Fingernail Delamination Secondary to Extravehicular Activity Cliff

Branch Baseline

Onycholysis is separation of the nail plate from the nail bed or complete nail plate loss. Depending on the magnitude of the fingernail injury, the erythema may be followed by onycholysis progressing over subsequent 2–3 weeks (Viegas, 2004)

Onycholysis is a loosening of the exposed portion of the nail from the nail bed, usually beginning at the free edge and continuing to the lunula (crescent-shaped whitish area of the bed). Onycholysis can result not only from trauma but also from internal conditions, infection, allergy, or as a drug side effect (Jones (Jones, 2008), 2008)

Subungual hematoma and nail bed trauma: Subungual hematoma occurs when blood becomes trapped between the nail plate and nail bed, usually as a result of trauma. Subungual hematoma causes significant pain and eventual separation of and temporary loss of the nail plate. When the cause is a crush injury, underlying fracture and nail bed damage are common. Nail bed damage may result in permanent nail deformity (Merck Manual, 2009).

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:	Proportion

Distribution Data	
Incidence:	Beta
Occurrence:	Binomial

EVA Data Characteristics	
Events:	31
Persons At Risk:	414
Space Flight Incidence Rate (Events / Persons at Risk):	31 / 414 = 0.0748792270531401

Incidence Comments

Source of the incidence data is a compliation of available in flight medical events (Inflight Compilation Lockdown, 2008)(EVA Review Lockdown: 2011).

Integrated 15 total medical events and 167 persons at risk based on the real world systems incidence data (Saile, 2017)

Information Regarding Prevention

Selection criteria

No astronaut selection criteria specifically relate to nail trauma.

Disqualifying criteria in the General category includes: History of sensitivity or demonstrated allergy of sufficient severity so as to interfere with the mission. In the Skin category adherent scars that interfere with the wearing of personal equipment or that impair movement to the extent that emergency egress would be impeded; infections of the skin, systemic or superficial, if communicable, extensive, or not amenable to treatment; and any skin disorder, acute or chronic, that is severe enough to cause interference with emergency egress, wearing of flight equipment, or successful mission completion.

The medical screening of astronauts should include any history of preexisting injuries and surgery that are likely to be aggravated by Extravehicular Mobility Unit (EMU) Neutral Bouyancy Lab (NBL) training. This can be accomplished at the time of the astronaut's annual physical examination. Then referrals to medical specialists and the Astronaut Strength, Conditioning and Rehabilitation (ASCR) Team can be made. All astronauts in EMU training should be encouraged to seek ASCR evaluation and recommendations for individualized exercise programs to best prepare them for the rigors of NBL EMU training and, ultimately, Extra Vehicular Activity (EVA) (Strauss, 2004).

Flight surgeons document, when possible, evidence of pre-existing conditions and feel that majority of injuries occurred in flight (Scheuring, 2009)

Contingency measure(s)

Nail trauma exam is part of Periodic Health Status (PHS) (International Space Station Integrated Medical Group, 2006)

Effective countermeasures to prevent or mitigate this condition in susceptible crewmembers includes: clipping of fingernails, hands clean and dry, the application of various dressings to fingertips, and the application of a barrier nail hardener (Strauss, 2005). The nail hardener used effectively in training is not available for flight use. An approved topical application for use in flight is Dermabond.

Generally 6 weeks is needed to recover tissue tensile strength and up to 3 months for the nail to fully grow out. Because NBL suited training often continues until close to launch, delamination lesions persist into flight. Rarely secondary infections, bacterial and fungal, have been seen. An identified problem having to do with the design of the current Phase 6 EMU glove concerns the position of a sizing cord that concentrates axial loading to the fingertip. (Viegas, 2004)

Glove assemblies, which attach to each arm assembly, are designed to allow the astronaut to have the best possible dexterity, tactility, and precision. (Strauss, 2004)

