Paresthesias Secondary to Extravehicular Activity Cliff

Branch Baseline

Paresthesia is defined as a sensation of pricking, tingling, or creeping on the skin having no objective cause and is usually associated with injury or irritation of a sensory nerve or nerve root (Merriam-Webster's Medical Dictionary, 2011)

Paresthesias occur when sustained pressure has been applied over a nerve inhibiting or stimulating its function. Removing the pressure will typically result in gradual relief of these paresthesias, often described as a "pins and needles" feeling. Persistent paresthesia in the EVA setting is often a symptom of compressive neuropathy of peripheral nerves. The most frequently observed are of the digital, ulnar, median, supra-clavicular, supra-acromial, and peroneal nerves. These usually resolve within 3 to 45 days. (Viegas, 2004) (Strauss, 2004)

Numerous conditions can lead to paresthesias post EVA, including pressure on neurovascular structures, hyperventilation, DCS, and electrolyte imbalances. For this CliFF we are considering paresthesias secondary to EVA suit pressure points.

The diagnosis of paresthesias is typically based on clinical signs and symptoms (numbness, tingling, and pain). Special testing (imaging, EMG/NCS) is rarely required to make the diagnosis. The treatment of paresthesias is usually cessation of the causative activity, change in position of the affected body part, rest, and analgesics.

Hot spots are generally considered pressure points resulting from contacts with internal spacesuit components. These may result from persisting hard contact, intermittent contact or due to rubbing while the affected body part is in motion in relation to the spacesuit component. Compression may be due to suit design ergonomics, suit fit, work movement, or body position. These may be manifested as painful erythematous areas, swelling or contusions with eccymoses. (Strauss, 2004)

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:	53
Persons At Risk:	414
Space Flight Incidence Rate (Events / Persons at Risk):	53 / 414 = 0.128019323671498

Incidence Comments

The incidence data of paresthesias in healthy adults in the United States is difficult to correlate to the in-flight occurrence of EVA-related paresthesias and hot-spots since the etiology of most terrestrial patients with paresthesias is a chronic condition. In flight, most of the paresthesias are caused by EVA related activity which has no correlation to actual terrestrial data.

Incidence has been determined based on in-flight data (Walton, 2010), counting events specifically listed as related to EVA (EVA Review Lockdown: 2011).

It is not possible to determine from the data the level of severity because it has not been graded and it is not documented for all events. Some events are described as “soreness”. A terrestrial analog study reported that it appeared that most of these complaints were minor and self-limited in nature (Strauss, 2005)

Added 27 events and 167 persons at risk from the real world incidence data to the existing incidence information (Saile, 2017)

Information Regarding Prevention

Selection criteria

Disqualifying conditions in the general category are: All injuries, contusions, fractures, or surgery unless healed and not associated with functional deficit that could interfere with the performance of duties; History of heat stroke, temperature intolerance or environmental injuries associated with significant sequelae which could interfere with performance of duties;

Decompression illness (DCI) involving joint pain, peripheral nervous system, or skin is not disqualifying if adequately treated and completely resolved.

Disqualifying conditions in the musculoskeletal disorders are traumatic, inflammatory, degenerative, congenital (or hereditary) and metabolic disorders, or disease of any bone, joint, muscle or supporting structure that interferes with the performance of duties

Preventive Treatment(s):

Prevention methods include optimizing suit fit, crew training including avoiding work outside of the normal work envelop, the application of suit padding and pressure absorbing dressings to known affected body areas. (Strauss, 2004)

Counter measures: (used in NBL)

Padding is available for various body sites, e.g. Teflon inserts, shoulder pads, heel pads, thermal slippers, crotch pad, stabilization back pad, and LCVG knee comfort pads. Astronauts also use Mosite or Moleskin protective dressings, (Strauss, 2005).

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
Walton, 2010	1	Incidence
Saile, 2017	1	Incidence

Alternative Incidence Data

A variety of neuropathies have been identified during long duration flights however there is not confirmation of the cause. One reported incident may have been due to carbon monoxide poisoning, and another from a possible toxic exposure cadmium in consumed water. There are also compressive neuropathies of the digital nerves, ulnar nerve, median nerve and brachial plexus. (Viegas, 2004)

Employees of the Johnson Space Center (JSC) Medical Operations and Occupational Medicine/Manned Test Support recognized early in 2002 that there was an apparent increased incidence of a variety of complaints associated with extravehicular activity (EVA) training at the Neutral Buoyancy Laboratory (NBL). Many of these had apparently been unreported or had not been completely captured by the Flight Medicine Clinic and the Astronaut Strength Conditioning and Rehabilitation records. These complaints and injuries have probably always been occurring at a low incidence. However, the unprecedented increase in EVA training to support construction and maintenance of the International Space Station (ISS) may have significantly accentuated this problem. 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. Up to this time no data had been developed to quantify and characterize these complaints.

