# Lumbar Spine Fracture Cliff

### Branch Baseline

A fracture of the lumbosacral spine involves a break in one or more bones of the lumbar and sacral regions of the spine (vertebrae L1 through L5 and S1 through S5) in the lower back (lumbosacral spine). The five lumbar vertebrae are located in the slightly curved (lordotic) portion of the back between the end of the thoracic vertebrae (T12) and beginning of the sacral vertebrae (S1). Increased mobility of the lumbar spine makes it a more common site for fractures than the more rigid thoracic spine. Because the lumbar spine must sustain compressive, bending, and twisting forces between the upper and lower body, its vertebrae are larger, wider, and heavier than other areas of the spine and are surrounded by strong muscles and ligaments that help protect them from severe injury. The five sacral vertebrae extend from the last vertebra of the lumbar spine to the end of the spinal column; these vertebrae are fused together to form the triangular “tailbone” at the base of the spine (Vinas, 2011).Fractures in the lumbosacral spine may be classified according to the mechanism of injury and the degree of instability. Categories of fractures include compression fracture, transverse process fracture, burst fracture, flexion-rotation injury, and pathologic fracture. The fracture may be classified further as stable or unstable. A stable fracture is one that is not likely to change as the weight-bearing load on the spine changes, which makes it less likely to result in nerve or spinal cord damage, e.g., neurologic deficit or paralysis. Unstable fractures are described by abnormal motion at the fracture site and may be associated with neurologic injury. Fracture of vertebrae in the lumbosacral area can result in either temporary or permanent disability. The majority of lumbosacral fractures occur without spinal cord injury: 10% to 38% of adults with fractures in the lumbosacral region are reported to have associated spinal cord injury (Vinas, 2011).

### 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: | 0.0001392462 |
| Standard Deviation: | 0.0005334137 |

**Incidence Comments**

After more than 40 years of space travel, there have been no lumbar spine fractures reported during missions in low Earth orbit or in the immediate post flight time frame (Sibonga, 2008).

Lacking phenomenological data on fracture risk in space, Glenn Research Center have developed a predictive tool based on biomechanical and bone loading models at any gravitational level of interest. Wrist fracture was the most likely type of fracture, followed by **spinal** and hip fracture (Nelson, 2009).

Estimates of ISS fracture probability for IMM models serve per 180 days mission is 0.0001392462 mean and 0.0005334137 standard deviation. Glenn developed four biomechanical loading models to estimate the loading at the most vulnerable skeletal locations during specific events. The two related to lumbar spine are: the load on the lumbar spine (LS) while holding a load with the trunk flexed (LS static lift) and the load on the LS at impact after a fall from a height but landing on two feet (LS feet-first fall). A Montecarlo 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. This information can then be used to update the current version of the IMM (Koslovsky, 2017).

Simulations for astronaut prediction and validation departed somewhat from this procedure on specifics, although the general construction remained the same. The lumbar spine fracture model did not include gender dependence or the effect of off-axis impact, but it did include a relevant modification for impacts of short vs. long duration. In the validation simulations, the distributions were varied to correspond to the population under investigation. The predicted fracture risk index results were compared to that of other studies.

The potential for spinal fracture due to lifting heavy objects is quite low while within the spacecraft, but it may pose a risk during EVAs on Mars missions due to the weight of the spacesuit and compromised bone integrity resulting from an extended period in reduced gravity. The risk of spinal fracture due to up to 2m jumps or falls on the moon appears to pose limited risk, but similar 2m drops or greater on Mars should be considered more carefully for adverse consequences (Nelson, 2009). The risk of lumbar spine fracture due to lifting heavy objects approached a 1% probability during EVAs on Mars missions due to the added spacesuit mass and reduced bone integrity. The risk of spinal fracture due to up to 2m drops on Mars boosted the probability to above 1%. For a 6.7m drop (equivalent to falling from the top of the Lunar Lander ladder), the risk of fracture increased to about 2% (Sibonga, 2008).

### Information Regarding Prevention

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).

