Sudden Cardiac Arrest Cliff

Branch Baseline

In Sudden Cardiac Arrest (SCA) the heart suddenly and unexpectedly stops beating. If this happens, blood stops flowing to the brain and other vital organs (Maron, 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:	Fixed
Space Adaptation:	No
Incidence Type:	Rate

Distribution Data	
Incidence:	Fixed
Occurrence:	Poisson

CAC Data Characteristics	
Fixed Rate:	0.0001

Non-CAC Data Characteristics	
Fixed Rate:	1.5E-05

Incidence Comments

CAC = 0 [Non-CAC Record]

100>CAC>0 [CAC Record]

Incidence data was derived using estimated acute myocardial infarction (AMI) likelihoods in out-of-hospital sex-adjusted groups age 48-65 without Framingham risks for coronary artery calcium (CAC) score of 0 or 100>CAC>0 (Gillis DB, 2012). Gillis and Hamilton (Gillis DB, 2012) assumed that among all potential AMIs in space, 50% would present as out of hospital (OOH) SCA based on findings from Zipes (ref 24 in Gillis DB 2012) and others noting that AMI of coronary artery disease origin presents as OOH SCA in approximately 50% of events. Thus 50% of the AMI likelihood values obtained from Table III [Gillis DB 2012] were used to assign SCA values for CAC = 0 (0.5*0.00003 events per person-year) and 0>CAC>100 (0.5*0.0002 events per person-year) (Gillis DB, 2012). These same likelihood values were reported for “hard events” (coronary heart disease death, nonfatal myocardial infarction) on sex-adjusted subgroups with an age range of 40-65 yr and CAC scores of 0 or 100>CAC>0 (Lamonte, 2005) . These studies (Gillis DB, 2012) (Lamonte, 2005) , extend beyond the age of the astronauts resulting in a conservative estimate of the AMI.

Although preferable to enlist analogue cohorts that match the astronaut cohort, no population exists; no astronaut has experienced sudden cardiac arrest (SCA). The average age of United States astronauts in 2002 was 44 $\pm$ 6.7 years for women and 44.5 $\pm$ 5.6 years for men. Their ten year risk of acute myocardial infarction is less than that of age- and gender-matched cohorts (Hamilton, 2005).

Information Regarding Prevention

Selection Criteria

NASA Medical Standards for ISS Crew Members list causes for rejection due to risk factors for heart disease include a history or evidence of hypertrophy, hypertension, pericarditis, myocarditis, endocarditis, congenital abnormalities, and a history of coronary artery disease, clinically significant cardiac dysrhythmias, or valvular disorders (Department of Defense, 2005). While the current mission selection standards require a CAC<100 for ISS crew members selection is another important mitigation strategy. These standards and vigorous cardiac health maintenance programs aid in reducing the likelihood of an AMI (Gillis, 2011).

Other

Periodic and pre-flight testing includes cardiovascular risk marker lab testing, resting ECG, exercise stress testing, and a 24 hour Holter monitor. Astronauts have an ongoing cardiovascular conditioning program and pre-flight aerobic functional capacity testing (International Space Station Program Medical Standards for ISS Crewmembers Working Group, 2009) (MSMB Working Group, 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
Gillis DB, 2012	4	Incidence
Hamilton, 2005	3	Incidence

Alternative Incidence Data

The challenge of screening sudden cardiac death is limited means of identifying individuals, rather than populations, at risk. Genetic and molecular risk factors are new measures currently being explored. Until effective risk recognition methods are available, prevention with an automatic external defibrillators and early interventions remains important (Zipes, 2005).

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 %: 0 - 37)	100	1	5 - 58	24 - 48 - 72	0 - 100	100	0
ISS-based Treatment (worst case scenario %: 63 - 100)	100	1 - 2	30 - 82	1 - 12.5 - 24	100	0	100
Untreated Best Case	0	0	30 - 82	24 - 48 - 72	0 - 100	100	0 - 100
Untreated Worst Case	0	0	60 - 100	1 - 12.5 - 24	100	0	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

Based on Gillis' research article Astronaut Cardiac Risk in Space, scenarios derived from Stiell's studies show that there are dismal salvage probabilities for asystole (0.2-0.3%) and Pulseless Electrical Activity (1.1-2.5%) . Survival rates were 36.7% for patients with ventricular tachycardia/ ventricular fibrillation initial rhythms which were EMS witnessed and shocked rapidly. Therefore, the estimated best case percent is 0-37% (Gillis, 2011).

The **best case scenerio** is defined as a crew member who experiences a sudden cardiac arrest and responds to the ACLS treatment protocol.

The **worst case scenario** is defined as a crew member who experiences sudden cardiac arrest and does not respond to the ACLS treatment protocol.

