Abdominal Injury Cliff

Branch Baseline

The etiology of terrestrial abdominal injury is typically trauma, which can be classified as penetrating or blunt. Penetrating abdominal injuries that are most frequently caused by firearms or stabbing, while blunt abdominal trauma is secondary to road accidents and falls (Smith, 2005).

Any part of the GI tract may become perforated from a variety of causes. Mortality is high, varying with the underlying disorder and the patient's general health. Esophageal, gastric, and duodenal perforation tend to present suddenly and catastrophically, with abrupt onset of acute abdomen with severe generalized abdominal pain, tenderness, and peritoneal signs. Teatment is with fluid resuscitation, antibiotics, and surgery (Merck Manual, 2007).

Traumatic abdominal injuries—particularly of the liver, pancreas, spleen, and intestines—may develop abscesses, with or without surgery. Treatment is with surgical or percutaneous drainage. Antibiotics are ancillary. Abscesses may form within 1 week of perforation or significant peritonitis. The mortality rate is 10 to 40% depending on the patient's injury and general medical condition (Merck Manual, 2007)

Traumatic injury strikes unexpectedly and has been an inevitable companion of exploration throughout history (Kirkpatrick, 2009). In 1996, Billica and colleagues ranked traumatic injury at the highest level of concern regarding the probable incidence versus impact on mission and health (Billica, 1996).

Abdominal sonography is available for the detection of intraperitoneal fluid in weightlessness. Sites of massive internal hemorrhage may be intrapleural, intraperitoneal, and/or retroperitoneal. On earth, the use of ultrrasound to quickly localize such bleeding has become standard practice. Studies in both parabolic flight and true space suggest that both thoracic and abdominal blood will remain quickly detectable in weightlessness with accuracy. ATLS invasive procedures have been evaluated in the microgravity environment of parabolic flight using a porcine animal model. Use of tissue sealant and intra-peritoneal packs has also been tested. Emergency extra-terrestrial care at the point of injury and stabilization for space-evacuation are possible; however, they pose challenges in a remote environment considering extremely limited on board care and time and transport for evacuation (Kirkpatrick, 2009).

Incidence Data Included in the Model

The model imports the following incidence information from the IMM database: incidence data category, space adaption status, incidence data, incidence and occurrence distribution data and incidence data characteristics. Data category defines the type of data available for incidence calculations (i.e. raw data vs. fixed data). Space adaptation identifies medical events that onset occurs in the first 5 days of flight and does not reoccur. Incidence values vary by data category and define the number of medical events per person-year or medical events per person-at-risk for each medical condition. Incidence values can be modified by crew characteristics such as gender. Modifying characteristics are noted below and incidence values are listed individually for each characteristic. Distributions are assigned to medical events incidence values and occurrences in the model. For each crew member in a given trial, the incidence and number of occurrences of each medical condition are randomly selected from these probability distributions. Detailed descriptions of the distributions are included in the IMM Technical Description Document.

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

Distribution Data	
Incidence:	Gamma
Occurrence:	Poisson

Data Characteristics	
Events:	50447
Person Years:	307006550
Space Flight Incidence Rate (Events / Person Years):	50447 / 307006550 = 0.000164318969741851

Incidence Comments

Terrestrial analogs data are either not comparable (Glover, 1981) (Thomas, 2003)or lacking, i.e. polar exploration. Consequently, terrestrial data is used as a surrogate for risk estimation.

The 2009 incidence rate for abdominal injury is based on the National Trauma Data Bank (American College of Surgeons, 2010). There were 86,978 overall incidents by Abbreviated Injury Scale (AIS - see below) body region-abdomen in 2009 (Table 28). We discounted incidents with mechanisms of injury (Table 19) unlikely to occur among our crew population, e.g. 30% of motor vehicle traffic, 5% of transport/other, 4% of fire arms, 2% of pedal/cyclist, and 1% self inflicted (Table25 Incidents and Case Fatality rate by intent). We estimated that 58% of overall injuries may occur on board, or 50447. The US census resident population estimates for 2009 (U.S.Census Bureau, 2009) 307,006,550 person-year served as denominator. Our incidence is estimated at 0.000164

Abbreviated injury scale - (AIS)

The AIS was originally designed to stratify victims of motor vehicle crashes.