A prospective observational study was conducted to characterize the symptoms and injuries experienced by NASA astronauts during their extravehicular activity spacesuit training at the Neutral Buoyancy Laboratory (NBL), located at the Sonny Carter Training Facility of JSC from July 19, 2002, to January 16, 2004. (Strauss, 2004)

Strauss identified the frequency and incidence rates of symptoms by each general body location and characterized mechanisms of injury and effective countermeasures. Based on these findings a comprehensive list of recommendations was made to improve training, test preparation, and current spacesuit components, and to design the next-generation spacesuit.

At completion of each test event a comprehensive questionnaire was produced that documented suit symptom comments, identified mechanisms of injury, and recommended countermeasures. Comments were analyzed by each general and specific anatomic location, severity, causal mechanism, and recommended countermeasure.

The study population was 86 crew members. Of the 770 test events studied, 352 reported suit symptom comments (45.7%). Of those symptoms 166 were in hands (47.16%), 73 were in shoulders (20.7%), and 40 were in feet (11.4%). Others ranged from 6.0% to 0.28%, respectively, from the legs, arms, neck, trunk, groin, and head. The major causal mechanisms for the hands included hard fingertip contacts associated with fingernail delamination, for the shoulders hard contact with suit components and strain mechanisms, and for the feet hard contact in boots.

The reported severity of symptoms in a scale of zero to five was highest in the shoulders 1.86, with 1.13 in the hands, and 1.66 in the feet. It ranged from 1.65 to 0.4 for the arms, legs, neck, and trunk, respectively. The investigator concluded that most extravehicular mobility unit suit symptoms were mild, self- limited, and controlled by available countermeasures. Some represented the potential for significant injury with short- and long-term consequences regarding astronaut health and interference with mission objectives. The location of symptoms and injuries that were most clinically significant was in the hands, shoulders, and feet. Correction of suit symptom issues will require a multidisciplinary approach to improve prevention, early medical intervention, astronaut's training, test planning, and suit engineering.

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.

For this study signs or symptoms are self- limited; it does not require medical care and does not restrict function. While an injury, such as a cut, a fracture, a sprain, an amputation, etc., results from a work related event or from a single instantaneous exposure in the work environment.

The Severity Scale was characterized as follows: 0 – no pain; 1 – very mild pain; 2 – mild pain; 3 – moderate pain; 4 – moderately severe pain; and 5 – severe pain

The reported time period for the study was 18 months. Incidence rate is the ratio of subjects with symptoms to subjects at risk (expressed as %). The Incidence rate of subjects with symptoms 60/86 = 70%. Incidence rate of subjects with one symptom 13/86 = 15%. Incidence rate of subjects with two or more symptoms 47/86 = 55%.

Most reported symptoms were minor and self- limited. Of the reported suit symptoms, the vast majority consisted of areas of localized discomfort that resolved rapidly and without injury.

To obtain an incidence more comparable to the EVA experience, we would have to delete injuries other than paresthesias. From the original population of 86, 13 astronauts were followed for onycholysis, which we accounted in the Fingernail Delamination CliFF; of 13 astronauts followed for shoulder injuries, 54% (7) had contact complaints. Therefore, we discounted 19 crewmembers from the 60 subjects with symptoms and obtained an incidence of 47.7% (60-19=41, 41/86 = 47.7%) (Strauss, 2004)

Between 2002 and 2007 there were three documented cases of sensory compressive neuropathy during EMU NBL space suit training. Two of these involved the radial and median nerves respectfully and were both attributed to nerve compression due to poor glove fit. These resulted in the suspension of NBL training until the glove fit problems were corrected and there was full resolution of the neuropathies. One case involved the peroneal nerve at the dorsal foot and was attributed to a poor boot fit. The boot fit problem was corrected and there was full resolution of the neuropathy. In each case these took approximately 6 weeks to fully resolve. No recurrences were subsequently reported and each crew member went on to complete successful missions including multiple EVAs. These would be consistent with our definition of worst case scenario. We calculated the incidence to be 3/114 = 0.263. Narrative, Samuel Strauss, NBL Flight Surgeon.

