

Small Bowel Obstruction Cliff

Branch Baseline

Postoperative adhesions and strangulated hernias are the most common causes of small bowel obstruction, while a variety of conditions, like cancer, diverticulitis, volvulus, constipation and inflammatory bowel disease, can cause large bowel obstruction (Dahl, 2011)

For the IMM, only cases of small bowel obstruction secondary to post-operative adhesions are considered. Therefore, this medical condition only applies to crew members with a history of abdominal surgery.

The common symptoms are pain (colicky at first), abdominal distension, vomiting, - and after some time absence of flatus and stool, vomiting and dehydration. It is essential to identify the patient with threatening or actual strangulation of the bowel. This is suggested by a sharper, more constant and more localized pain, and the patient have often fever and signs of peritonitis (diffuse tenderness, guarding). (Dahl, 2011)

A bowel obstruction is an emergency and requires medevac (Dahl, 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:	Fixed
Space Adaptation:	No
Incidence Type:	Rate

Distribution Data

Incidence:	Fixed
Occurrence:	Poisson

Data Characteristics

Fixed Rate:	0.0048
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Incidence Comments

Postoperative adhesions are a significant problem after colorectal surgery. The Surgical and Clinical Adhesions Research Study has investigated the scale of the problem in a population of 5 million from the Scottish National Health Service Medical Record Linkage Database. This study involved adhesion related re-admissions after open surgery on the small intestine, appendix, colon, rectum and abdominal wall; duodenal surgeries were included with the small intestinal category, over a period of 15 years, starting in 1986. The incident cohort of patients undergoing lower abdominal surgery was then followed during a ten year period for readmissions for defined outcomes, i.e., subsequent hospital admissions for adhesion-related disease or further abdominal surgery unrelated to adhesions but which could be potentially complicated by adhesions from previous surgery. The rate of readmission directly related to adhesion was 0.057 (5.7 per 100 initial procedures) during ten years. Twenty five percent of readmissions were during the first postoperative year; however, readmissions continued to occur steadily during the ten years studied (Parker, 2001). Since it is unlikely that astronauts would be certified for flight within one year of abdominal surgery, the incidence rate for small bowel obstruction is calculated based on post-operative years 2 through 10. Therefore, the incidence rate is estimated as 0.0048 events/person-year.

Information Regarding Prevention

Selection criteria

Disqualifying conditions include in general, any medical condition that, in the judgment of the MSMB, may compromise mission operations, performance of duties, or crew health or safety. In abdomen and digestive systems: chronic diseases or disorders of the alimentary tract that interfere with performance of duties; wounds, injuries, scars or weaknesses of the muscles of the abdominal wall sufficient to interfere with function; chronic gastritis or chronic abdominal pain, history of gastrointestinal surgery for malignant or recurrent conditions, history of intestinal obstruction due to any chronic or potential recurrent disease. History of obstruction due to adhesive disease may be reviewed for certification with Special Consideration by the MSMB after a 10-year observation period. (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
Parker, 2001	4	Incidence

Alternative Incidence Data

Analog populations

Glover reported 1 bowel obstruction aboard UK Polaris submarines, during the period 1968-1978. The incidence was estimated to be 1 surgical patient per 7,944 man-days (0.000125×365) 0.045 person-years. No EVAC was reported (Glover, 1981)

Tansey reported medical events in US submarines. There were 2 small bowel obstruction events during the period 1968-73, causing 7 sick days (Tansey, 1979). We estimated the incidence rate $0.000165 (2/4,410,000 \text{ man-days} \times 365 \text{ days/1 year})$. There were EVACS for surgical conditions but they are not segregated by condition (Tansey, 1979).

Nice reported two evacuations at sea caused by intestinal obstruction (Nice, 1984)

There is anecdotal report of 1 medevac from Antarctica due to bowel obstruction (US Antarctic Projects Officer, 1961).