Other

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

### 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 |

| Female Data Characteristics | |
|---|---|
| Mean: | 0.000172753 |
| Standard Deviation: | 0.000177828 |

| Male Data Characteristics | |
|---|---|
| Mean: | 0.00020097 |
| Standard Deviation: | 0.00020909 |

**Incidence Comments**

After more than 40 years of space travel, there have been no lumbar spine fractures reported during missions in low Earth orbit or in the immediate post flight time frame. (Sibonga, 2008)

Lacking phenomenological data on fracture risk in space, Glenn Research Center have developed a predictive tool based on biomechanical and bone loading models at any gravitational level of interest. Wrist fracture was the most likely type of fracture, followed by **spinal** and hip fracture. (Nelson, 2009)

Estimates of ISS fracture probability for IMM models serve per 180 days mission are: 0.0000851 cases for females, Standard Deviation (SD) 0.0000876; 0.0000990 cases for males; SD 0.000103 (Licata, 2007); (Lewandowski, 2011). We estimated rates per person-years to serve as our model incidence: **0.000172753** For females and **0.00020097** for males**,** SD **0.000177828** and **0.00020909** respectively.

Glenn developed four biomechanical loading models to estimate the loading at the most vulnerable skeletal locations during specific events. The two related to lumbar spine are: the load on the lumbar spine (LS) while holding a load with the trunk flexed (LS static lift) and the load on the LS at impact after a fall from a height but landing on two feet (LS feet-first fall). A Montecarlo probabilistic simulation was carried out for each mission scenario and biomechanical models.

Simulations for astronaut prediction and validation departed somewhat from this procedure on specifics, although the general construction remained the same. The lumbar spine fracture model did not include gender dependence or the effect of off-axis impact, but it did include a relevant modification for impacts of short vs. long duration. In the validation simulations, the distributions were varied to correspond to the population under investigation. The predicted fracture risk index results were compared to that of other studies.

The potential for spinal fracture due to lifting heavy objects is quite low while within the spacecraft, but it may pose a risk during EVAs on Mars missions due to the weight of the spacesuit and compromised bone integrity resulting from an extended period in reduced gravity. The risk of spinal fracture due to up to 2m jumps or falls on the moon appears to pose limited risk, but similar 2m drops or greater on Mars should be considered more carefully for adverse consequences. (Nelson, 2009)

The risk of lumbar spine fracture due to lifting heavy objects approached a 1% probability during EVAs on Mars missions due to the added spacesuit mass and reduced bone integrity. The risk of spinal fracture due to up to 2m drops on Mars boosted the probability to above 1%. For a 6.7m drop (equivalent to falling from the top of the Lunar Lander ladder), the risk of fracture increased to about 2%. (Sibonga, 2008).

**Information Regarding Prevention**

**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).

**Other**

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

**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 |
|---|---|---|
| Licata, 2007 | 2 | Incidence |
| Lewandowski, 2011 | 2 | Incidence |

## Alternative Incidence Data

**Analog Populations**

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 longitudinal, prospective, epidemiologic database was used to determine the incidence, injury history, and aero medical disposition of U.S. Army aviators who sustained thoracolumbar fractures for calendar years 1987 to 1997. The overall incidence rate of thoracolumbar fracture was 12.8 per 100,000 aviators per year. By gender, female incidence was 33.4, and male 12.2, both per 100,000 aviators per year. Of 35 fractures, 9% occurred at T1-T10, 66% at T11-L1, and 26% at the cauda equina. By mechanism of injury Helicopter crashes and parachuting accidents accounted for 73% of fractures, motor vehicle and sports for 23%, and falls for 3%. Neurologic injury occurred in 10% of aviators. Seventy-seven percent of injured aviators recovered sufficiently to return to aviation service. There was no association between type of treatment and eventual termination from aviation duties (relative risk, 1.1; 95% confidence interval, 0.7-1.6). The incidence rates per person year are overall 0.000128, female 0.000334, and male 0.000122. Lumbar spine incidence is 91%, overall 0.00011648, female 0.00030394, and male 0.00011102 (Belmont, 2001). By type, fractures were burst (axial compression) 40% , and compression (collapse of several spine bones) 53%

**Non Analog Populations**

In Sweden, among patients younger than 60 years of age the annual incidence was 13 per 100,000 and was twice as high in men compared to women. The proportion operated on was 15%. The 90-day case-fatality rate after surgery was 1.4%. By location 62. 3% of the total was lumbar fractures and 37.7% thoracic fractures. (Jansson, 2010) Annual rate per person year is 0.00013 (13/100,000). The incidence for lumbar fractures is 0.00008099 (62.3% of 0.00013).