During NBL EMU training sessions a significant amount of sweat moisture forms in spacesuit gloves. This occurs in this closed system with little means for evaporation due to the glove design that does not provide for cooling or evaporation from the liquid cooling vent tube garment. The mechanism for this form of traumatic onycholysis (fingernail delamination) is softening of the nail due to prolonged emersion resulting in weakening of nail plate adhesion and separation due to the axial loading that occurs from gripping during normal work in space suit gloves. Studies of astronauts in NBL training have shown that about 14% are susceptible to this injury (Viegas, 2004)

In the following NBL study publication, Jones evaluated the use of a long ventilation tube to determine if improved gas circulation into the hand area could reduce hand moisture and thereby decrease the associated symptoms (Jones, 2008).

Six astronauts were examined pre and post-run. There were consistent trends in the reduction of relative hydration ratios at dorsum and first ring finger joint when the ventilation tube was employed. Ventilation appeared more effective on the left versus the right hand, implying an interaction with hand anthropometry and glove fit. Symptom score was lower on the hand that had the long ventilation tube relative to the control hand in 2/6 EVA crew members. Jones concluded that increased ventilation to the hand was effective in reducing the risks of hand and nail discomfort symptoms from moderate to low in one-third of the subjects. Improved design in the ventilation capability of EVA spacesuits is expected to improve efficiency of air flow distribution. Findings are also limited by three factors: glove fit, anthropometry, and task. The current vent tube design was more effective on the non-dominant hand with the looser fit (Jones, 2008)

Recommendations to prevent injury to the hands include: increase hand strength and endurance using exercise prescription and follow up program; train on proper ergonomic use of hands in EMU gloves, with training provided by astronaut instructors; both are coordinated by the Astronaut Strength, Conditioning, and Rehabilitation (ASCR) Team; train astronaut on achieving the optimal glove fit and adjustments prior to NBL training; train astronaut on achieving optimal elbow convolute suit fit; train astronaut to understand the full range of available countermeasures; and continue to improve countermeasures available.

Two countermeasures were suggested by the NBL investigator: development of Moisture-Wicking Comfort Gloves – Nylon Tricot (in use for training and flight) and a nail protecting/strengthening application Sally Hansen Hard as Nails (in use at the NBL, and substituted with Dermabond in flight). Recommendations regarding glove development include: to keep glove position stable on wrists and hands/fingers; incorporate protective finger caps; improved ventilation of fingers; and improve palm bar position options (Viegas, 2004) (Strauss, 2004).

Ansari proposed that during EVAs or spacewalks astronauts over use their fingertips under pressure inside the confined spaces of gloves/space suit. The repetitive hand motion is a probable cause for discomfort and injuries to the fingertips. A noninvasive blood perfusion measurement in distal fingertips while performing hand-grip exercises is simulating the use of space tools using a new wireless fiber-optic probe. This can be integrated inside the astronaut glove. The preliminary study results suggest that forces on the fingers and hand change the blood flow to the fingertips. Identifying and measuring the pressure possible differences between astronauts and a control group can help to understand onycholysis (Ansari, 2009).

Scheuring studied musculoskeletal injuries and minor trauma during space flight. The in-flight musculoskeletal database also provides the foundation for directing operationally relevant research in space medicine. The human research program and the EVA Physiology Systems and Performance Project at NASA-Johnson Space Center have the responsibility of directing research efforts for intravehicular activity and EVA, respectively. Flight surgeons document, when possible, evidence of pre-existing conditions and feel that majority of injuries occurred in flight. He identified 219 in flight musculoskeletal injuries (198 injuries in male and 21 injuries in female astronauts). Injuries reported are per 24 h (1 d) on orbit. The incidence of in-flight musculoskeletal injuries was found to be to 0.021 injuries per day for male crewmembers and 0.015 injuries per day for female crewmembers. More than 70 are hand injuries. EVA suit resulted in 48 injuries (Scheuring, 2009). We cannot extrapolate onycholysis or other soft tissue injuries incidence from this study and found no comments on fingernail delamination.

