Incidence Dist.
Gamma

Mean
0.000108999

SD
5.58697E-06

Gamma
(Shape): 380.62
(Rate): 3.49196E+06

TABLE 2. INCIDENCE LEVEL OF CONFIDENCE (LOC)

Citation	Source	LOC Value
Barillo, DJ et al. 2004	Military analog	1
Koh, DH et al. 2017	Terrestrial	3
Hall, AH et al. 2018	Terrestrial	1
Eldad, A et al. 1998	Terrestrial	1
Herbert, K et al 1989	Terrestrial	1

Military analog literature included Barillo, DJ et al. 2004, a review of 50 years of chemical burns but did not provide total visits thus incidence could not be calculated and received a LOE of 1. Hall et al., Eldad et al., and Herbert et al. were all terrestrial studies that included chemical burns as a proportion of all burns but did not give total patient visits thus incidence could not be calculated and these studies received a 1. Koh, DH et al. 2017 was a large cohort study of >1 million people that provided incidence of chemical skin burns of the South Korean population per 10,000 person years. Given the size of the study, inclusion of both home and work related burns, and exclusion of chemical eye burns this study recieved an LOE value of 3.

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

There are no screening or preventative measures for chemical skin burns as they are environmental exposure related and independent of crew health and history

BEST CASE SCENARIO DEFINITION

Chemical exposure to the skin requiring irrigation that causes superficial damage, OR partial thickness damage involving less than 5% TBSA that meets all of the following criteria: i) non-circumferential, ii) does not cross a major joint line, iii) is not at risk for permanent impairment of body part function (e.g. extensive burns to hands, face, perinium, genitals).

WORSE CASE SCENARIO DEFINITION

Chemical exposure to the skin requiring irrigation that causes partial thickness burns involving greater than 20% TBSA, full thickness burns involving greater than 5% TBSA, or burns that meet any of the following criteria: i) circumferential, ii) crosses a major joint line, iii) threatens to impair body part function.

CONDITIONS INCLUDED, BUT NOT EXPLICITLY STATED (CNES)

None

BEST CASE/WORST CASE PROBABILITY COMMENTS

Herbert et al. 1989 looked at burn admissions and noted 34% of skin burn admissions were admitted <24h, 42% <1week, 15% 1-2week, and 9%>2weeks. It is reasonable to assume that for our definition of BC scenario these patients have small chemical burns that are not involving important structures and thus need minimal treatment. This would be clinically consistent with a <24h stay. Koh, DH et al. 2017 parsed their data into severity categories of first degree, second degree, second-third degree, and 3rd degree however approximately 25% of the charts reviewed did not specify depth. Of these, only 4.1% were first degree while 63.8% were second degree, 31.1% were second-third degree or third degree. Our WC definition does include partial thickness burn if >20% TBSA but also any chemical burn that threaten to impair body part function thus I would include all burns greater than first degree as WC scenario which is 95.9%. This is a significant overestimate as all studies on chemical burns are limited to those that seek care and in reality the most common burn would be an extremely small, superficial burn that a patient would treat at home. However, this subset of patients (even though they likely represent the majority of chemical burns) is difficult if not impossible to capture and is not represented in the literature available. Our BC probability range was 4.1% - 34% and our WC probability range was 66%-95.9%

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

Citation	Source	LOC Value
Herbert K, et al. 1989	Terrestrial	2
Koh, DH et al. 2017	Terrestrial	3

Herbert, K et al. 1989 was a 7 year retrospective study providing a chart review of all patients admitted to the Birmingham Accident Hospital. Separates patients into to type of burn by agent and provides LOS however does not provide information on burn severity. We assume that our definition of BC scenario in this condition would require a <24 hour stay in a burn unit, thus the <24h stay cohor was used to represent this scenario. Ths study size in this paper is small but does provide data relevant to our question, recieved an LOE of 2. Koh, DH et al. 2017 was a very large study of all chemical burn admissions over 4 years among a population of 1 million. It also provided mortality, incidence, and location of chemical burn which gave a more accurate representation of our scenario. Given study size and study groups used this paper recieved an LOE 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)	Mean=1.09E-4; SD= 5.587E-6	4.1 - 34	100	1.4	12.6761	48	1512	3.85331	0	0	0	0.6
Treated Worst Case (TWC)		66 - 95.9	100	1.5	55.0093	504	8760	10.0186	100	100	9.5	32.1
Untreated Best Case (UTBC)	N/A	N/A	N/A	1.4	66.3832	48	8760	66.3832	0	100	0	21
Untreated Worst Case (UTWC)	N/A	N/A	N/A	1.5	100	504	17520	100	100	100	21	32.1

