Wrist Fracture Cliff

Branch Baseline

The wrist is an anatomic linkage bridging the hand to the forearm. The hand relative to the forearm can flex, extend, pronate, supinate, and deviate radially and ulnarly. Malfunction of the wrist occurs when the structural alignment of the bones has changed, i.e. distal radius malunion and acute fracture of carpal bones. (Steinberg, 2002)

The most injured carpal bone is the scaphoid where 70% of carpal fractures occur. (Steinberg, 2002)

Scaphoid fractures usually result from a forceful extension of the wrist. Scaphoid fractures should be classified as either undisplaced, stable or displaced, unstable. Nonsurgical treatment with cast immobilization (short arm-thumb spica cast) is recommended for stable fractures; however, there is increased interest in percutaneous screw (or pin) fixation. The recommended treatment for unstable scaphoid fractures is open reduction and screw fixation. Closed reduction and percutaneous screw or pin fixation can be considered in minimally displaced or reducible fractures, whereas open reduction is recommended for all other displaced fractures (Cooney, 2003)

Fractures of the distal end of the radius are among the most common orthopedic injuries, and treatment of these fractures has changed over the course of time. Many fractures of the distal radius are in fact relatively uncomplicated and are effectively treated by closed reduction and casting. However, fractures that are either unstable and/or involve the articular surfaces can jeopardize the integrity of the articular congruence and/or the kinematics of these articulations. The goal of the treating physician should then be to restore the functional anatomy by a method that does not compromise hand function. The fracture pattern, degree of displacement, the stability of the fracture, and the age and physical demands of the patient determine the best treatment option. (Simic, 2003)

Distal radius fracture is one of the most common fractures seen by orthopedic surgeons. Fractures of the distal end of the radius account for nearly one in every six fractures that are treated in emergency departments in the United States. They are also called Colles' fractures since the first description of this injury by Abraham Colles in 1814,(Bindra, 2009)

Acute distal radius fracture results in pain, tenderness, swelling and potential deformity. Patients may be faced with substantial morbidity if fracture healing is delayed or results in clinically significant deformity. Additionally, there are known complications in the treatment of distal radius fracture. The recovery period for distal radius fracture can be substantial and the impact of the method of fixation on activities and daily living can be significant. (Lichtman, 2010)

Fracture of the distal radius is the result of trauma. There is a bimodal distribution of distal radius fractures where high-energy fractures occur in younger persons, predominately male, and high and low-energy fractures occur in older persons, predominately female. (Lichtman, 2010)

Because the hands are used to provide stability and propulsion on microgravity the chance of injury may be greater in space flight than on the ground. (Marshburn, 2008) Spaceflight-induced bone atrophy is due to the mechanical unloading of the skeletal system and is targeted to specific regions of the skeleton. These site-specific losses occur at normally weight-bearing skeletal areas (on Earth) suggesting that the regions that experience the larger deficits in mechanical loading undergo the greater adaptation. Collectively, the average decrement of preflight areal bone mineral density (BMD) per month is 1-1.5%, although there are considerable variations of loss between different skeletal sites and between different crewmembers. In microgravity demineralization is potentiated by the poor absorption of vitamin D. The radiation shielding on ISS prevents ultraviolet conversion of 7-dehydrocholesterol in the skin to vitamin D. Vitamin D is associated with improved neuromuscular coordination. In addition, a deficiency in vitamin D could lead to mal-absorption of calcium in the intestine and poor re-absorption by the proximal tubules of the kidney. The failure to conserve calcium because of vitamin D deficiency will limit the availability of calcium to support the anabolic effects of exercise and physical activity on bone and muscles. It is noted that the hands and wrists are the primary means of ambulation on orbit. The possible effect of mineralization or de-mineralization of wrist bones is not known. (Sibonga, 2008)

Potential mechanisms of injury for wrist fracture in space include impact to structure from an outstretched hand during intra-vehicular translation, hyperflexion or a direct blow to the wrist such as while stowing equipment, or excessive forces exerted such as doing a repair during an EVA. (Scheuring, 2009)