Post flight

This condition may persist until the crewmember returns, depending on the severity of injury to the nail(s). However, this condition is typically self-limiting and a new nail is expected to replace the damaged one unless there has been trauma to the nail bed as well. If necessary, the old nail could be removed to assist new nail growth once the crewmember has returned from spaceflight.

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
EVA Review Lockdown: 2011	1	Incidence
Saile, 2017	1	Incidence

Incidence data not included in the model

The model pulls the incidence information from the IMM database ... the information shown below does not go into the model.

Incidence	
Data Category:	Raw Data
Space Adaptation:	No
Incidence Type:	Proportion

Distribution Data	
Incidence:	Beta
Occurrence:	Binomial

EVA Data Characteristics	
Events:	13
Persons At Risk:	86
Space Flight Incidence Rate (Events / Persons at Risk):	13 / 86 = 0.151162790697674

Incidence Comments

A prospective observational study with 86 subjects in the NBL provides a ground analog incidence (Strauss, 2004). In this study there were a total of 770 test events. Of those, 47.16% were symptomatic in their hands (right 25.28, left 21.88). During this study 18 astronauts were followed for hand complaints, and thirteen of these were fingernail delamination.

It appeared that most of these complaints were minor and self- limited in nature. However, it was suspected that some of these represent injuries that could persist and thereby impact astronaut health and possibly mission objectives. Anticipated potential biases included underreporting by study subjects, delay in the onset of complaint symptoms, variations in exposure types and times, variations in astronaut gender, age, conditioning, body type, and experience, and differences in tasks/equipment (HUT/glove designs and tools used). Another bias was due to the correction of problems as they were identified.

These primarily involve fingernail delamination (onycholysis) attributed to axial loading and moisture in comfort gloves. Fingertip pain was attributed to hard contact to the fingertips with extended reaching and forceful grasping. Other assorted complaints included superficial abrasions, contusions, and two peripheral nerve impingements that were attributed to glove fit and unprotected contacts. Some of the astronauts complained of generalized hand fatigue following several hours of repeated and forceful grasping. Average Severity 1.13/5 (Scale of 0 – 5).

Causes (distribution by specific location) of hand complaints, including fingernail delamination are:

· Fingertips / nails contact – 55%

· Other glove contact – 35%

· Fatigue – 8%

Information Regarding Prevention

null

Alternative Incidence Data

Following NBL study publication, Jones evaluated the use of a long ventilation tube to determine if improved gas circulation into the hand area could reduce hand moisture and thereby decrease the associated symptoms (Jones et al. 763-68).

Six astronauts were examined pre and post-run. There were consistent trends in the reduction of relative hydration ratios at dorsum and first ring finger joint when the ventilation tube was employed. Ventilation appeared more effective on the left versus the right hand, implying an interaction with hand anthropometry and glove fit. Symptom score was lower on the hand that had the long ventilation tube relative to the control hand in 2/6 EVA crew members. Jones concluded that increased ventilation to the hand was effective in reducing the risks of hand and nail discomfort symptoms from moderate to low in one-third of the subjects. Improved design in the ventilation capability of EVA spacesuits is expected to improve efficiency of air flow distribution. Findings are also limited by three factors: glove fit, anthropometry, and task. The current vent tube design was more effective on the non-dominant hand with the looser fit.

(Jones et al. 763-68)

Recommendations to prevent injury to the hands include: increase hand strength and endurance using exercise prescription and follow up program; train on proper ergonomic use of hands in EMU gloves, with training provided by astronaut instructors; both are coordinated by the Astronaut Strength, Conditioning, and Rehabilitation (ASCR) Team; train astronaut on achieving the optimal glove fit and adjustments prior to NBL training; train astronaut on achieving optimal elbow convolute suit fit; train astronaut to understand the full range of available countermeasures; and continue to improve countermeasures available.