Backpackers are at risk for particular paresthesias in specific distributions due to the compression of backpack straps, waist belts, and boots. Backpackers who hiked a minimum of 7 days were interviewed while hiking. Following their hike, a written questionnaire was mailed to the participants that explored the incidence of injuries and illnesses among hikers. Paresthesias were defined as either numbness or "phantom, burning, or shooting pains". Paresthesias were reported by 34% (96 of 280). Ninety-eight percent of the paresthesias (94 of 96) had resolved by the time of follow-up (median = 30 days). Although they were distressing during backpacking, these neuropathies were self-limited and resolved after completion of hiking. The author acknowledged that no study has previously systematically evaluated the frequency of this problem. The largest weakness of this study is its written survey format with its inability to examine patients at the time of their paresthesias (Boulware, 2003)

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 %: 96.3 - 98.15)	100	0.25	0 - 11	0 - 12 - 24	0	0	0
ISS-based Treatment (worst case scenario %: 1.85 - 3.7)	100	0.25 - 0.5	2 - 21	24 - 96 - 168	0 - 11	0	0
Untreated Best Case	0	0	2 - 21	0 - 12 - 24	0	0	0
Untreated Worst Case	0	0	12 - 36	24 - 96 - 168	2 - 36	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 scenario** is defined as having mild paresthesias or local pain from an EVA suit pressure point, with mild tingling, numbness, or pain, which resolve spontaneously.

The **worst case scenario** is defined as having moderate to severe numbness and or localized pain from an EVA suit hot-spot that may require treatment with analgesics and or steroids.

Best case/Worst case percentages

A study of astronauts at NBL (Strauss, 2004), an analog population, had (6/86) 6.9% who required referral for more definitive care after injuries sustained during training. This study includes all injuries including onycholysis which is not part of this CliFF; however, injuries requiring additional care were located at neck, shoulders and elbows and were more severe than our worst case scenario. On the other hand, based on the scale used to measure severity the average severity only groin injury was graded as moderately severe(grade 4), none at extreme (grade 5) and the rest at very mild and mild (grades 1 and 2). Discounting the severe injury, the analog study has 5.8% (5/86).

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 2/54 or 4% of cases as worst cases. If the next case is best case, we would have 53/54 or 98%. Thus the percentage range for best case is 96-98% and the worst percentage range would be 2%-4%.(Saile L., 2017)

Best Case Comments

Paresthesias/Hot Spots (EVA) functional impairments (FI) calculation follows the IMM mild non-space adaptation template, except for the untreated best case. Peripheral nerve impairment – Upper Extremity Impairments level of severity and description are based on Table 15-14, pp.425. Gradings are based on Table 15-21, p 436, Peripheral Nerve (UEI) (American Medical Association, 2008). Peripheral nerve (UEI) ratings are then converted to percentage of Whole Person Impairment (WPI), which are based on Table 15-1, p 385 (American Medical Association, 2008). Dysesthetic Pain is based on Table 13-17, p. 339 and its ratings are for whole person impairment (American Medical Association, 2008). Combined FI ratings are calculated combining the mentioned tables using the Combined Values Chart as indicated in Appendix A, pp 604-606 (American Medical Association, 2008). For further information refer to the CliFF Appendix

By definition during **Clinical Phase I**, FI is 100% and duration is estimated to be 15 minutes. Diagnosis evaluation for paresthesia is a subset of Periodic Health Status (PHS) –EVA. During **Clinical Phase II**, Functional Impairment is estimated at 0-11%. Duration is estimated at 0-24 hours based on in-flight data (In-flight Compilation Lockdown revised, 2010). During **Clinical Phase III,** by definition complete recovery is expected with no EVAC or LOCL. FI is 0%. Paresthesia is a Class I medical event with no mission impact (Johnston, 2008)

Worst Case Comments

Paresthesias/Hot Spots (EVA) functional impairments (FI) calculation follows the IMM mild non-space adaptation template, except for the untreated best case. Peripheral nerve impairment – Upper Extremity Impairments level of severity and description are based on Table 15-14, pp.425. Gradings are based on Table 15-21, p 436, Peripheral Nerve (UEI) (American Medical Association, 2008). Peripheral nerve (UEI) ratings are then converted to percentage of Whole Person Impairment (WPI), which are based on Table 15-1, p 385 (American Medical Association, 2008). Dysesthetic Pain is based on Table 13-17, p. 339 and its ratings are for whole person impairment (American Medical Association, 2008). Combined FI ratings are calculated combining the mentioned tables using the Combined Values Chart as indicated in Appendix A, pp 604-606 (American Medical Association, 2008). For further information refer to the CliFF Appendix

By definition during **Clinical Phase I**, FI is 100% and duration is estimated to be 15 to 30 minutes. Diagnosis evaluation for paresthesia is a subset of Periodic Health Status (PHS) –EVA. During **Clinical Phase II**, Functional Impairment is estimated at 2-21%. Duration is estimated at 24-168 hours, or 1 to 7 days based on in-flight data (In-flight Compilation Lockdown revised, 2010). During **Clinical Phase III,** recovery is expected with available treatment, FI is estimated at 0-11%. EVAC and LOCL are not expected. Paresthesia is a Class I medical event with no mission impact (Johnston, 2008)

