Eye Chemical Burn Cliff

Branch Baseline

According to Barratt (Barratt, 2008) (p. 111 – 112), ocular injuries during spaceflight are common, and potentially quite serious. The microgravity environment increases the risk of eye injury because free-floating particulate debris, which can include droplets or flakes of chemical substances, do not settle out of the air as they would on the ground. Although ground data from submarines and the emergency department are reviewed here for comparison, they do not accurately reflect the true nature of the microgravity environment. Further, changing procedures and process on the ground during spacecraft preparation, and during hatch opening on orbit may alter the future incidence in either direction. Other scientific and vehicle maintenance procedures may also impact the incidence.

Burns to the sclera, conjunctiva, cornea, and eyelid are considered ocular burns. Ocular burn injuries are classified by etiologic agents as chemical injuries, i.e. acid, or alkali. Chemical burns, particularly those involving the cornea, are considered a true ophthalmologic emergency.

Chemical and thermal burns can cause devastating injuries to the anterior segment. The consequences of alkali injuries are notoriously severe due to the rapid penetration of these agents into the ocular tissues. Denaturation of tissue, inflammation, and scarring leads to loss of function. An understanding of the pathogenesis of tissue damage has lead to a rational approach to treatment. Emergency irrigation of the eye is essential and there is a 'window of opportunity' during the first 7–10 days after injury when medical treatment can significantly limit the potentially blinding consequences. (Tuft, 2009)</p

Incidence Data Included in the Model

The model imports the following incidence information from the IMM database: incidence data category, space adaption status, incidence data, 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. fixed data). Space adaptation identifies medical events that onset occurs in the first 5 days of flight and does not reoccur. Incidence values vary by data category and define the number of medical events per person-year or medical events per person-at-risk for each medical condition. Incidence values can be modified by crew characteristics such as gender. 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 crew member 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 IMM Technical Description Document.

Incidence	
Data Category:	In-flight
Space Adaptation:	No
Incidence Type:	Rate

Distribution Data	
Incidence:	Gamma
Occurrence:	Poisson

Data Characteristics	
Events:	4
Person Years:	45.49
Space Flight Incidence Rate (Events / Person Years):	4 / 45.49 = 0.087931413497472

Incidence Comments

Six cases have occurred in flight. (Walton, 2010)

Causative agents identified are: carboxyl ester hydrolase, lithium hydroxide, detergent, buffer solution, and anti-fog soap. Two cases occurred during extravehicular activities EVAs.

Defogging solution used for the EMU visor has been reported to occasionally flake off of the inside of the visor and cause a minor eye chemical burn during EVA. This has been analogous to the best-case scenario described in this CliFF. The incidence or severity may change with changes in the composition of the defog solution or with changes in procedures.

The incidence data was updated to integrate the Real World System observed events (STS 8 events added) including the person years (added 18.17 person years) from our validation data set. This data set included the remaining Shuttle missions and ISS Expedition 31/32 through Expedition 39/40 (Saile, 2017).

Updated the Person-Years based on the revised real world system integrated incidence data. The integrated person years changed from 18.17 to 18.13 so the conditions person years changed from 45.53 to 45.49(Saile L., 2017)

4/6/2020 - Review of LSAH data (both dumps) shows that there were 14 total events of Eye Chemical Burns. 10 of those specifically were due to the EVA helmet/visor surfactant issue. The surfactant was discontinued prior to ISS missions and is no longer an issue, so those events should be excluded from consideration. Therefore:

* New incidence = 4 events per 45.49 person years = 0.08793141

* (Decreased from 0.30775995)

Information Regarding Prevention

Selection criteria

Disqualifying medical conditions in the eye category include: disease of either eye or supporting structure that may interfere with the performance of duties; impaired normal eyelid function; and inflammation of the uveal tract (iris, ciliary body, and choroid) acute, chronic or recurrent. Conditions requiring special consideration by MSMB include: conjunctivitis, keratitis, chronic or recurrent; history of corneal ulcer or erosion other retinal vascular disturbances or conditions that potentially impair vision. (International Space Station Program, 2009)