On orbit ultrasound orthopedic examination was developed by the Advanced Diagnostic Ultrasound in Microgravity program. It was shown to be feasible for the diagnosis and management of fractures. A detailed ISS ultrasound user guide has been published. (Sargsyan, 2006) (Marshburn, 2004) The hardware-specific requirements to expand the operational use of ultrasound in space are available. We took our best case vs. worse case confidence intervals from the best terrestrial data available (Earnshaw, 2002) and modified the range to reflect the microgravity flight environment. The risk for fracture is minimal during missions in low Earth orbit because applied loads associated withfalling, or with other events, are non-existent in a weightless environment or are mitigated by operational procedures. (Sibonga, 2008)

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:	Model
Space Adaptation:	No
Incidence Type:	Rate

Distribution Data	
Incidence:	Lognormal
Occurrence:	Poisson

Data Characteristics	
Mean:	0.002239238
Standard Deviation:	0.009392985

Incidence Comments

After more than 40 years of space travel, it is assumed that fractures have not occurred during missions in low Earth orbit nor in the immediate post flight time frame. (Sibonga, 2008)

Lacking phenomenological data on fracture risk in space, Glenn Research Center has developed a predictive tool based on biomechanical and bone loading models at any gravitational level of interest. Wrist fracture is the most likely type of fracture (Nelson, 2009)(Lewandowski, 2013).

The fracture risk index (FRI) is a measure used to help assess the likelihood that a fracture will occur during a particular loading event. FRI is defined as the ratio of load at the wrist during an impact to the strength of the bone.

Another factor in the determination of the risk of wrist fracture takes into account the opportunity for a loading event to occur. A database of in-flight musculoskeletal injuries has recently been compiled, from which incidence rates have been calculated (Scheuring, 2009). The authors report a total of 219 musculoskeletal injuries during the 231,724.7 hours of in-flight operations by U.S. Astronauts. This equates to 0.023 musculoskeletal injuries per day during space flight. Scheuring et al. also broke out the number of injuries at each skeletal location and 5 out of the 219 injuries occurred at the wrist or 5.18e-4 wrist injuries per day. This injury rate was used as our mean event rate and ± 10% of the mean was used as the standard deviation.

Since the incidence rate used represents the rate of injury rather than the average number of times per day an astronaut translates through the spacecraft and impacts a wall to slow and stop him or herself, the assumption must be made that the corresponding impact force is at a higher level than the nominal force experience. In other words, since the incidence rate only takes into account events where an injury could occur, the impact force must also represent a force which is capable of producing an injury. No data exists on injury capable force vs. nominal force. Instead, an assumption was made that the mean injury capable force is equal to the 90th percentile of the normal force and for our analysis we shifted the mean value of the PF_{73}, distribution to this higher force value. A normal distribution for PF_{73} was still used and standard deviation remained the same.

Glenn developed four biomechanical loading models to estimate the loading at the most vulnerable skeletal locations during specific events. A Monte Carlo probabilistic simulation was carried out for each mission scenario and biomechanical models (Lewandowski, 2013). In the IMM, times to fracture event are simulated from an exponential distribution given a set rate. There is simulated from a log normal distribution with mean and std. deviation. Thus in its current form, the probabilities of fracture events within a mission cannot be used to inform the IMM. Therefore, we need to transform the probabilities of a fracture in a given mission type to a rate that can be used to simulate the time to event in simulation settings. For the fracture probability mean was estimated at 0.002239238 and the standard divation is 0.009392985. This information can then be used to update the current version of the IMM (Koslovsky, 2017).

Information Regarding Prevention

NASA requirements and documents support safety first. However, injuries result from an accident and there are no real medical preventive measures available.