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

For this DRM the engineering systems are still in the development stages and thus the list of potentially hazardous chemicals is also unknown. It is possible, though unlikely, that the crew may not have any chemicals on board and thus have no risk of cutaneous skin injury. However, it is also possible that chemicals used may have rapid skin absorption and systemic toxicity in conjunction with a local burn wound. The International Space Station (ISS) for example uses the Active Thermal Control System (ATCS) which uses ammonia coolant that is potentially hazardous to crew members and has leaked on several occasions but not caused any clear crew harm (Cowan, DT et al. 2019). As such, the risk of disability or loss of crew life will vary significantly depending on the systems involved and medical care teams must be prepared broadly for these type of injuries. Initial management of essentially all chemical burns is rapid decontamination and copious irrigation which may be difficult within the confines of spaceflight and microgravity. For severe burns, tissue excision and skin grafting is vital to reducing risk of complications such as insensible fluid loss and sepsis and will be unavailable in flight requiring RTDC to a very high level of care, likely terrestrial. The RTDC surrogate in this condition includes the criteria for medical evacuation/transfer to a specified burn center for thermal burns as guidelines recommend that all chemical burns be transported which is likely overly conservative for our crewmembers in flight. Instead we have used the equivalent burn severity (depth and size) of a thermal burn as the surrogate

TREATED BEST CASE (TBC) SCENARIO COMMENTS

The definition of BC includes chemical burns causing superficial burns or partial thickness burns that are <5% TBSA and not causing risk for impairment. This definition roughly follows the guidelines provided by the Wilderness Medical Society, the American Burn Association, and the American College of Surgeons for burns not requiring medical evacuation/transfer to a burn center (Kagan, RJ et al. 2013, Rotondo MF et al. 2014, and Quinn et al. 2014) . Technically all three of these governing bodies recommend medical evacuation/transfer of any chemical burns however it is the opinion of the reviewer that this is overly conservative management for our designed reference mission (DRM). Many small and superficial chemical burns can be effectively managed in spaceflight and would not require RTDC thus the criteria for medical evacuation/transport of a thermal burn of the same characteristics was used. Because the BC definition is based on the criteria for medical evacuation/transfer of thermal burns, all BC scenario burns do not require RTDC and thus have a rate of 0%. With regards to LOCL, Mahaluxmivala et al. 1997 provided a mortality rate of 0% for small burns and Jafary, Z et al. 2021 provided a rate of 0.6% which were the upper and lower bounds of our data set. No studies that evaluated mortality rate of superficial chemical burns was available thus terrestrial data from all burn types was used.

TREATED WORST CASE SCENARIO (TWC) COMMENTS

The treated WC definition includes partial thickness burns >20%, full thickness burns >5% and any burn involving a part part that impacts crew function. TWC duration was based on Kagan, RJ et al. 2013 which was a review of ABA recommendations for treatment. This study notes that time to recovery for a partial thickness burn is 3 weeks of standard care which was the minimum duration value used. This same study notes that severely burned patients may require 1 year of inpatient and outpatient treatment to achieve adequate scarring and regaining maximum post burn capacity and is typical for the severely burned patient. This same groups notes that patients with severe burns may require up to 2 years in very rare instances so the more typical value of 1 year was used as the maximum while 2 years was used in the untreated burn as this is likely to take much longer to improve. The definitions for BC and WC scenarios are based on Wilderness Medical Society, American Burn Association, and American College of Surgeons guidelines/recommendations for medical evacuation or transport to a burn center in thermal burns which was the surrogate for RTDC in this condition. Therefore WC conditions have a RTDC of 100% by definition. With regards to LOCL, Mahaluxmivala et al., 1997 noted that superficial burns may have a mortality of 0% which was used as minimum LOCL given our definition as stated above. A maximum of 32.1% LOCL was based on Song, DH et al. 2005.