On its own it is not designed to provide any outcome prediction. It forms the basis of the ISS (Injury Scale Score).

It has undergone six revisions since its initial first description in 1971

AIS - 90 has 1300 individual injuries.

The AIS injury severity values are consensus-derived and range from 1 (minor) to 6 (fatal). Only blunt injuries were included in the first AIS.

Injury/AIS Score

1/minor

2/ moderate

3/ serious

4/severe

5/critical

6/unsurvivable

Limitations of AIS:

- Score 5 and 6 represent the "threat to life" associated with an injury and are not intended to provide a comprehensive measure of severity.
- AIS - 90 makes no provision for open or comminuted femoral fractures, important for functional outcome, less important in predicting mortality
- AIS on its own is unable to predict mortality or outcomes.
- AIS assigned rather than derived viz inter and intra rater error.
- AIS not a true scale (ie difference between AIS 1 and 2 is not the same as between AIS 4 and 5).
- **]{Association for the Advancement of Automotive Medicine (AAAM), 2004 18**

Information Regarding Prevention

Disqualifying conditions in the abdomen area include wounds, injuries, scars, or weaknesses of the muscles of the abdominal wall sufficient enough to interfere with function. (NASA, 2007) (International Space Station Program, 2009)

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

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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
American College of Surgeons, 2010	4	Incidence
U.S.Census Bureau, 2009	4	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:	Fixed
Space Adaptation:	No
Incidence Type:	Rate

Distribution Data	
Incidence:	Fixed
Occurrence:	Poisson

Data Characteristics	
Fixed Rate:	0.09

Incidence Comments

A retrospective registry review of all adult trauma patients admitted to Liverpool Hospital (Australia) between January 1996 and December 2003 reported 0.09 admission rate by year for trauma patients with abdominal injuries (Smith, 2005).

The study involved 1224 patients with abdominal injuries. Of these, 969 (79%) were a result of blunt trauma. The main causes were road accidents (61%), interpersonal violence (24%) and falls (7%). There were 1274 intra-abdominal injuries, made up of 607 solid organ (liver (n = 220, 36%), spleen (n = 195, 32%), renal (n = 144, 24%)), 291 hollow viscus (small bowel (n = 160, 55%), large bowel (n = 104, 36%)) and 168 vascular.

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)	100	0.5	3 - 51	24 - 48 - 72	0	0	0
ISS-based Treatment (worst case scenario %: 25)	100	1.5	32 - 74	48 - 108 - 168	0 - 74	100	34 - 100
Untreated Best Case	0	0	32 - 74	24 - 48 - 72	0 - 51	0 - 100	0
Untreated Worst Case	0	0	60 - 93	48 - 108 - 168	60 - 93	100	100

[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 mild or moderate blunt abdominal injury resulting in localized pain/discomfort and/or ecchymosis, with no hollow or solid organ involvement and no evidence of peritonitis or bleeding, requiring only minimal treatment.

The worst case scenario is defined as severe abdominal injury resulting in abdominal cavity injury, which may develop into hemorrhage and/or shock; or a blunt abdominal trauma that causes damage of the internal abdominal organs with secondary complications of shock, peritonitis, and sepsis.

Shock and sepsis are addressed in the Hypovolemic Shock and Sepsis CliFFs respectively.

Percentages of how often best versus worst case scenarios occur were estimated using the NTDB with AIS 3 or greater. (Table 28 incidents by body region) (American College of Surgeons, 2010)22,135 serious or greater abdomen incidents/ 86978 overall abdomen incidents =25%. Based on subject matter expert's opinion (Kerstman, 2010), we are using a single number (25%) rather than a range for this medical condition.

The Abbreviated Injury Scale (AIS) is designed to stratify victims of motor vehicle crashes. It initiated in 1969 and was last revised in 1990. AIS 3 indicates a serious injury. AIS forms the bases of the Injury severity Score (ISS) (Association for the Advancement of Automotive Medicine (AAAM), 2004).

The Injury Severity Score (ISS) stratifies injury severity numerically using a 1 to 75 range (1-8 minor, 9-15 moderate, 16-24 severe and >24 very severe) (American College of Surgeons, 2010).