Non Analog populations

Cases of small bowel obstruction caused by postoperative adhesions were obtained from electronic medical records at an Asian hospital. The 155 patients had had a total of 293 admissions, from January 1999 to December 2001, with 1 patient being admitted 11 times. The interval between initial laparotomy and subsequent admissions varied widely. The shortest was 2 weeks, while the longest approached 30 years. Of the 293 admissions, medical management alone was used during 220 (75.1 %) admissions. Repeat laparotomy was performed in 73 admissions. The duration of observation until resolution of bowel obstruction ranged from 2 to 12 days (average 6.9 days) (Shih, 2003)

Treatment and Outcomes

Based on the best evidence available best and worst case percentage ranges are assigned. The medical condition is divided into three clinical phases in all three clinical phases a functional impairment is assigned. The clinical phase I and II's functional impairments remain for the duration for that respective clinical phase. The function impairment in clinical phase III represents final impairment for this medical condition and remains for the rest of the mission. Other mission end states include evacuation and loss of crew life.

The IMM checks medical resource availability once the number of medical events and scenarios has been established. If there is not sufficient essential resources called out in the ClIFF, then the medical condition will go down an untreated best or worst case scenario pathway.

The table below summarizes the treated and untreated best and worst case scenarios.

	Clinical Phase I Diagnosis & Initial Treatment ¹		Clinical Phase II On-going Treatment / Convalescence ²		Clinical Phase III Recovered / Mission End State ³		
	FI* (%)	Duration (hrs)	FI* (%)	Duration (hrs) (Min - ML - Max)	FI* (%)	EVAC** (%)	LOCL** (%)
ISS-based Treatment (best case scenario %: 75 - 100)	100	1	2 - 28	24 - 72 - 120	0	5 - 93	0
ISS-based Treatment (worst case scenario %: 0 - 25)	100	1 - 1.5	17 - 50	24 - 96 - 168	17 - 50	100	0 - 10
Untreated Best Case	N/A	N/A	17 - 50	24 - 72 - 120	0 - 28	0 - 100	0
Untreated Worst Case	N/A	N/A	31 - 76	24 - 96 - 168	31 - 76	100	0 - 100

¹Clinical 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".

²Clinical 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.

³Clinical 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 an uncomplicated course of small bowel obstruction which responds to conservative medical treatment (antibiotics and symptomatic treatment) and involves relatively minor functional impairment.

The **worst case scenario** is defined as having a complicated course of small bowel obstruction that is not responsive to conservative treatment and involves significant systemic symptoms, such as severe pain, such as fever, leukocytosis, tachycardia, elevated BUN, serum amylase or alkaline phosphatase, metabolic acidosis and a major functional impairment.

Complicated bowel obstruction may progress to sepsis which is addressed in the Sepsis ClIFF

The percentages of how often best versus worst case scenarios occur were determined based on a study of cases of small bowel obstruction caused by postoperative adhesions 75.1% of admissions were managed by medical treatment, while surgery was performed in almost 24.9% . Of note, the study reported that 27 of 73 procedures, 9.2%, were for treatment of intestinal complications. It is possible that some of the 46 remaining surgical cases might have recovered during a longer observation period. The patients chose to undergo surgery mainly because they became inpatient with medical treatment (Shih, 2003). Based on these data, the worst case scenario is estimated to occur in 0-25% of cases thus making the best case scenario 75-100%.

Best Case Comments

Small Bowel Obstruction is not included in the AMA Guides to the Evaluation of Permanent Impairment. We derived the Functional Impairment (FI) by using the IMM severe non-space adaptation condition template. We are deviating from the template in the treated worst case, Clinical Phase III, where FI is estimated to remain unchanged from clinical Phase II because by definition of worst case scenario, a response to conservative treatment is not expected. Colonic and Rectal disorders ratings are based on Table 6-5, p.114. 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. Final FI ratings are calculated combining the Colonic and Rectal FI and Whole Body Impairment using the Combined Values Chart as indicated in Appendix A, pp 604-606 (American Medical Association, 2008). For further description of gradings and calculations refer to this ClIFF Appendix.

In **clinical phase I**, by definition a 100% FI is recognized. The duration of this phase is estimated to be 60 minutes, which encompasses use of the ISS Medical Checklist for examination and diagnosis of the affected crewmember. In **clinical phase II FI is estimated at 2 to 28%**. Duration for conservative treatment ranged from 2-14 days, with an average of 5.9 days (Shih, 2003). We are estimating 24-120 hours for this scenario. For **clinical phase III**, the signs and symptoms are expected to resolve with medical therapy (IV antibiotics, IV fluids, and other medications), with the FI returning to 0%.