UNTREATED BEST CASE (UTBC) SCENARIO COMMENTS

There is no literature available that describes untreated chemical cutaneous burns. The definition of our BC scenario includes superficial burns, partial thickness <5% TBSA, and excludes burns that may permanently impact bodily function. assumptions with the UTBC scenario are that a very small and minor superficial burn is likely to have the same recovery as the treated burn and therfore the minimum RTDC, duration, and LOCL is the same as the TBC. However, we also assume that an untreated partial thickness burn <5% TBSA is likely to progress to a larger full thickness burn wound given the natural progression of burns as well as the ongoing caustic injury of a chemical exposure in a patient who does not recieve decontamination. Sykes, RA et al. 1986 was the cohort that most closely represents this scenario as it includes patients inadequately decontaminated and irrigated within their dataset. This group had a mortality of 21% but includes partial thickness burns >5% and full thickness burns which likely overestimates mortality

UNTREATED WORST CASE (UTWC) SCENARIO COMMENTS

The WC scenario definition includes chemical burns with partial thickness burns >20%TBSA, full thickness burns>5% TBSA or burns that threaten to impair bodily functions. The untreated WC scenario of a chemical skin burn would have a minimum duration the same as that of the treated worst case scenario, an agreed 3weeks based on guideline and expert opinion in Kagan, RJ et al. 2013. In reality, some chemical substances have the potential of resulting in rapid systemic toxicity and death however those sequela are captured by other conditions (ie cardiac arrest, etc...). The maximum duration would include a moderately severe deep partial thickness burn that does not lead to patient death but instead causes a large

chronic wound that has the potential to be complicated by recurrent infection etc... and without treatment would be a persistent issue. RTDC was set at 100% for the min and max as the definition for WC scenario were based on the RTDC surrogate. LOCL was determined to be a minimum of 21% and a maximum of 32.1% based on several setudies of severe chemical burns that had similar mortality rates. All patients studied with severe chemical burns were treated at burn centers with standard of care and thus likely LOCL is an significant understimate.

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

Citation	Source	LOC Value
Kagan, RJ et al. 2013	Terrestrial	2
Herbert, K et al. 1989	Terrestrial	
Ohtani, M et al. 2007	Terrestrial	

Kagan, RJ et al. 2013 is the American Burn Association 'White papers' which are a combination of practice review and guidelines. This committee provides general timeframes of recovery based on burn depth which were used to as duration but does not provide specific data. These values are based on expert opinion but may be innacurrate as they do not provide primary data. Herbert, K et al. 1989 was reviewed but does not provide minimum or maximum LOS and instead breaks their study population into LOS cohorts with a minimum LOS <24 hours and maximum >2weeks, and does not provide outpatient care time. Ohtani, M et al. 2007 was used in UTWC duration. This case report of a patient with rapid cardiac arrest after hydrofluoric acid burn represents the absolute minimum duration of illness in a worst case scenario. Many chemical exposures can causes severe systemic effects outside of skin burn and lead to rapid LOCL. A single case report has low level of evidence but no other representations of severe full body or systemic toxicity of skin burns were identified. This lack of concrete data makes our LOE value 2.

TABLE 6. RTDC LEVEL OF CONFIDENCE (LOC)

Citation	Source	LOC Value
Rotondo, MF et al. 2014	Terrestrial	3
Kagan, RJ et al. 2013	Terrestrial	
Quinn, et al. 2014	Terrestrial	

Rotondo, MF et al. 2014 is the American College of Surgeons Comittee on Trauma recommendations of the management of the injured patient which includes recommendations on the management and tranfer of burn related injuries. Kagan, RJ et al. 2013 is the American Burn Association guidelines/comprehensive review of burn treatment. Quinn, RH et al. 2014 is the Wilderness Medical Society practice guidelines for wound care in the austere environment and includes managemen of burns. Our RTDC surrogate is to use guideline recommendations for the transfer or medical evacuation of thermal burns. These recurring guideline documents have slightly different criteria but nonetheless set the standard of care for burn management and thus recieved an LOE of 3. We adapted our definitions based on thermal burn criteria rather than chemical burn criteria which slightly changes this condition and limits this literature from recieving a LOE 4.