Best Case Comments

Abdominal injury's functional impairments (FI) calculation follows the IMM severe non-space adaptation template. Liver Disease ratings are based on Table 6-8, p-119 (American Medical Association, 2008). Complex Regional Pain Syndrome-Lower Extremity is based on Table 16-15, p.541 (American Medical Association, 2008). The CRPS (LEI) ratings are then converted to percentage of Whole Person Impairment (WPI), which are based on Table 16-1, p 495 (American Medical Association, 2008). Bleeding disorders are based on Table 9-11, p 205 (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 on impairment grading and calculation 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, and observation period for the best case scenario, is estimated in 30 minutes. During Clinical Phase II, FI is estimated in 3 to 51%. Duration is estimated in 24 to 72 hours. In Clinical Phase III, full recovery is expected and FI is 0%. By definition EVAC and LOCL would not be expected for the best case scenario.

Worst Case Comments

Abdominal injury's functional impairments (FI) calculation follows the IMM severe non-space adaptation template. Liver Disease ratings are based on Table 6-8, p-119 (American Medical Association, 2008). Complex Regional Pain Syndrome-Lower Extremity is based on Table 16-15, p.541 (American Medical Association, 2008). The CRPS (LEI) ratings are then converted to percentage of Whole Person Impairment (WPI), which are based on Table 16-1, p 495 (American Medical Association, 2008). Bleeding disorders are based on Table 9-11, p 205 (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 on impairment grading and calculation 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, intravenous fluids, and ultrasound for the worst case scenario, is estimated in 1.5 hours. During Clinical Phase II, FI is estimated in 32 to 74%. Duration is estimated in 48 to 168 hours (2-7 days), based in Smith's study (Smith, 2005). In Clinical Phase III, full recovery is not expected and FI is 0-74%.

A retrospective study among US Army troops in Iraq (Belmont, 2010)found 27% (17/63) cases of non battle disease and gastro-intestinal injuries required medevac ($p<0.0001$). Of note, the US Army has portable trauma services providing care locally. Because worst case scenario abdominal injury would be considered as a Class IIc medical event, i.e. an event manageable with HMS but may necessitate urgent evacuation if condition does not improve or worsens, or Class III requiring emergent evacuation (Johnston, 2008), we are estimating 100% EVAC.

The US Army (Belmont, 2010) reported 0% deaths, NTDB (American College of Surgeons, 2010)7.8%, Australia (Smith, 2005) 6.7%, and Spain (Rey, 2009)12.5%. Terrestrial data are from trauma centers with high level care. In space with limited on-board care, mortality is expected to be higher. In the US NTDB Emergency Departments discharged 19.34 % to intensive care unit (ICU), and 12.05% to operating room. Data are not stratified by injury site. In Spain, 44% of abdominal trauma were admitted to the ICU; 40% of penetrating injuries required urgent surgery. In Australia, 29% of blunt and 57% of penetrating abdominal injuries required laparotomy. Standard deviation or confidence intervals are not provided. We estimated the lower limit by averaging the number of cases with ICU or surgery admission per country, i.e. 15.69 +42 +43/3, or 33.56 %. Thus our LOCL range is 34 to 100%.

Untreated Best Case Comments

Abdominal injury's functional impairments (FI) calculation follows the IMM severe non-space adaptation template. Liver Disease ratings are based on Table 6-8, p-119 (American Medical Association, 2008). Complex Regional Pain Syndrome-Lower Extremity is based on Table 16-15, p.541 (American Medical Association, 2008). The CRPS (LEI) ratings are then converted to percentage of Whole Person Impairment (WPI), which are based on Table 16-1, p 495 (American Medical Association, 2008). Bleeding disorders are based on Table 9-11, p 205 (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 on impairment grading and calculation refer to the CliFF Appendix A.

During Clinical Phase II, FI is estimated in 32 to 74%. Duration is 24 to 72 hours, similar to the treated best case scenario. In Clinical Phase III, recovery may or may not occur and FI is 0-51%. Based on severity of injury and pain, 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

Abdominal injury's functional impairments (FI) calculation follows the IMM severe non-space adaptation template. Liver Disease ratings are based on Table 6-8, p-119 (American Medical Association, 2008). Complex Regional Pain Syndrome-Lower Extremity is based on Table 16-15, p.541 (American Medical Association, 2008). The CRPS (LEI) ratings are then converted to percentage of Whole Person Impairment (WPI), which are based on Table 16-1, p 495 (American Medical Association, 2008). Bleeding disorders are based on Table 9-11, p 205 (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 on impairment grading and calculation refer to the CliFF Appendix A.