Selection criteria Disqualifying conditions in the musculoskeletal category include: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; chronic arthritis with functional disability that interferes with the performance of duties; benign tumors or cysts, single or multiple, sufficiently large to interfere with performance of duties, or to create a fracture potential. Osteochondromatosis or multiple cartilaginous exostoses that interfere with performance of duties; history of osteochondromatosis or multiple cartilaginous exostoses that have been successfully surgically excised requires special consideration by the MSMB. Joint instability (recurrent subluxations or dislocations of an articulation); history of joint instability that has been medically or surgically corrected requires special consideration by the MSMB. Intra-articular loose bodies in any joint (osteocartilaginous or metallic foreign objects) that interfere with performance of duties; history of intra-articular loose bodies in any joint surgically removed with no residual dysfunction requires special consideration by the MSMB. Non-union of fractures; mal-union of fractures that interferes with performance of duties; any fracture in which hardware (e.g., rod, plate, pin or screw) was used for fixation, if the fixation devices remain in place, will require orthopedic consultation and special consideration by the MSMB. Less than functional range of motion and stability of all joints. A total range of motion of the wrist of 70 degrees dorsal extension plus 80 degrees palmar flexion: ulnar deviation 45 degrees plus 15 degrees radial deviation. Minor deviations from the range of motion of the wrist require special consideration by the MSMB. Pronation of the hand to 90 degrees and supination to 80 degrees. Chronic or recurrent bursitis, tendinitis, and synovitis sufficient to interfere with the performance of duties. Osteopenia requires special consideration by the MSMB and will require endocrine evaluation and possibly other specialized scanning techniques.

The WHO definition of osteopenia is based on a DEXA measurement of Bone Mineral Density of total lumbar spine less than 0.937gm/cm2 or femoral neck less than 0.738 gm/cm2, or greater trochanter of the femur less than 0.602 gm/cm2. T-score: -1.0 to -2.5 SD. Osteoporosis. The WHO definition of osteoporosis is based on a DEXA measurement of Bone Mineral Density of total lumbar spine less than 0.772 gm/cm2 or femoral neck less than 0.572 gm/cm2 or greater trochanter of the femur less than 0.451 gm/cm2. T-score: Lower than -2.5 SD. (NASA, 2007); (International Space Station Program, 2009)

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
Lewandowski, 2013	3	Incidence
Koslovsky, 2017	3	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:	Model
Space Adaptation:	No
Incidence Type:	Rate

Distribution Data	
Incidence:	Lognormal
Occurrence:	Poisson

Data Characteristics	
Mean:	0.00445
Standard Deviation:	0.0233

Incidence Comments

This is the prior model incidence, derived from Myers Probabilistic Risk Assessment (Unpublished work, 2009)

Alternative Incidence Data

A longitudinal cohort study of 4,122 US Army deployed to Iraq for 15 months was performed (Belmont, 2010). A casualty in customary military usage means active duty service member lost to the theater of operations for medical reasons. This study covers only disease and non battle injuries (DNBI). Musculoskeletal injuries were classified in three major categories: upper extremity, lower extremity and axial spine There were 667 total musculoskeletal injuries; a total of 66 fractures, with 19.7% medevacs (13/66). 4.2% injuries occurred to the wrist. Musculoskeletal injury incidence rates were fivefold greater than the general population.

A nine-month study of US Navy medical communications and Evacuations at sea (Nice, 1987) determined that 31% of medical communications were related to injuries, mainly fractures and lacerations and 36% of medevacs included fractures and lacerations. Medevac was defined as the non routine transfer of a patient from a ship at sea for the purpose of receiving more definitive care.

Another study among US Navy Submarines (Thomas, 2003) determined that the incidence of arthropathies was 0.007 (0.7/100) for officers and 0.011 (1.1/100) for enlisted men per person-years. Information was not stratified by type of joint. Among officers most lost duty days were due to musculoskeletal conditions (46 days), and among enlisted men lost duty days (350 days) for musculoskeletal conditions were third, after injury and digestive. The population was composed of 240 submarine patrols, between 1 January 1997 and 30 September 2000; total of 1389 officers and 11,952 enlisted crew members served aboard participating submarines for 215,086 and 1,955,521 person-days at sea.