Ansari proposed that during extra-vehicular activities (EVAs) or spacewalks astronauts over use their fingertips under pressure inside the confined spaces of gloves/space suit. The repetitive hand motion is a probable cause for discomfort and injuries to the fingertips. A noninvasive blood perfusion measurements in distal fingertips while performing hand-grip exercises simulating the use of space tools using a new wireless fiber-optic probe that can be integrated inside the astronaut glove. The preliminary study results suggest that forces on the fingers and hand change the blood flow to the fingertips. Identifying and measuring the pressure possible differences between astronauts and a control group can help to understand onycholysis **(Ansari, 2009).**

Scheuring studied musculoskeletal injuries and minor trauma during space flight. The in-flight musculoskeletal database also provides the foundation for directing operationally relevant research in space medicine. The human research program and the EVA Physiology Systems and Performance Project at NASA-Johnson Space Center have the responsibility of directing research efforts for intravehicular activity and EVA, respectively. Flight surgeons document, when possible, evidence of pre-existing conditions and feel that majority of injuries occurred in flight. 219 in-flight musculoskeletal injuries were identified (198 injuries in male and 21 injuries in female astronauts). Injuries reported are per 24 h (1 d) on orbit. The incidence of in-flight musculoskeletal injuries was found to be to 0.021 injuries per day for male crewmembers and 0.015 injuries per day for female crewmembers. More than 70 are hand injuries. 50 injuries due to EVA suites, and 23 contusions (Scheuring et al. 117-24). We cannot extrapolate onycholysis or other soft tissue injuries incidence from this study and found no comments on fingernail delamination.

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 %: 93.75 - 96.87)	100	0.33	0 - 9	0 - 168 - 336	0	0	0
ISS-based Treatment (worst case scenario %: 3.13 - 6.25)	100	0.33	1 - 27	240 - 288 - 336	0 - 9	0	0
Untreated Best Case	0	0	1 - 27	0 - 168 - 336	0 - 9	0	0
Untreated Worst Case	0	0	11 - 42	240 - 288 - 336	1 - 42	0	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

The **best case definition** is a mild to moderate nail bed trauma with partial onycholysis that responds to treatment. The **worst case definition** is severe nail bed trauma causing onycholysis and/or nail loss despite treatment.

Best vs. worst case percentages

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 2/32 or 6% of cases as worst cases. If the next case is best case, we would have 31/32 or 97%. Thus the worst case percentages are 3%-6% (Saile L., 2017).

Best Case Comments

Functional impairment (FI) grading follows the IMM Mild non space adaptation template and is derived from Skin disorders (American Medical Association, 2008). Description of ratings is included in the CliFF Appendix A.

By definition FI in **Clinical Phase I is 100%** and duration is estimated in 20 minutes. There is no procedure in the ISS Medical Checklist for fingernail Delamination. We are estimating that the duration will be comparable to the skin treatment procedure in the ISS medical checklist, including to unstow the medications and photo document the injury. In **Clinical Phase II** FI is estimated to be 0 to 9%. Duration for nail recovery is 6 weeks to recover tissue tensile strength (Viegas, 2004). We are estimating duration at 0 to 14 days to recover dexterity even if tissue recovery is not complete. In **Clinical Phase III** recovery is expected and FI is estimated at 0%. Based on in-flight occurrences of fingernail delamination EVAC and LOCL are not expected (Walton, 2010).

Worst Case Comments

Functional impairment (FI) grading follows the IMM Mild non space adaptation template and is derived from Skin disorders (American Medical Association, 2008). Description of ratings is included in the CliFF Appendix A.

By definition Functional impairment (FI) in **Clinical Phase I is 100%** and duration is estimated in 20 minutes, similar to the best case scenario. In **Clinical Phase II**, FI is estimated at 1 to 27%. The time for the nail to regrow fully has been estimated to be 6 months (Viegas, 2004). Our duration is estimated at 10 to 14 days based on the time to recover dexterity. In **Clinical Phase III**, FI is estimated to be 0 to 9%. EVAC and LOCL are not expected (Walton, 2010)

Untreated Best Case Comments

Functional impairment (FI) grading follows the IMM Mild non space adaptation template and is derived from Skin disorders (American Medical Association, 2008). Description of ratings is included in the CliFF Appendix A.