During Clinical Phase II, FI is estimated in 60 to 93%. Duration is 72 to 168 hours (3-7 days), similar to the treated worst case scenario. In Clinical Phase III, recovery is unlikely and FI remains 60-93%. EVAC is estimated in 100%, similar to the treated worst case. LOCL could occur and our estimate is 100% without ATLS and urgent surgical care.

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 College of Surgeons, 2010	4	BCWC
American Medical Association, 2008	3	FI
American Medical Association, 2008	3	FI
American Medical Association, 2008	3	FI
Johnston, 2008	2	EVAC
Belmont, Jr., 2010	2	EVAC

Additional Comments

We searched PubMed using the terms abdominal injury and epidemiology, abdominal injury and microgravity, abdominal injury and astronauts. We refined our search by relevance and dates.

The Resource Table (RT)

Resource	Units Required Best Case	Units Required Worst Case	Units Available At Start Of Mission	Consumable	Essential	Rationale
Blood Oximeter	1	1	1	No	Yes	To monitor vital signs
Blood Pressure Cuff (regular, large)	1	1	2	No	Yes	To measure blood pressure
Blood Pressure Monitor	1	1	1	No	Yes	Measure blood pressure
BZK wipes	0	4	60	Yes	No	Cleanse skin.
CMRS	0	1	1	No	No	Restrain crew member to ensure safety
ECG Monitor (Device, USB Charge Cable, Lead Set Cable, Cue Card)	0	1	1	No	Yes	Measure and monitor ECG
Gauze pads (4x4)	0	25	50	Yes	No	To absorb blood or fluids from skin
IV administration set	0	1	3	Yes	Yes	To provide tubing for administration of IVF through IO set.
IV Cap	0	1	5	Yes	No	IV administration
IV Catheter (18G, 20G, or 22G)	0	1	14	Yes	Yes	IV fluid administration
IV Fluid 1L (1000mL)	0	4	5	Yes	Yes	To replenish fluids
IV Fluid Air Filter	0	1	3	Yes	No	To filter air from IV set
IV pressure infuser	0	1	1	No	No	**For rapid infusion of IV Fluids**
Medical tape	0	1	5	Yes	No	Single-coated tapepressure adhesive tape
Needle (23G)	0	1	20	Yes	Yes	To draw medication from vial
Needle [25g]	0	1	4	Yes	Yes	Rocephin administration
Nitrile gloves (large, medium, and small) (pair)	0	3	30	Yes	No	Personal Protective equipment for CMO
Pack of 12 ECG electrodes	0	1	5	Yes	Yes	Measure and monitor ECG
Rocephin (Ceftriaxone) 1 GM	0	1	3	Yes	Yes	Antibiotic
Sharps container	0	1	40	No	No	To dispose of medical waste such as used medical needles, scalpels, IV catheters, razors, vials
Stethoscope	1	1	2	No	Yes	To listen to lung,heart, and bowel sounds, to blood flow in arteries and veins
Syringe (3cc)	0	1	20	Yes	Yes	Rocephin administration
Thermometer	1	1	1	No	No	To measure temperature
Tourniquet	0	1	1	No	No	To stop blood flow and engorge vein, this facilitates IV insertion

Resource	Units Required Best Case	Units Required Worst Case	Units Available At Start Of Mission	Consumable	Essential	Rationale
Tylenol (Acetaminophen) 325 mg	8	0	150	Yes	Yes	Pain relief
Ultrasound gel (2 packets)	2	2	17	Yes	Yes	For diagnostic purposes
Ultrasound machine	1	1	1	No	Yes	For diagnostic purposes
Urine chemstrips	0	1	10	Yes	Yes	To rule out hematuria
Urine Color Chart	0	1	1	No	No	To rule out hematuria
Vicodin HP (Hydrocodone/ Acetaminophen HP) 10 mg/660 mg	0	12	30	Yes	Yes	Pain relief

Resource Comments

The Table was revised on November 15, 2010 .

Notes: We added Lidocaine, carpuject, needle 18g, and needle 22g.

All resources are available in the ISS medical checklist (Mission Operations Directorate (MOD), 2011).

Required Resources Level of Evidence (LOE)

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

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

Level Of Evidence

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

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

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