Best Case Comments

The functional impairments (FI) calculation for this condition follows the IMM Severe (nonSA) Medical Conditions template for Clinical Phase II (Kerstman, 2010)and in Clinical Phase III differs from it to account for severity of outcomes. Dysrhythmias, coronary artery disease (CAD) and central nervous system: consciousness and awareness conditions are combined for the determination of the FI, According to the template in Clinical Phase II the FI follows Class 1-2 in the Guide to the Evaluation of Permanent Impairment, which translates to 2-23% Whole Person (WP) for both dysrhythmias and CAD, and 1-30% for consciousness and awareness. Once the scores are combined the CPII is 5-58% WP impairment for duration of 24-72 hours. While in Clinical Phase III the FI is 0-100% WP impairment (American Medical Association, 2008), (American Medical Association, 2008), (American Medical Association, 2008). Consequently, the outcomes in Clinical Phase III are 0% chance of LOCL and 100% EVAC. Although the affected crewmember survives, they will need to be evacuated to a definitive care facility for further treatment.

Worst Case Comments

The IMM Severe (nonSA) Medical Conditions template (Kerstman, 2010)is used in Clinical Phase II throughout the functional impairment determination of this condition. Also dsyhythmias, coronary artery disease (CAD) and central nervous system: consciousness and awareness conditions are combined for the determination of the FI as well. According to the template in Clinical Phase II the FI follows Class 2-3 in the Guide to the Evaluation of Permanent Impairment, which translates to 11-40% Whole Person (WP) for both cardiac conditions, and 11-50% for consciousness and awareness. Once the scores are combined the CPII is 30-82% WP impairment for duration of 1-24 hours. While in Clinical Phase III the FI, deviates to account for the condition outcome. 100% WP impairment (American Medical Association, 2008), (American Medical Association, 2008), (American Medical Association, 2008). Consequently, the outcomes in Clinical Phase III are 0% risk of EVAC and 100% LOCL (Gillis DB, 2012). The timeliness of rapid defibrillation after SCA is critical to the outcome. In the ISS, with a 3-person crew, daily activities will strongly influence the interval to recognition of an SCA. By definition in a worst case scenerio the crew member did not respond to the ACLS treatment protocol. EVAC is not required since the crew member has not survived the event.

Untreated Best Case Comments

The functional impairments (FI) calculation for this condition follows the IMM Severe Non-Space Adaptation Medical Conditions template during Clinical Phase II (Kerstman, 2010). Dysrhythmmias, CAD, and central nervous system: consciousness and awareness are combined for the determination of the FI. According to the template in Clinical Phase II the FI follows Class 2-3 in the Guide to the Evaluation of Permanent Impairment, which translates to 11-40% Whole Person Impairment (WPI) for dysrhythmmias and CAD each, while 11-50% for consciousness and awareness (American Medical Association, 2008), (American Medical Association, 2008), (American Medical Association, 2008). Once the scores are combined the CPII is 30-82% WPI for duration of 24-72 hours. While in Clinical Phase III the FI is 0-100% WPI. Consequently, the outcomes in Clinical Phase III are 0-100% risk of LOCL and 0-100 % EVAC. This accounts for the uncertainty of the outcome without treatment (Gillis DB, 2012).

Untreated Worst Case Comments

The functional impairments (FI) calculation for this condition follows the IMM Severe Non-Space Adaptation Medical Conditions template during Clinical Phase II (Kerstman, 2010). Dysrhythmias and CAD, and central nervous system: consciousness and awareness are combined for the determination of the FI. According to the template in Clinical Phase II the FI follows Class 3-4 in the Guide to the Evaluation of Permanent Impairment, which translates to 24-65% Whole Person Impairment (WPI) for both cardiac conditions and consciousness and awareness 31-100% WPI. When the FI are combined the WPI equals 60-100% (American Medical Association, 2008), (American Medical Association, 2008), (American Medical Association, 2008) for duration of 24-72 hours. While in Clinical Phase III the FI deviates from the template to account for the expected outcome of this condition if untreated, 100% WPI. Consequently, the outcomes in Clinical Phase III are 0% risk of EVAC and 100% LOCL (Gillis DB, 2012). By definition in a worst case scenario the crew member did not respond to the ACLS treatment protocol. EVAC is not required since the crew member has not survived the event.

Treatment and Options Level of Evidence (LOE)

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

Citation	LOE Value	LOE Category
American Medical Association, 2008	3	FI
American Medical Association, 2008	3	FI
American Medical Association, 2008	3	FI
Gillis DB, 2012	4	BCWC
	4	EVAC

Additional Comments

Pubmed keyword searchs include myocardial infarction, AED, epidemiology, arrthymias, lethal arrthymias, ardiovascular risk markers and heart desease.

In microgravity there is no collapsing fall to alert other crew members.