Medical treatment could delay the need for definitive surgical care until evacuation or completion of the mission. EVAC has occurred in submariners (Nice, 1984) and Antarctica (US Antarctic Projects Officer, 1961). It is assumed that with a physician CMO and with the currently available medical resources on ISS, a maximum of 48 hours of conservative treatment would occur prior to considering evacuation. In the Shih study (Shih, 2003), 15 of 220 cases (7%) responded to conservative treatment within 48 hours. In the Chen study (Chen, 2005), approximately 95% of cases responded to conservative treatment within 48 hours. Therefore, it is estimated that 7% to 95% of best case scenarios would respond to conservative treatment and not require evacuation. Conversely, it is estimated that 5% to 93% of best case scenarios would require evacuation. LOCL is not expected in the best case scenario since by definition, best case scenarios respond to conservative medical treatment.

Worst Case Comments

Small Bowel Obstruction is not included in the AMA Guides to the Evaluation of Permanent Impairment. We derived the Functional Impairment (FI) by using the IMM severe non-space adaptation condition template. Colonic and Rectal disorders ratings are based on Table 6-5, p.114 (American Medical Association, 2008). 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 (American Medical Association, 2008). Final FI ratings are calculated combining the Colonic and Rectal FI and Whole Body Impairment using the Combined Values Chart as indicated in Appendix A, pp 604-606. (American Medical Association, 2008). For further description of gradings and calculations refer to this ClIFF Appendix.

By definition in Clinical Phase I, FI is 100%. Duration to follow procedures specified in ISS checklist, i.e. physical exam, vital signs, intravenous fluids, and ultrasound for the worst case scenario, is estimated in 1.5 hours. During Clinical Phase II, FI is estimated in 17 to 50%. Duration is estimated in 24 to 168 hours (2-7 days), based in Shih's study and the time to EVAC. EVAC has occurred in submariners (Nice, 1984) and Antarctica (US Antarctic Projects Officer, 1961). In Clinical Phase III, FI is estimated to remain at 17 to 50% because by definition of worst case scenario, a response to conservative treatment is not expected. Worst case scenario bowel obstruction would be considered as a Class III event requiring emergent evacuation (Johnston, 2008), thus we are estimating 100% EVAC. A complicated case of small bowel obstruction is considered to be a medical emergency in which the obstruction has progressed to intestinal ischemia, gangrene, and/or perforation. These are life threatening emergencies that may require urgent resuscitation and surgical intervention. These complicated cases of small bowel obstruction may result in loss of crew life. Published studies (Shih, 2003); (Miller, 2000), (Mucha, 1987)) indicate that complicated cases of small bowel obstruction occur in 6% to 9% of total cases. The Duron study (Duron, 2006) reported a mortality rate of 3%, and other prior studies have reported mortality rates between 0% (Shih, 2003) and 7.2 to 9.8% (Menzies, 2001). Therefore, to account for uncertainty, LOCL is estimated as 0% to 10%.

Untreated Best Case Comments

Small Bowel Obstruction is not included in the AMA Guides to the Evaluation of Permanent Impairment. We derived the Functional Impairment (FI) by using the IMM severe non-space adaptation condition template. Colonic and Rectal disorders ratings are based on Table 6-5, p.114 (American Medical Association, 2008). 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 (American Medical Association, 2008). Final FI ratings are calculated combining the Colonic and Rectal FI and Whole Body Impairment using the Combined Values Chart as indicated in Appendix A, pp 604-606. (American Medical Association, 2008). For further description of gradings and calculations refer to this ClIFF Appendix.

In **clinical phase II**, the FI is estimated to range from 17 to 50%, The **duration** for the untreated case is 24 to 48 hours, similar to the treated scenario, assuming evacuation will take place within this timeframe. For **clinical phase III**, **FI range is estimated at 0 to 28%** depending on the severity of symptoms in the course of the untreated disease. **Clinical phase III mission end state results** include EVAC, which is estimated to be 0-100%, based on the fact that EVAC is required for a Class IIc medical condition if it does not improves or worsens (Johnston, 2008). Complication of small bowel obstruction may lead to sepsis. LOCL is estimated to be 0%.