Untreated Best Case Comments

Paresthesias/Hot Spots (EVA) functional impairments (FI) calculation follows the IMM mild non-space adaptation template, except for the untreated best case. Peripheral nerve impairment – Upper Extremity Impairments level of severity and description are based on Table 15-14, pp.425. Gradings are based on Table 15-21, p 436, Peripheral Nerve (UEI) (American Medical Association, 2008). Peripheral nerve (UEI) ratings are then converted to percentage of Whole Person Impairment (WPI), which are based on Table 15-1, p 385 (American Medical Association, 2008). Dysesthetic Pain is based on Table 13-17, p. 339 and its ratings are for whole person impairment (American Medical Association, 2008). Combined FI ratings are calculated combining the mentioned tables using the Combined Values Chart as indicated in Appendix A, pp 604-606 (American Medical Association, 2008). For further information refer to the CliFF Appendix

During **Clinical Phase II**, Functional Impairment is estimated at 0-11%. Duration is estimated at 0-24 hours based on in flight data (In-flight Compilation Lockdown revised, 2010). Both similar to the treated best case scenario. During **Clinical Phase III,** by definition complete recovery is expected with no EVAC or LOCL. FI is 0%. Paresthesia is a Class I medical event with no mission impact (Johnston, 2008). Because the condition is defined as resolving spontaneously, lack of treatment does not affect the outcome.

Untreated Worst Case Comments

Paresthesias/Hot Spots (EVA) functional impairments (FI) calculation follows the IMM mild non-space adaptation template, except for the untreated best case. Peripheral nerve impairment – Upper Extremity Impairments level of severity and description are based on Table 15-14, pp.425. Gradings are based on Table 15-21, p 436, Peripheral Nerve (UEI) (American Medical Association, 2008). Peripheral nerve (UEI) ratings are then converted to percentage of Whole Person Impairment (WPI), which are based on Table 15-1, p 385 (American Medical Association, 2008). Dysesthetic Pain is based on Table 13-17, p. 339 and its ratings are for whole person impairment (American Medical Association, 2008). Combined FI ratings are calculated combining the mentioned tables using the Combined Values Chart as indicated in Appendix A, pp 604-606 (American Medical Association, 2008). For further information refer to the CliFF Appendix

During **Clinical Phase II**, Functional Impairment is estimated at 2-36%. Duration is estimated at 24 to 168 hours similar to the treated worst case scenario. During **Clinical Phase III,** FI is 2 to 36%. Some relief is expected by removing the stimulus of the pressure points but recovery may be delayed without treatment. EVAC and LOCL are not expected. Paresthesia is a Class I medical event with no mission impact (Johnston, 2008).

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
American Medical Association, 2008	3	FI
American Medical Association, 2008	3	FI
Johnston, 2008	1	EVAC
Saile L., 2017	1	BCWC

The Resource Table (RT)

Resource	Units Required Best Case	Units Required Worst Case	Units Available At Start Of Mission	Consumable	Essential	Rationale
Prednisone 20 mg	0	10	40	Yes	Yes	Anti inflammatory
Tylenol (Acetaminophen) 325 mg	0	18	250	Yes	Yes	Pain relief (first line)

Resource Comments

ISS does not address paresthesias or hot spots though the content list was consulted during the development of the resource table for this CliFF (MOD, 2011). Paresthesias are mentioned as part of Bends-Decompression Sickness (DCS), in cuff class 1 difficult to distinguish from suit pressure points, or cuff class 3 migratory, truncal, or multiple site paresthesia. These are addressed in the DCS CliFF.

As stated, data about paresthesias in the United States is difficult to correlate to the in-flight occurrence of EVA-related paresthesias and hot-spots. The same challenge presented in searching for clinical guidelines. The American society of Anesthesiologists' Task Force Consensus report (American Society of Anesthesiologists, 2000)recommends frequent re-positioning and padding to prevent peripheral nerve injury. These recommendations are being updated in 2011.

The American Academy of Orthopaedic Surgeons (AAOS) Clinical Practice Guidelines (Keith, 2010)made recommendations for the treatment of carpal tunnel syndrome: a course of non-operative treatment, a second course of treatment when symptoms do not resolve in 2 to 7 weeks, and oral steroids. There is no recommendation for or against the use of NSAIDs.

Recently, an individual review of the AAOS guidelines (Ono, 2010)included 25 more recent studies from 2007 to 2010, where the usefulness of splinting and steroids as initial treatments for improving patients' symptoms are also supported by the recent literature albeit their effects are temporary.

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
Keith, 2010	3	Resources

Level Of Evidence

Input Data	LOE Average
Incidence	1
Functional Impairment	3
Best Case / Worst Case	1
EVAC / LOCL	1
Resources	2.5
QUALITY OF EVIDENCE	**1.7**

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

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