A study using the Defense Medical Epidemiology Database (DMED) (Wolf, 2009), ICD9 code 814.01, noted 14,704 first occurrence scaphoid fractures in a military population at risk of 12,117,749 person-years, during the 1998-2006 period. Incidence was 0.00121 (1.21/1000) person-years. Gender was a significant risk factor. Male incidence was 0.00129 (1.29/1000) and female 0.00079 (0.79/1000) both per person-years. Males were most likely to sustain scaphoid injuries, with an adjusted ratio of 1.55 compared to females. Incidence rates increased with age: for the 30-35 cohorts 0.00008698 (0.08698/1000), 35-39 0.0007544 (0.7544/1000), and 40 and older cohort 0.0006494 (0.6494/1000). Incidences reported by this study are higher than previously reported in the literature.

A US population study presented incidence of fractures among adults treated in US Hospital emergency departments (Orces, 2011), caused by unintentional falls between 2001 and 2007. For 2007 the incidence was 68.8 for male and 192.9 for female, rates are per 100 000 person for the age 50-59 cohort. Limitations are that persons treated at physician’s offices are not represented; diagnosis recorded for main injury and body area, so some of wrist injuries may have been missed. There is no information about long term outcomes. 90% were treated and released, 1.5% transferred to another hospital, 8.5% were hospitalized.

A study in the United Kingdom, including 225 patients in the general population (Earnshaw, 2002), with Colles fractures who presented to the hospital between August 1997 and October 1998, resulted in overall, of the 225 fractures, 195 (87% [95% confidence interval, 82% to 91%]) were successfully reduced into an acceptable position according to the criteria of <10° of dorsal angulation and <5 mm of radial shortening. The rate of successful reduction was 87% in both the manual manipulation group (98 of 113) and the finger-trap group (97 of 112) ($p = 0.41$). At one week, fifty-six (50%) of the 113 fractures in the manual manipulation group and 48 (43%) of the 112 in the finger-trap group had redisplaced with 10 degrees or greater of dorsal angulation or 5 mm or greater of radial shortening ($p = 0.16$). By five weeks, fifty-six (25%) of the 225 fractures had been treated with surgical intervention because of failed closed treatment and only sixty-five (29% [95% confidence interval, 21% to 38%]) remained in a satisfactory position. Survivorship analysis revealed no significant difference ($p = 0.56$) between the two groups with regard to the rate of failure at any stage of treatment.

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 %: 75 - 84)	100	1.5	2 - 28	672 - 840 - 1008	0	0	0
ISS-based Treatment (worst case scenario %: 16 - 25)	100	1.5	15 - 50	1008 - 1512 - 2016	0 - 50	100	0
Untreated Best Case	0	0	15 - 50	672 - 840 - 1008	0 - 28	100	0
Untreated Worst Case	0	0	29 - 50	1008 - 1512 - 2016	29 - 50	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

The **best case scenario** is defined as a stable, non-displaced wrist fracture.

The **worst case scenario** is defined as an unstable, displaced, or intra-articular fracture requiring operative intervention.

Percentages of best case vs. worst case scenario

A population study in Sweden (Earnshaw, 2002)found that at one week, 56 of 113 (50%) fractures in the manual manipulation group and 48 of 112 (43%) in the finger-trap group had redisplaced with 10 degrees or greater of dorsal angulation or 5 mm or greater of radial shortening (p = 0.16). By five weeks, 56 of 225 (**25%**) fractures had been treated with surgical intervention because of failed closed treatment and only 65 (29%) [95% confidence interval, 21% to 38%]) remained in a satisfactory position.

A high-school sport related fractures surveillance study (Swenson, 2010)found that among a total of 568177 occurred nationally between 2005 and 2009, 10.4% were wrist fractures, second after hand/finger frequency (28.3%). Most fractures resulted in 3 weeks or greater time lost (34.3%) or a medical disqualification from participation (24.2%). Overall, **16.1%** of fractures required surgery.

Based on the above studies, it is estimated that between 16% and 25% of wrist fractures may require surgical treatment. Therefore, worst case scenario is estimated as **16% to 25%** and best case scenario is estimated as **75% to 84%**.