## 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 %: 67 - 100) | 100 | 0.5 | 2 - 23 | 0 - 168 - 336 | 0 | 0 | 0 |
| ISS-based Treatment (worst case scenario %: 0 - 33) | 100 | 1 | 15 - 38 | 0 - 168 - 336 | 0 - 38 | 100 | 0 |
| Untreated Best Case | 0 | 0 | 15 - 38 | 0 - 168 - 336 | 0 - 23 | 0 - 100 | 0 |
| Untreated Worst Case | 0 | 0 | 24 - 60 | 0 - 168 - 336 | 24 - 60 | 100 | 0 |

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

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

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

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

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

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

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

**Scenario Comments**

**Best case scenario is defined as** an uncomplicated non-displaced fracture of the vertebral body, with no dislocation, and mild to moderate pain that responds to analgesics and conservative treatment.

**Worst case scenario is defined** as severe fracture that would require surgical procedure and/or is associated with severe or refractory pain.

**Percentage of worst case versus best case scenario**

Based on Belmont's study 66% (20/30) of injured aviators were treated non-operatively, by different periods of recumbency followed by external immobilization and 33.3 required surgical treatment (Belmont, 2001). To allow for uncertainty, we are estimating 0-33% as our worst case scenario. Thus, the best case scenario estimated range is 67 to 100%.

**Best Case Comments**

Lumbar Spine Fracture functional impairments (FI) calculation follows the IMM severe non-space adaptation template. Lumbar spine regional grid fracture ratings are based on Table 17-4, pp.570-574 (American {American Medical Association, 2008) Whole Person Impairments for Lumbar Spine are the same percentages as the regional grid impairment. Complex Regional Pain (LEI) is based on Table 16-15, p.541. The CRPS (LEI) ratings are then converted to percentage of Whole Person Impairment (WPI), which are based on Table 16-1, p 495 and Table 16-10 pp.530-531. (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)

By definition in Clinical Phase I, FI is 100%. Duration to follow procedures specified in ISS checklist, i.e. physical exam, vital signs, and observation period for the best case scenario, is estimated to be a half hour. During Clinical Phase II, FI is estimated in 2 to 23%. Duration is estimated in 0 to 336 hours, or 0 to 14 days. 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**

Lumbar Spine Fracture functional impairments (FI) calculation follows the IMM severe non-space adaptation template. Lumbar spine regional grid fracture ratings are based on Table 17-4, pp.570-574 (American {American Medical Association, 2008) Whole Person Impairments for Lumbar Spine are the same percentages as the regional grid impairment. Complex Regional Pain (LEI) is based on Table 16-15, p.541. The CRPS (LEI) ratings are then converted to percentage of Whole Person Impairment (WPI), which are based on Table 16-1, p 495 and Table 16-10 pp.530-531. (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)

By definition in Clinical Phase I, FI is 100%. Duration to follow procedures specified in ISS checklist, i.e. physical exam, vital signs, splint, is estimated to be 1 hour. During Clinical Phase II, FI is estimated in 15 to 38%. Duration is estimated in 0-336 hours, or 0 to 14 days. Recovery from spinal fusion surgery may take several weeks; the time estimated is based on the time to EVAC. In Clinical Phase III, full recovery may or may not occur and FI is estimated at 0-38%. EVAC is estimated at 100% to allow for transfer to a definitive care facility if surgery or closed reduction is required. Lumbar spine fractures have not occurred among astronauts on the ground; fractures are a Class IIb or IIC, a medical event manageable with the HMS but may require the astronaut to return at the next available opportunity for further evaluation and treatment, or may necessitate emergent evacuation if condition does not improve or worsens. None of the astronaut corps hospitalizations has been for lumbar spine fracture. (Johnston, 2008) Aviators have required surgical treatment for lumbar spine fracture (Belmont, 2001). LOCL is not expected.