An eye chemical burn is not in itself a disqualifying condition. The sequalae that may occur from an eye chemical burn would create a condition that would be given another name, e.g. keratitis, cataract, glaucoma, other, which would then be potentially disqualifying. Please refer to other eye-related CliFFs for further details

Contingency measures

Unilateral and bilateral irrigation systems are provided in the Shuttle and International Space Station. (Manuel, 2008)

Other

Crews are advised to wear protective goggles during transfer operations to protect from metal shavings, loose debris, and dust. Ophthalmic ointments and antibiotics are available on board. .(Marshburn, 2008)

Incidence Level of Evidence (LOE)

The IMM level of evidence appropriate assessment of the quality of the IMM input data. Since IMM incorporates input data from a wide variety of sources including astronaut population, terrestrial or analog populations, and external models, an innovative approach to assess the quality of input data was required. Information obtained from the astronaut population and/or space flight is the more relevant so it is assigned the highest level of evidence and less relevant data sources are assigned a lower level of evidence.

Citation	LOE Value	LOE Category
Walton, 2010	1	Incidence
Saile L., 2017	1	Incidence

Alternative Incidence Data

Analog populations

An analysis of 10 years of data collected on Polaris submarine patrols over the ten year period 1963-1973 reported a total of 1685 medical events treated. Illness rates are indicated as new/cases/1000 man-days. There were a total of 48 eye events. 23 eye cases during the 1963-67 period with an illness rate of 0.007; 77 sick days, and 1 EVAC; 25 cases during the 1968-73 period, with an illness rate of 0.006; 44 sick days and, 2 EVACS. . There were 4 incidents of chemical conjunctivitis from a total of 48 diseases of the eyes (Table A9). (Tansey, 1979)

Eye events (n 48) accounted for 2.85% of the total medical events. Averaging the two period rates, we calculated an incidence of 0.0065 per 1000 man-days (0.0065*365 = 2.3725 / 1000 person years) or 0.0023725 person-years. Chemical conjunctivitis, (4/48) accounted for 8.33% of total eye events, or a rate of 0.00019762925. No information on which conditions required EVAC.

Thomas (Thomas, 2003) reported on health of US Navy submarine crews during periods of isolation. ICD-9 codes 360-379 (Eye and adnexa) occurred in 6 officers and 54 enlisted men. Total rate was 1.0 per 100 person years. Eye conditions included keratitis, disorders of the conjunctiva and inflammation of eyelids among officers. There is no similar information for enlisted men. Effect of illness was minimal 0.75 (officers) to 1 day (enlisted men). Only 4.2 officers and 7% of enlisted man had greater than 2 days illnesses. Some eye injury codes may have been included under the injury category, such as 870 laceration, open wound of eye and adnexa, or 918 eye abrasion but it is not possible to segregate this information further. Thomas concluded that officers are most analogous to current space program participants. Majority of medical events reported were minor, non life-threatening, with little or no impact on unit mission.

NICE (Nice, 1987) reported the major diagnostic categories associated with medical communications, 5% were nervous and sense organs which include the eyes. Eye conditions were not among the leading diagnostic categories for MEDEVACs.

Another report by Thomas, detailed 4.2% of procedures recorded during submarine patrols from January 1997 through December 1998 were Fluorescein staining of the eye. (Thomas, 2000)

During Operation Telic, conflict period March 27 and May 1st 2003, 45 eye casualties presenting to a British Army Field Hospital accounted for 2% of all attendance (n 2292). Most common were eye injuries 58.7%, and conjunctivitis was the most frequent non traumatic presentation. A total of 6 casualties required transfer to a UK facility (15.55%) 3 petrochemical injuries, 2 corneal abscesses, 1 corneal abrasion and 1 iritis. There is no report of the total population at risk or mission time to calculate incidence rates. (Aslam, 2005)

Non Analog populations

The rate of emergency department–treated eye injury in the United States is 3.15 per 1000 population (95% confidence interval, 2.66-3.63). Rates were highest among those in their 20s and 30s, among males, and The most common injury to the eye was a contusion or abrasion (44.4%), followed by foreign bodies (30.8%), burns (10.2%), and conjunctivitis (9.9%) (Figure 3). These rates include only eyeball injuries and exclude adnexa. (McGwin, 2005). We calculated 10.2% of 0.00315 to be 0.0003213 for burns. This may be an over estimation because there is no segregation by type of burns.