TABLE 7. LOCL LEVEL OF CONFIDENCE (LOC)

Citation	Source	LOC Value
Mahaluxmivala, S et al. 1997	Terrestrial	2
Jafaryparvar, Z et al. 2021	Terrestrial	
Sykes, RA et al. 1986	Terrestrial	
Song, DH et al. 2005	Terrestrial	
Barillo, DJ et al. 2004	Military Analog	

Mahaluxmivala, S et al. 1997, and Jafaryparvar, Z et al. 2021 were used for the TBC LOCL as they provided the minimum and maximum mortality rates for what were determined to be minor burns most consistent with our BC definition. Both evaluated mortality from minor burns treated at burn centers and provided consistent mortality rates with other studies evaluated. However, these studies were underpowered and included all burn types which limits their application to our crewmember population. Barillo, DJ et al. 2004 was based on 50 years of military data on chemical burns and thus more closely represents the demographics of the astronaut corps. however it includes a substantial number of war time injuries, primarily from white phosphorous in the Vietnam war, which is likely an overestimate of mortality in our crew members who are more closely represented by industrial workers. Song, DH et al. 2005 was a very large study of all burn types over 6 years and reported mortality rate of burns by %TBSA which was more representative of our WC and BC definitions. It didn't report depth and only 8% of all admissions were from chemical burns which may be

less accurate. Sykes, RA et al. 1986 was a small cohort study of chemical burns and included patients who recieved adequate initial treatment as well as a cohort that did not recieved adequate initial treatment and thus was representative of the untreated scenario. The study was underpowered and the inadequately treated cohort did get standard of care after admission which may underestimate LOCL. Due to these limitations on the power and representation of our study groups this LOE value is 2.

CAPABILITY RESOURCE TABLE (CRT) OVERVIEW

Capabilities and Resourcing Scope Overview The Best case of this condition deals with a chemical burn that can be managed in an outpatient setting. Damage is limited to superficial skin or a small area less than 5% TBSA of partial thickness damage. It specifically excludes all criteria for which a terrestrial patient might require burn center care. The worst case covers larger partial thickness surface areas, full. thickness burns and those affecting sensitive body parts for which specialized care may be required. Resources were assigned assuming a maximum TBSA of 30%. This is based on literature describing a dramatic increase in mortality even with maximal care for patients sustaining larger burns in the age range expected for the astronauts. The CRT working group agreed that within the constraints of the spaceflight environment and mission parameters larger burns would be unlikely and the necessary treatment would be an exceptional case requiring real time decisions beyond the scope of this effort. Infection management is not part of this CLIFF since it is covered in other conditions. CNES: None Diagnostic Scope and Resourcing Diagnosis was scoped to include removal of toxic agents by either brushing, irrigation or both to expose the extent of the wound, taking a history, and performing a physical exam. This was deemed sufficient to enable triage assessment, treatment decisions, and prognostic assessments for both the best and worst case definitions. 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): 1.4 hours including a history, removal of toxic elements (irrigations and dry brushing), and physical exam CP1 WC (Treated or Untreated): 1.5 hours including a history, removal of toxic elements (irrigations and dry brushing), and physical exam The best case of this condition requires a scope of practice code of 4 commensurate with a skilled first year resident (intern) owing to the challenges of medical decision making and exam interpretation. The worst case requires the procedure knowledge to sedate a patient and perform an escharotomy. This is expected to require a scope of practice 5 commensurate with an experienced procedure trained generalist physician. Treatment Scope and Resourcing Specific chemical antidotes were excluded since the exact chemicals on a specific mission are not known and will require mission specific considerations. The treatment described here includes general chemical burn care therapies only. Treatment for the best case scenario includes wound care with dressings, bandages and topical antibiotics such as silver sulfadiazine. It also includes resources for mild pain management with moisturizing creams, and neuropathic pain agents commensurate with terrestrial guidelines. The worst case treatment adds capabilities for, IV hydration, local anesthetic, fasciotomy/escharotomy, IV and oral narcotics, monitoring for blood counts and electrolytes, and monitoring for vital signs. Communications and Support Needs Ground communication is not needed for the best case beyond routine medical downlinks. In the worst case ground communication with both audio and video downlinks was deemed essential for procedural guidance and given the severity of the worst case definition. REFERENCES Taylor S, Jeng J, Saffle JR, et al. Redefining the outcomes to resources ratio for burn patient triage in a mass casualty. J Burn Care Res 2014; 35:41. DOI: 10.1097/BCR.0000000000000034. American College of Surgeons Committee on Trauma. Advanced Trauma Life Support (ATLS) Student Course Manual, 9th ed, American College of Surgeons, Chicago 2012 American Burn Association: Burn center referral criteria. http://ameriburn.org/BurnCenterReferralCriteria.pdf (Accessed on July 02, 2012). Mlcak R, M Buffalo, C Jimenez. Pre-hospital management, transportation and emergency care. In: Total Burn Care, 4th ed, Herndon DN (Ed), 2012. Jeschke MG, Williams FN, Gauglitz GG, Herndon DN. Burns. In: Sabiston Textbook of Surgery, Townsend M, Beauchamp RD, Evers MB, Kenneth ML (Eds), Elsevier, Philadelphia 2012. Vol 19, p.521. Osler T, Glance LG, Hosmer DW. Simplified estimates of the probability of death after burn injuries: extending and updating the baux score. J Trauma. 2010;68(3):690 Eldad A, Weinberg A, Breiterman S, et al. Early nonsurgical removal of chemically injured tissue enhances wound healing in partial thickness burns. Burns 1998; 24:166. American Burn Association (ABA): Guidelines on the management of acute pain in the adult burn patient – A review of the literature, a compilation of expert opinion and next steps (2020) ABA: Guideline for burn care under austere conditions – Special care topics (2017) Wilderness Medical Society (WMS): Practice guidelines for basic wound management in the austere environment, update (2014) ISBI: Practice guidelines for burn care (2016) World Health Organization (WHO): A plan for burn prevention and care (2008)