In a report on acute wrist injuries in the athlete (Steinberg, 2002)95% of non displaced scaphoid fractures heal after approximately 10 weeks (1680 hrs) with thumb spica cast immobilization. With fixation healing time is about 6 weeks. Fixation is not available on board. The isolated triquetrum avulsion fracture is usually treated with splint immobilization and pain along the ulnar aspect will resolve in 3 to 6 weeks.(504 to 1008 hrs)

There are several classifications to describe distal radial fractures. The Melone classification is based on the displacement of medial fragments. Melone type I stable distal radial fractures can be treated with cast immobilization for 4 to 6 weeks (672 to 1008 hours). Type II fractures can be reduced by closed means like external fixation and pinning. Recovery is 3 to 6 months after surgery. Progressive patterns, Types III-V may require external fixation and bone grafting. Return to activity may take 4 to 6 months or longer. (Steinberg, 2002)

In a series of 341 patients from 1992-1995 Lindau, et. al. found that the primary treatment was plaster cast in 89% of distal radius fractures (53% without reduction, 36% following closed reduction) and surgery 11% (7% open reduction and internal fixation and 4% with closed reduction and external fixation). Re-reduction was performed in 13% in the plaster-treated group; in half of these patients, external fixation was used as a new treatment. The median (90th percentile) duration of immobilization was 4 (3-6) weeks. (Lindau, 1999)Based on these data we selected 11% as the worst case incident rate.

Based on Steinberg, we are using the 4 to 6 weeks for time to include radial, scaphoid, and other carpal bones for duration in the best case scenario. For the worst case scenario we are estimating 6 to 12 weeks (3 months, 2016 hours)

Best Case Comments

Wrist Fracture functional impairments (FI) calculation follows the IMM severe non-space adaptation template. Wrist regional grid fracture ratings are based on Table 15-3, pp.395-397 (American Medical Association, 2008). Complex Regional Pain Syndrome-Upper Extremity CRPS (UEI) is based on Table 15-26, p 454 (American Medical Association, 2008). The Wrist Regional Grid and CRPS (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). 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 detailed information on grading and FI calculations refer to the CliFF Appendix A.

By definition in Clinical Phase I, FI is 100%. Duration to follow procedures specified in ISS checklist, i.e. physical exam, vital signs, ultrasound, and observation period for the best case scenario, is estimated in 1 hour and a half. During Clinical Phase II, FI is estimated in 2 to 28%. Duration is estimated in 672 to 1008 hours, or 4 to 6 weeks based on Steinberg's report (Steinberg, 2002). 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

Wrist Fracture functional impairments (FI) calculation follows the IMM severe non-space adaptation template. Wrist regional grid fracture ratings are based on Table 15-3, pp.395-397 (American Medical Association, 2008). Complex Regional Pain Syndrome-Upper Extremity CRPS (UEI) is based on Table 15-26, p 454 (American Medical Association, 2008). The Wrist Regional Grid and CRPS (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). 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 detailed information on grading and FI calculations refer to the CliFF Appendix A.

By definition in Clinical Phase I, FI is 100%. Duration to follow procedures specified in ISS checklist, i.e. physical exam, vital signs, dressing to contain bleeding, and ultrasound is estimated in 1 hour and a half. During Clinical Phase II, FI is estimated in 15 to 50%. Duration is estimated in 1008 to 2016 hours, or 6 to 12 weeks (Steinberg, 2002). In Clinical Phase III, full recovery may or may not occur and FI is estimated at 0-50%. EVAC is estimated to be occur in 100% of cases to allow for transfer to a definitive care facility since operative treatment will be required. Fractures are a Class IIa, manageable with HMS and not likely to require evacuation or IIb, manageable with the HMS but may require return of the astronaut at the next available opportunity for further evaluation and treatment. (Johnston, 2008)

Untreated Best Case Comments

Wrist Fracture functional impairments (FI) calculation follows the IMM severe non-space adaptation template. Wrist regional grid fracture ratings are based on Table 15-3, pp.395-397 (American Medical Association, 2008). Complex Regional Pain Syndrome-Upper Extremity CRPS (UEI) is based on Table 15-26, p 454 (American Medical Association, 2008). The Wrist Regional Grid and CRPS (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). 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 detailed information on grading and FI calculations refer to the CliFF Appendix A.