Treatment and Outcomes

Based on the best evidence available best and worst case percentage ranges are assigned. The medical condition is divided into three clinical phases in all three clinical phases a functional impairment is assigned. The clinical phase I and II's functional impairments remain for the duration for that respective clinical phase. The function impairment in clinical phase III represents final impairment for this medical condition and remains for the rest of the mission. Other mission end states include evacuation and loss of crew life.

The IMM checks medical resource availability once the number of medical events and scenarios has been established. If there is not sufficient essential resources called out in the CliFF, then the medical condition will go down an untreated best or worst case scenario pathway.

The table below summarizes the treated and untreated best and worst case scenarios.

	Clinical Phase I Diagnosis & Initial Treatment[1]		**Clinical Phase II On-going Treatment / Convalescence**[2]		**Clinical Phase III Recovered / Mission End State**[3]		
	FI* (%)	**Duration (hrs)**	**FI* (%)**	**Duration (hrs) (Min - ML - Max)**	**FI* (%)**	**EVAC** (%)**	**LOCL** (%)**
ISS-based Treatment (best case scenario %: 80 - 100)	100	0.3	8 - 47	0 - 12 - 24	0	0	0
ISS-based Treatment (worst case scenario %: 0 - 20)	100	0.5	28 - 72	24 - 96 - 168	0 - 72	0 - 1	0
Untreated Best Case	0	0	28 - 72	0 - 12 - 24	0 - 47	0 - 100	0
Untreated Worst Case	0	0	61 - 85	24 - 96 - 168	61 - 85	100	0

[1]Clinical Phase I: Clinical phase I covers only the initial assessment of the affected crew member to define his or her medical condition, and completion of appropriate initial treatment to stabilize the crew member. While the affected crew member is being assessed, he or she is not able to perform any assigned tasks, thus Functional Impairment during this phase is considered 100%. In the untreated case, there is no diagnosis performed or treatment given, therefore Functional Impairment and Duration will always be "not applicable".

[2]Clinical Phase II: On-going Treatment and Convalescence- During clinical phase II, the affected crew member is receiving any appropriate follow-on treatment for his or her medical condition to allow the crew member to recover as much as he or she is able to recover in the ISS environment. Clinical phase II also encompasses relapses or reoccurrences of the same original medical condition in clinical phase I necessitating additional treatment or recovery time due to unsuccessful primary treatment response. The duration in Clinical Phase II is expressed in minimum, most likely (ML) and maximum hours. This was updated for future capabilities in IMM but is currently not being used by the model.

[3]Clinical Phase III: Recovered/Mission End State- Clinical phase III is reached once the affected crew member has recovered from the medical condition as much as he or she is able to recover in the ISS environment. This may or may not be recovery from the given medical condition to the full extent possible. If this "recovered" state results in an evacuation or loss of the crew member, this will be noted in the mission end state results.

*Functional Impairment (FI) is a measure of the affected crew member’s health and performance ability.

**Two mission end state results are addressed in the CliFF: 1) Evacuation (EVAC) - crew and patient are evacuated from the spacecraft due to the medical condition, and 2) Loss of crew (LOCL) - death of affected crew member due to medical condition. EVAC is considered as an end state result if any of the following criteria are met: 1) potential LOCL, 2) potential significant permanent impairment, or 3) potential intractable pain. Probability distributions are assigned for each range of values within the Table of Treatments and Outcomes.

Refer to the Integrated Medical Model Technical Document for more information on how risk is reported by the IMM, Crew Health Index (CHI) and Quality Adjusted Mission Time calculations.