In Clinical Phase II FI is estimated at 1 to 27%, similar to the best case scenario but there is no treatment available. Duration is 0 to 336 hours, similar to the treated case scenario. In **Clinical Phase III**, Untreated fingernail delamination may have variable outcome depending on the severity of symptoms and the pain tolerance of the affected crewmember. Although most cases will be expected to resolve over time without specific treatment, it is expected that the signs or symptoms will persist for the duration of the flight. FI is estimated to be 0 to 9. EVAC and LOCL are not expected (Walton, 2010)

Untreated Worst Case Comments

Functional impairment (FI) grading follows the IMM Mild non space adaptation template and is derived from Skin disorders (American Medical Association, 2008). Description of ratings is included in the CliFF Appendix A.

During **Clinical Phase II**, FI is estimated at 11 to 42% when there is no treatment available. Duration is similar to the treated worst case scenario In **Clinical Phase III**, recovery may not occur without treatment, and FI is estimated to be 1 to 42%. EVAC and LOCL are not expected (Walton, 2010)

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
Walton, 2010	1	EVAC
Saile L., 2017	1	BCWC

Additional Comments

We searched PubMed using the terms fingernail Delamination, and onycholysis results. A second search using onycholysis and epidemiology returned no new results. Searches with onycholysis and space medicine, onycholysis and astronauts, and onycholysis and space flight returned no results.

The Resource Table (RT)

Resource	Units Required Best Case	Units Required Worst Case	Units Available At Start Of Mission	Consumable	Essential	Rationale
Bacitracin 500 units/gm. 28 gm tube	0	0.003	1	Yes	Yes	anti infective - topical
Dermabond applicator 0.5mL	0	1	2	Yes	Yes	For fingernail adhesion and protection
Tylenol (Acetaminophen) 325 mg	0	9	250	Yes	Yes	pain relief

Resource Comments

Tylenol for pain control. We added Bacitracin to prevent or treat subungual bacterial infection and Lotrimin to prevent or treat subungual fungal infection.

There is no procedure for fingernail delamination treatment in the ISS medical checklist. However, all resources included in the table are available on board (Mission Operations Directorate (MOD), 2011).

Dermabond may be used to help prevent delamination by application to affected nails pre-EVA. An average of two applicators will be needed for each affected crewmember per EVA. Dermabond applicators and other required dressings will be provided as requested to each crewmember in their ISS Medical Accessory Kit (IMAK) and will not deplete the available ISS resources.

The effective countermeasures for onycholysis (fingernail delamination) and fingertip pain are to provide optimal glove fit, keep the nails short, and use appropriate dressings/topical applications, including Dermabond, Tegaderm, Band-Aids, Moleskin, and tape that protects fingertips/nails and helps to keep them dry (Strauss, 2004).

There is no moleskin onboard ISS but some crewmembers do use this while training in the NBL.

Nail hardener is used during NBL training (EVA Configuration Control Board, 2005). There is no Sally Hansen’s Hard As Nails on the ISS. Toxicological analysis precluded Sally Hansen’s Hard As Nails from gaining approval for spaceflight.

There is one finger splint available on board and its use for fingernail delamination must be weighed against the risk of depleting resources for finger fracture.

Dermabond is no longer part of the ISS Medical Kit but has been approved for in flight So it is important to not that individual crewmembers may carry it upon request

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
Strauss, 2004	2	Resources

Level Of Evidence

Input Data	LOE Average
Incidence	1
Functional Impairment	3
Best Case / Worst Case	1
EVAC / LOCL	1
Resources	2
QUALITY OF EVIDENCE	**1.6**

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

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