During Clinical Phase II, FI is estimated in 15 to 50%. Duration is 672 to 1008 hours, similar to the treated best case scenario. In Clinical Phase III, recovery may or may not occur. A splint can be improvised with on board supplies, but there are not analgesics to treat pain. FI is estimated at 0-28%. By definition, EVAC is estimated in 100% for the untreated best case, considering that an untreated wrist fracture may cause potential significant permanent impairment. By definition LOCL would not be expected for this scenario.

Untreated Worst Case Comments

Wrist Fracture functional impairments (FI) calculation follows the IMM severe non-space adaptation template. Wrist regional grid fracture ratings are based on Table 15-3, pp.395-397 (American Medical Association, 2008). Complex Regional Pain Syndrome-Upper Extremity CRPS (UEI) is based on Table 15-26, p 454 (American Medical Association, 2008). The Wrist Regional Grid and CRPS (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). 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 detailed information on grading and FI calculations refer to the CliFF Appendix A.

The maximum FI Class for wrist regional grid-fracture is III and for CPRS (UEI) is IV. To maintain class consistency, both wrist grid and CRPS (UEI) were graded with the same Class III for the untreated worst case scenario.

During Clinical Phase II, FI is estimated in 29 to 50%. Duration is 1008 to 2016 hours, or 6 to 12 weeks, similar to the treated worst case scenario. In Clinical Phase III, recovery is unlikely and FI remains 29-50%. EVAC is estimated in 100%. LOCL is not expected.

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
Earnshaw, 2002	4	BCWC
Johnston, 2008	2	EVAC

The Resource Table (RT)

Resource	Units Required Best Case	Units Required Worst Case	Units Available At Start Of Mission	Consumable	Essential	Rationale
Ace bandage 3 inches	1	1	1	No	Yes	elastic bandage (also known as an ACE bandage, elastic wrap or compression bandage) is a "stretchable bandage used to create localized pressure
Bandaid strip	0	1	20	Yes	No	small adhesive bandages, to cover a wound
Blood Oximeter	0	1	1	No	Yes	To measure oxygen perfusion distal to the fracture site.
Blood Pressure Cuff (regular, large)	0	1	2	No	Yes	Measure blood pressure
Blood Pressure Monitor	0	1	1	No	Yes	Measure blood pressure
Gauze pads (4x4)	2	2	50	Yes	No	To control bleeding, if necessary
Motrin (Ibuprofen) 400mg	8	16	400	Yes	Yes	Pain relief , second line
Nitrile gloves (large, medium, and small) (pair)	0	2	30	Yes	No	Personal Protective equipment for CMO
SAM splint - Leg/Arm Splint	1	1	1	No	Yes	To immobilize wrist
Tylenol (Acetaminophen) 325 mg	20	30	150	Yes	Yes	pain relief , first line
Vicodin HP (Hydrocodone/ Acetaminophen HP) 10 mg/660 mg	8	16	30	Yes	Yes	Pain relief, third line

Resource Comments

The table was revised on 3/9/2011. Resources for skin abrasion and/or skin laceration are included in the Skin Abrasion and Skin Laceration CliFFs respectively. Pain medication has been added from terrestrial guidelines (Lichtman, 2010)and the Pain Relief Section in the ISS Medical Checklist (Mission Operations Directorate (MOD), 2011).

Terrestrial Guidelines (Lichtman, 2010)refer to surgical treatment of fractures while ISS Checklist main focus is emergency immobilization of the joint and pain relief.

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
Lichtman, 2010	3	Resources

Level Of Evidence

Input Data	LOE Average
Incidence	3
Functional Impairment	3
Best Case / Worst Case	4
EVAC / LOCL	2
Resources	2.5
QUALITY OF EVIDENCE	**2.9**

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

Reference List

Reference

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