Definition and Probability of Best and Worst Case Scenario: (includes definitions of best and worst case scenarios and identifies the probability of those scenarios.)

Scenario Comments

Best case scenario is a mild eyelid burn or an ocular burn which does not affect vision.

Worst case scenario is defined as a moderate or severe burn that causes corneal scarring or ulceration, or intraocular pressure changes. Treatment for the initial phase may be given on board but this scenario may require surgical debridement, lens implant and other treatments that require surgical care by an ophthalmologist.

Percentages of how often best versus worst case scenarios occur: based on the Real World Systems data there were no worst cases so to integrate this data into the BC/WC percentage the algorithm developed with the original data set was used for all the medical events in both data sets. Therefore, if the next case is a worst case we would 1/15 or 7% of cases as worst cases. If the next case is best case, we would have 15/15 or 100%. Thus the percentage for worst case is 0-7% (Saile L., 2017)

With the removal of 10 best case STS events (April, 2020) that were specifically due to anti fog surfactant in the EVA helmets, best case RWS events are back to 4 total events. Using the algorithm described above, if the next case is worst case we would have 1/5 or 20% for worst case and 5/5 or 100% for best case. Thus the percentage for worst case is 0-20%.

Best Case Comments

Our functional impairments calculation for Eye Chemical Burn follows the IMM severe non-space adaptation template. Impairments of the Visual System and of the Whole Person are based on Table 12-10, p.307. Impairment for the Visual System's class 3 is divided in 3a and 3b. (American Medical Association, 2008) We are arbitrarily using class 3b which provides more severe impairments.

By definition in Clinical Phase I, FI is 100%. Duration to follow procedures specified in ISS checklist, i.e. eye wash and eye exam, for the best case scenario, is estimated in 20 minutes. During Clinical Phase II, FI is estimated in 8 to 47%. Duration is estimated in 0 to 24 hours. In Clinical Phase III, full recovery is expected and FI is 0%. By definition EVAC and LOCL would not be expected for the best case scenario.

Worst Case Comments

Our functional impairments calculation for Eye Chemical Burn follows the IMM severe non-space adaptation template. Impairments of the Visual System and of the Whole Person are based on Table 12-10, p.307. Impairment for the Visual System's class 3 is divided in 3a and 3b. (American Medical Association, 2008) We are arbitrarily using class 3b which provides more severe impairments.

By definition in Clinical Phase I, FI is 100%. Duration to follow procedures specified in ISS checklist, i.e. eye wash and eye exam, and applying topical medications for the worst case scenario, is estimated in 30 minutes, or half hour. During Clinical Phase II, FI is estimated in 28 to 72%. Duration is estimated in 1 to 7 days, 24 to 168 hours. In Clinical Phase III, full recovery is not expected and FI is 0-72%. To allow for uncertainty of crew members not responding to treatment EVAC is estimated in 0-1%. LOCL is not expected for eye injuries.

Untreated Best Case Comments

Our functional impairments calculation for Eye Chemical Burn follows the IMM severe non-space adaptation template. Impairments of the Visual System and of the Whole Person are based on Table 12-10, p.307. Impairment for the Visual System's class 3 is divided in 3a and 3b. (American Medical Association, 2008) We are arbitrarily using class 3b which provides more severe impairments.

During Clinical Phase II, FI is estimated in 28 to 72%. Duration is 0 to 24 hours, similar to the treated best case scenario. In Clinical Phase III, recovery may or may not occur and FI is 0-47%. EVACs have occurred for chemical burns in Operation Telic. Even minor injuries may incapacitate personnel and if untreated cause severe visual loss. (Aslam, 2005) To allow for uncertainty EVAC is estimated in 0 to 100% for the untreated best case. LOCL is not expected for eye injuries.

Untreated Worst Case Comments

Our functional impairments calculation for Eye Chemical Burn follows the IMM severe non-space adaptation template. Impairments of the Visual System and of the Whole Person are based on Table 12-10, p.307. Impairment for the Visual System's class 3 is divided in 3a and 3b. (American Medical Association, 2008) We are arbitrarily using class 3b which provides more severe impairments.