IMM CLIFF RECONCILATION COMMENTS

This CRT is a new condition from the IMM condition list. The IMM list included "burns secondary to fire" and "eye chemical burns" which have been carried into the CRT condition list as well. Thus, "Burns - Chemical Skin" is not a edit or variation of a prior condition either. However, the BC RTDC and WC RTDC are built on the same criteria as thermal burn criteria for evacuation or hospitalization. In the IMM "Burns secondary to fire" condition BC RTDC is 0% as the definition itself excludes burns that meet clinical criteria for evacuation/transfer or hospitalization and the WC RTDC is 100% as the definition includes burns that meet criteria for evacuation/transfer or hospitalization. The remainder of the IMM "burns secondary to fire" is not applicable with regards to this CRT as it specifically discusses thermal burns, scalds, inhalational injuries, etc.

LIMITATIONS SUMMARY

- The BC definition includes partial thickness burn <5% TBSA and the WC scenario include partial thickness >20% TBSA which leaves a cohort of patients that are not covered in either group of medium severity - Surrogate BC and WC scenario for RTDC reference ABA burn criteria for referral however in the ABA criteria all chemical burns should be referred to a burn center which is not feasible for our mission parameters as small chemical burns without sensitive tissue involvement will likely be treated primarily without evacuation - BC and WC have a large range as studies evaluated do not break down burn type the same way our definitions for BC and WC do. For example, many will break down partial thickness burns into superficial and deep. There are also different cutoffs for minor burn based on TBSA% with some using 5% while many will use 10%. Likely WC scenario is a slightly overestimated range - Durations are often dependent on burns in general and are not specific to chemical burns. Chemical burns often involve deep tissue and the duration of condition may be an underestimate but dependent on the chemical involved and location of injury. - Literature on chemical burns in general is sparse as it only consists of ~10% of all burns. Thermal burns were used in many instances to determine incidence, RTDC, duration, and LOCL which may not represent these values accurately - As with many conditions, literature on untreated conditions does not exist for ethical reasons and thus duration, RTDC, and LOCL are likely to significantly underestimate actual values. (Cowan 2019)

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)		664					145					
Untreated Best Case (UTBC)	223	664		89			145					
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)									809	3763	0.214988	21.4988
Untreated Best Case (UTBC)	132	564	414	22			34	211	2498	3763	0.663832	66.3832
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)							145					
Untreated Best Case (UTBC)	223	664		89			145					
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)									145	3763	0.0385331	3.85331
Untreated Best Case (UTBC)	132	564	414	22			34	211	2498	3763	0.663832	66.3832
Treated Worst Case (TWC)	132						34	211	377	3763	0.100186	10.0186
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