**Untreated Best Case Comments**

Lumbar Spine Fracture functional impairments (FI) calculation follows the IMM severe non-space adaptation template. Lumbar spine regional grid fracture ratings are based on Table 17-4, pp.570-574 (American {American Medical Association, 2008) Whole Person Impairments for Lumbar Spine are the same percentages as the regional grid impairment. Complex Regional Pain (LEI) is based on Table 16-15, p.541. The CRPS (LEI) ratings are then converted to percentage of Whole Person Impairment (WPI), which are based on Table 16-1, p 495 and Table 16-10 pp.530-531. (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)

During Clinical Phase II, FI is estimated in 15 to 50%. Duration is 0 to 336 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 0-23%., EVAC is estimated in 0 to 100% for the untreated best case. By definition LOCL would not be expected for this scenario.

**Untreated Worst Case Comments**

Lumbar Spine Fracture functional impairments (FI) calculation follows the IMM severe non-space adaptation template. Lumbar spine regional grid fracture ratings are based on Table 17-4, pp.570-574 (American {American Medical Association, 2008) Whole Person Impairments for Lumbar Spine are the same percentages as the regional grid impairment. Complex Regional Pain (LEI) is based on Table 16-15, p.541. The CRPS (LEI) ratings are then converted to percentage of Whole Person Impairment (WPI), which are based on Table 16-1, p 495 and Table 16-10 pp.530-531. (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)

During Clinical Phase II, FI is estimated in 24 to 60%. Duration is 72 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 |
|---|---|---|
| Belmont, Jr., 2001 | 2 | BCWC |
| American Medical Association, 2008 | 3 | FI |
| American Medical Association, 2008 | 3 | FI |
| American Medical Association, 2008 | 3 | FI |
| 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 |
|---|---|---|---|---|---|---|
| Blood Pressure Cuff (regular, large) | 0 | 1 | 2 | No | Yes | Measure blood pressure |
| Blood Pressure Monitor | 0 | 1 | 1 | No | Yes | Measure blood pressure |
| CMRS | 0 | 1 | 1 | No | No | To provide support and stability to the spine |
| Dexamethasone (Decadron) 10mg injectable | 0 | 10 | 20 | Yes | Yes | For inflammation and swelling. |
| Nitrile gloves (large, medium, and small) (pair) | 0 | 1 | 30 | Yes | No | Personal Protective equipment for CMO |
| Tylenol (Acetaminophen) 325 mg | 20 | 30 | 150 | Yes | Yes | Pain relief |
| Ultrasound gel (2 packets) | 1 | 1 | 17 | Yes | Yes | For use with ultrasound machine |
| Ultrasound machine | 1 | 1 | 1 | No | Yes | For diagnostics. |
| Valium (Diazepam) 5 mg/mL, 2 mL syringe | 4 | 4 | 2 | Yes | Yes | To mitigate muscle spasm |
| Vicodin HP (Hydrocodone/ Acetaminophen HP) 10 mg/660 mg | 8 | 18 | 30 | Yes | Yes | Pain relief |

**Resource Comments**

The table was revised on 8/1/2011. ISS does not address lumbar spine fractures. All resources included in the table are available on board (MOD, 2011).

Thoracolumbar brace is not available on board; CMRS can be used as an alternative, along with using available equipment to devise support for the head, neck and thoracolumbar spine. Neurogenic or hypovolemic shocks are addressed in separate Clinical Finding Forms.

We added prednisone, CMRS, ace bandage, and tape.

Terrestrial Guidelines recommend triple immobilization, i.e. cervical spine using collar, blocks and tape; log roll transfers. Patients are transferred to a definitive care facility for X-rays, neurological examination, and consultation with neurosurgeon or orthopaedic surgeon. (Parks, 2011) Compression injuries are usually stable. Burst injuries are associated with fall from a height and compress the anterior and middle columns. (Woolard, 2005)

**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 |
| Parks, 2011 | 3 | Resources |

### Level Of Evidence

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

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

## Reference List


| Reference |
| --- |
| American Medical Association. Spine and Pelvis. In: Rondinelli R, editor. Guides to the Evaluation of Permanent Impairment. 6th ed. Chicago: American Medical Association Press; 2008. p. 373-431. |
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