During Clinical Phase II, FI is estimated in 61 to 85%. Duration is 24 to 168 hours, similar to the treated worst case scenario. In Clinical Phase III, recovery is unlikely and FI remains 61-85%. Because of potential significant permanent impairment EVAC is estimated in 100%. LOCL is not expected for eye injuries.

Treatment and Options Level of Evidence (LOE)

The IMM level of evidence appropriate assessment of the quality of the IMM input data. Since IMM incorporates input data from a wide variety of sources including astronaut population, terrestrial or analog populations, and external models, an innovative approach to assess the quality of input data was required. Information obtained from the astronaut population and/or space flight is the more relevant so it is assigned the highest level of evidence and less relevant data sources are assigned a lower level of evidence.

Citation	LOE Value	LOE Category
American Medical Association, 2008	3	FI
Aslam, 2005	2	EVAC
Saile L., 2017	1	BCWC

Additional Comments

PubMed searches were conducted using the terms eye chemical burn AND incidence OR Epidemiology, eye chemical burn AND microgravity, eye chemical burn AND astronauts; eye AND Clinical guidelines. Searches results were refined by date and relevance.

The Resource Table (RT)

Resource	Units Required Best Case	Units Required Worst Case	Units Available At Start Of Mission	Consumable	Essential	Rationale
Cyclopentolate 1% 15mL bottle	0	0.0133	1	Yes	Yes	Pupil dilation
eye wash goggles & tubing	1	1	1	No	Yes	to wash eye
Eyewash waste water bag	1	2	6	Yes	Yes	to collect water after eye wash
Medical tape	0	0.03	5	Yes	No	single-coated tapepressure adhesive tape
Moxifloxacin (Avelox) 0.5%, 3ml bottle	0	0.28	4	Yes	Yes	Antibiotic
Otoscope (Head, Handle, and USB cable)	1	1	1	No	Yes	Light source for eye exam
Proparacaine eye drops 0.5%, 15mL bottle	0.013	0.013	1	No	No	eye anesthetic
Refresh artificial tears (Carboxymethylcellulose) 0.5%, 0.4mL bottle	1	1	40	Yes	Yes	Relief dryness/irritation of the eyes
Space station eye wash	1	1	1	No	Yes	to wash eye
Urine chemstrips	3	4	10	Yes	Yes	To test pH of affected eye, using the unaffected eye (if possible) as the pH control. pH testing done at intervals during course of treatment/irrigation.
Vicodin HP (Hydrocodone/ Acetaminophen HP) 10 mg/660 mg	0	6	30	Yes	Yes	Pain relief
Water	1	1	1	No	No	Eyewash with drink water

Resource Comments

Eye chemical burn is included in the ISS Medical Checklist (Mission Operations Directorate (MOD), 2011). We updated the list to match resources to the checklist; e.g. added water, towel, eyewash waste water bag and eye wash goggles and tubing.

Comparison with terrestrial guidelines

Eye guidelines from the Work Loss Data Institute (ECRI Institute, 2011)are comparable with the ISS medical checklist, except for the use of pH testing after the wash, which is not available on board.

Required Resources Level of Evidence (LOE)

The IMM level of evidence appropriate assessment of the quality of the IMM input data. Since IMM incorporates input data from a wide variety of sources including astronaut population, terrestrial or analog populations, and external models, an innovative approach to assess the quality of input data was required. Information obtained from the astronaut population and/or space flight is the more relevant so it is assigned the highest level of evidence and less relevant data sources are assigned a lower level of evidence.

Citation	LOE Value	LOE Category
NASA Mission Operations Directorate (MOD), 2011	2	Resources

Level Of Evidence

Input Data	LOE Average
Incidence	1
Functional Impairment	3
Best Case / Worst Case	1
EVAC / LOCL	2
Resources	2
QUALITY OF EVIDENCE	**1.8**

Description	Range
Excellent	1-2
Good	2.1-3
Fair	3.1-4
Poor	4.1-5

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