Untreated Worst Case Comments

Small Bowel Obstruction is not included in the AMA Guides to the Evaluation of Permanent Impairment. We derived the Functional Impairment (FI) by using the IMM severe non-space adaptation condition template. Colonic and Rectal disorders ratings are based on Table 6-5, p.114 (American Medical Association, 2008). 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 (American Medical Association, 2008). Final FI ratings are calculated combining the Colonic and Rectal FI and Whole Body Impairment using the Combined Values Chart as indicated in Appendix A, pp 604-606. (American Medical Association, 2008). For further description of gradings and calculations refer to this ClIFF Appendix.

In the clinical phase II FI ranges from 31 to 76%. The **duration** for the untreated case is 24 to 168 hours assuming evacuation will take place within this timeframe.

In **Clinical Phase III** FI remains 31 to 76%. Clinical phase III mission end state results include EVAC, which is estimated to be 100%, based on the fact that EVAC is required for a Class III medical condition (Johnston, 2008). LOCL is estimated to be 0-100% to allow for uncertainty based on untreated disease.

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
Shih, 2003	4	BCWC
American Medical Association, 2008	3	FI
Nice, 1984	2	EVAC
American Medical Association, 2008	3	FI
American Medical Association, 2008	3	FI
Johnston, 2008	2	EVAC
Menzies, 2001	4	EVAC

The Resource Table (RT)

Resource	Units Required Best Case	Units Required Worst Case	Units Available At Start Of Mission	Consumable	Essential	Rationale
BZK wipes	3	25	60	Yes	No	Cleanse skin
CMRS	1	1	1	No	No	Restrain crew member to ensure safety
Dexamethasone (Decadron) 10mg injectable	0	5	20	Yes	Yes	For inflammation of lungs
Dilaudid (Hydromorphone) 2mg/mL, 1mL syringe	3	9	18	Yes	Yes	Pain relief
Ertapenem 1gm	0	6	6	Yes	Yes	Antibiotic
Gauze pads (4x4)	2	2	50	Yes	No	to absorb blood or fluids from skin
IV administration set	1	1	3	Yes	Yes	IV Fluids infusion
IV Cap	1	1	5	Yes	No	To maintain IV when not in use.
IV Catheter (18G, 20G, or 22G)	1	1	14	Yes	Yes	IV fluid administration
IV Fluid 1L (1000mL)	4	4	5	Yes	Yes	to replenish fluids
IV Fluid Air Filter	1	1	3	Yes	No	To filter air from IV line
IV pressure infuser	1	1	1	No	No	IV Fluids infusion
Lidocaine (Xylocaine) plain 1%, 10mL multi dose vial	0	6	3	Yes	Yes	To decrease pain during ertapenem administration
Medical tape	1	1	5	Yes	No	single-coated tape pressure adhesive tape
Needle (23G)	1	1	20	Yes	Yes	To draw medication from vial
Sharps container	1	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
Suction Tubing - Gastric Tube	1	1	1	Yes	Yes	To decompress bowel
Syringe (3cc)	4	4	20	Yes	Yes	To flush iv line as needed
Syringe (60mL)	1	1	1	Yes	Yes	to verify placement of gastric tube and to pull stomach contents.
Thermometer	1	1	1	No	No	To measure temperature
Tourniquet	1	1	1	No	No	To stop blood flow and engorge vein, this facilitates IV insertion

Resource Comments

In-flight Treatment(s): Antibiotics are available for treatment of acute intra-abdominal infections and analgesics are available for abdominal pain (Mission Operations Directorate (MOD), 2011). The condition, Small Bowel obstruction is not included in the ISS medical checklist (Mission Operations Directorate (MOD), 2011).

Of note, for Metronidazole and Rocephin; treatment of one crew member would deplete the total on-board supply. Dosage used in this table considers the available medications.

Treatment follows the Bologna clinical guidelines for diagnosis and management of Adhesive Small Bowel Obstruction (Catena, 2011) Metronidazole was added as recommended by the Guidelines issued by the Infectious Diseases Society of America (Solomkin, 2003).

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
Catena, 2011	3	Resources
Solomkin, 2003	3	Resources

Level Of Evidence

Input Data	LOE Average	Description	Range
Incidence	4	Excellent	1-2
Functional Impairment	3	Good	2.1-3
Best Case / Worst Case	4	Fair	3.1-4
EVAC / LOCL	2.66666666666667	Poor	4.1-5
Resources	2.66666666666667		
QUALITY OF EVIDENCE	3.26666666666667		

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