The Resource Table (RT)

Resource	Units Required Best Case	Units Required Worst Case	Units Available At Start Of Mission	Consumable	Essential	Rationale
Adrenaline (Epinephrine 1:10000) 10mL	1	4	4	Yes	Yes	Symnpathometic vasopressor that increases heart rate and constricts blood vessels
AED	1	1	1	No	Yes	Automatic diffibralator that will shock patients based on cardiac rhythm.
Ambu bag and mask	1	1	1	No	Yes	hand-held device used to provide positive pressure ventilation to a patient who is not breathing or is breathing inadequately
Blood Oximeter	1	1	1	No	Yes	monitors the oxygen saturation of a patient's blood
Blood Pressure Cuff (regular, large)	1	1	2	No	Yes	Measure blood pressure
Blood Pressure Monitor	1	1	1	No	Yes	Measure blood pressure
BZK wipes	4	12	60	Yes	No	Cleanse skin.
CMRS	1	1	1	No	No	Restrain crew member to ensure safety
ECG Monitor (Device, USB Charge Cable, Lead Set Cable, Cue Card)	1	1	1	No	Yes	Measure and monitor ECG
Endotracheal Stylet	1	1	1	No	Yes	Assist with advanced airway placement
Endotracheal Tube 7.0/8.0	1	1	4	Yes	Yes	Establish and maintain patent airway and ventilation.
EtCO2 Monitor with EMMA adapter	1	1	1	No	Yes	Measure end tidal CO2
Gauze pads (4x4)	0	2	50	Yes	No	to absorb blood or fluids from skin
Intraosseous Device Starter Kit	1	1	1	Yes	Yes	Provide access for fluid and medication
Intraosseous Injection device	1	1	2	Yes	Yes	Provide access for fluid and medication.
IV administration set	1	1	3	Yes	Yes	IV tubing for administration of IV fluids
IV Cap	1	1	5	Yes	No	To maintain IV when not in use
IV Fluid 1L (1000mL)	2	2	5	Yes	Yes	To provide IV hydration and to get emergency medications into bloodstream.
IV Fluid Air Filter	1	1	3	Yes	No	To filter air from IV line
IV pressure infuser	1	1	1	No	No	Applys pressure to IV to administer fluid in microgravity
Ketamine 50 mg/mL, 10 mL multi dose vial	0.3	0.3	6	Yes	Yes	For sedation in case of intubation/ventilation.
King Supraglottic Airway (SGA) Tube (size 3/size 4)	1	1	2	Yes	Yes	Establish and maintain patent airway and ventilation.

Resource	Units Required Best Case	Units Required Worst Case	Units Available At Start Of Mission	Consumable	Essential	Rationale
Laryngoscope (blade)	1	1	1	No	Yes	For intubation
Laryngoscope handle	1	1	1	No	Yes	For intubation
Medical tape	0.1	0.1	5	Yes	No	single-coated tapepressure adhesive tape
Nasal Airway (6mm, 7mm)	1	1	2	No	Yes	Establish and maintain patent airway and ventilation.
Needle (23G)	0	3	20	Yes	Yes	For medication administration
Nitrile gloves (large, medium, and small) (pair)	1	1	30	Yes	No	Personal Protective equipment for CMO
Oral Airway	1	1	2	No	Yes	Establish and maintain patent airway and ventilation.
Pack of 12 ECG electrodes	1	1	5	Yes	Yes	Measure and monitor ECG
PEEP Valve	1	1	1	No	Yes	Provides positive airway pressure during ventilation
SGA Cue Card	1	1	1	No	Yes	Guidance for use of supraglottic airway
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 Cartridge	1	1	1	No	Yes	Provide airway suctioning
Suction device	1	1	1	No	Yes	to clean out secretions or vomit
Suction device collection bag	1	1	2	Yes	No	To collect fluids suctioned from mouth/airway
Suction device syringe	1	1	1	No	Yes	to remove fluids, secretions, vomit from mouth
Suction tip - mouth (curette)	1	1	1	No	Yes	used for suction by inserting into the end of a suction tube
Suction Tubing - Endotracheal Tube	1	1	1	Yes	Yes	Provide airway suctioning
Surgical Lubricant	1	1	6	Yes	No	Provide lubrication during the ILMA insertion.
Syringe (35cc)	1	1	1	Yes	Yes	Inflation of SGA
Syringe (3cc)	0	3	20	Yes	Yes	For medication administration.
T-adapter	1	1	1	No	Yes	Connection for ventilation tubing
Thermometer	1	0	1	No	No	measure temperature
Tongue depressor	1	1	20	Yes	No	Aids in visualizing vocal cords
Valium (Diazepam) 5 mg/mL, 2 mL syringe	0	1	2	Yes	Yes	For sedation with intubation

Resource	Units Required Best Case	Units Required Worst Case	Units Available At Start Of Mission	Consumable	Essential	Rationale
Variable Oxygen System	1	1	1	No	Yes	gas delivered to assist resuscitation of patient
VOS Intubated Patient Hardware (Ventilator/Respirator)	0	1	1	No	Yes	Mechanical Ventilation

Resource Comments

The source of the resource table data was derived from teh ISS Medical Check List (International Space Station Integrated Medical Group, 2008).

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
International Space Station Integrated Medical Group, 2008	2	Resources

Level Of Evidence

Input Data	LOE Average
Incidence	3.5
Functional Impairment	3
Best Case / Worst Case	4
EVAC / LOCL	4
Resources	2
QUALITY OF EVIDENCE	**3.3**

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

Reference List

Reference
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