Exploration Medical Capability
Medical Scenarios

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Baseline

National Aeronautics and Space Administration
Lyndon B. Johnson Space Center
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Exploration Medical Capability
Medical Scenarios

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CHANGE HISTORY

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Change/ Revision	Date	Description of Change	Pages Affected
Baseline	September 2021	Baseline Document	All

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1.0 INTRODUCTION

Medical systems supporting exploration class missions to cislunar space, the lunar surface, and the vicinity of Mars require an evolution in medical capability beyond that available for today's low Earth orbit centric paradigm. Progress in developing more capable medical systems will be driven by the requirements of prolonged mission duration, increasing distance from Earth, and the realities of orbital mechanics, all necessitating a concomitant need for progressively Earth independent medical decision-making capabilities. These medical systems (which include the crewmembers) are expected to be capable of evaluating, diagnosing, treating and managing a defined list of medical conditions as well as addressing unanticipated medical conditions that may arise.

The prioritized medical capabilities and associated resources needed to treat these medical conditions and support anticipated inflight medical events provide robust content that informs system designers and allows for a more complete evaluation of both medical and overall mission risk. Communication of these medical capabilities to system, vehicle, and mission designers can be enhanced using scenarios that characterize the system's operations. Carefully considered scenarios provide the context needed to explore expected human and system interfaces, roles of ground and inflight crew (including periods of interrupted or delayed communications), identify training needs, assess data needs, etc.

Mission-based scenario content varies dependent upon the needs, medical capabilities, conditions and context they are intended to illustrate. This document explicitly seeks to capture and codify those scenarios that have been useful to the Exploration Medical Capability Element of the Human Research Program in defining the enhanced medical systems required for future space exploration. It is expected that this document will continue to evolve through the refinement and characterization of current and future scenarios, respectively, as our knowledge grows, and requirements increasingly focus on Earth independent spaceflight operations.

1.1 CHANGE AUTHORITY AND PARENT DOCUMENT

This document will be controlled by the Exploration Medical Capability Control Board

2.0 MEDICAL DECISION-MAKING ALGORITHM

When managing a patient with a medical condition – especially one requiring immediate or emergency, life-saving care – medical decision-making can often come across as perplexing, arbitrary, non-rigorous, hurried, and ultimately, very confusing from an outsider's perspective. This perspective is more common amongst laypersons who do not have the requisite medical training, experience, or who are not aware of the particular context of the clinical situation.

This dilemma is not aided by the fact that medical providers undergo extensive training that enables them to efficiently collect and interpret data, derive viable differential diagnoses, interpret multisource data streams, and transmit and consult with other providers. Practicing clinicians must settle on a likely diagnosis and appropriate treatment plan, arrange for a myriad

of resources to bring to bear to the situation, and perform these collective tasks all within short time frames and oftentimes incomplete information on the patient's illness or injury. These skills, and more importantly the ability to act on limited or constrained data, are crucially important in clinical decision-making and allow for the definitive and rapid execution, tracking, reevaluation, and integration of oftentimes disparate results, allowing providers to deliver their assessments intuitively and without any obvious outward facing or visible algorithmic methodology.

It is held as a common truth that such veiled (but more so "internal") processes are often necessary because of the serious nature and timing of the clinical situation. This is often best exemplified in the actions of clinicians caring for patients in trauma response situations in that emergency provider decision and actions must be undertaken rapidly and "subconsciously" so as to give patients in such situations the best chance for survival and positive outcomes when lost seconds or missed opportunities to intervene dictate survival, permanent incapacitation, or demise. Understandably, this lack of an obvious observable "clinical assessment" methodology can be confusing. The clinician's "process" can be especially bewildering to and among individuals with diverse, non-medical backgrounds who are not yet familiar with, exposed to, or well versed in the rigors of health care delivery where clinically focused critical decision-making is employed to make life and death decisions on a routine basis.

Given this context, it is important to realize that underlying the intuitive and subconscious decision-making of clinical practitioners there are very specific patterns, sound logic pathways, and scientifically based methodologies undergirding their actions. These patterns are algorithmic in nature and are universally taught within the medical communities. They are taught in health care professional schools, internships, residencies, and hospitals, and are understood and endorsed by practitioners of different backgrounds, specialties, training and cultures. They are used regularly and consistently regardless of disease process of concern and are describable using practical terms.

Thus, it should be feasible to identify and define these methodologies in a way that helps to elucidate and illuminate the processes of medical decision-making for non-medical operatives. Such an effort could be undertaken so as to facilitate the adaptation of these processes for improved medical tool development. Further, such efforts would likely positively impact the generation and confirmation of more robust medically/clinically centric risk analyses resulting in improved operational and health/performance related needs assessments for emerging mission profiles.

With this concept in mind the goal of this paper is to attempt to outline an algorithm that describes, in easy-to-understand language, the intuitive methodologies used by medical practitioners. These methodologies are employed to evaluate, assess, diagnose, develop and execute a treatment plan, and, where possible evaluate a treatment's effectiveness and adjust accordingly as the clinical situation dictates.

Initially the purpose of designing a medical decision-making algorithm was to develop a tool that could be employed for designing medical scenarios and used, for example, in developing operational simulation training. This document outlines the processes followed in the development of an initial algorithm equipped with specific narratives used to describe a particular set of clinical scenarios that represent medical conditions that are likely to occur during a deep space mission. It further describes the steps that would be needed to mitigate the related medical contingencies. By designing and describing these scenarios within clinically-based narratives, the algorithm is based in a story telling framework that allows for more natural descriptions while simultaneously demonstrating the need for more robust medical capabilities to address the most likely and clinically relevant issues that would be expected to arise during a deep space mission.

Initial iterations of the algorithm started with emergency medical procedures, drawing from EMT (pre-hospital) and ACLS standard medical procedures and algorithms. The algorithm was designed as a block flow diagram to make it easier to understand, with each block describing an engineering task or step in the clinical assessment. The purpose of the diagram was to describe not only the stepwise approach a clinician takes to make medical decisions, but also identify the ancillary parts surrounding the clinical decision-making process: what are the knowledge, tools, and resources that are used to support clinical decision-making. Because of this, subcategories were used for each block to identify the Summary, Decision, Information Source, Resources, Functionality, and Training needed for that block or step. This process functions to capture the critical and ancillary parts of the clinical decision-making process. These subcategories were developed in collaboration with the ExMC Systems Engineering Team.

From initial iterations describing emergency medical procedures, the algorithm was then expanded to include non-emergency medical care and procedures. The goal of this iterative process was to create a comprehensive, step-by-step, disease-agnostic algorithm that could support a non-clinician through the medical decision-making process required to provide care for any medical contingency. From there, this algorithm was used to describe how these decision-making processes may be executed for specific test cases. To this end, the finished algorithm (described in section 3.0) was implemented to describe the management for multiple medical scenarios believed to be of high operational concern for future deep space missions. Descriptions of these medical scenarios and the resulting management descriptions are laid out below.

Though initially designed to provide simulation cases for operational training and demonstration cases that highlight the need for a robust medical capability for deep space missions, it was quickly realized that developing this algorithm – and with it, the subsequent clinical case scenarios – provides a unique and highly useful tool for informing various engineering questions with regards to future vehicle and crew support systems design. Objective and in-depth descriptions of the medical decision-making process, and how associated methodologies can be used to derive various mission critical medical scenarios, is highly advantageous as it allows engineers to deconstruct such process, to make trade analyses

of the different pieces of the clinical decision-making process, and, ultimately, to use these components to inform design requirements for the development of future mission hardware and software.

Though the clinical scenarios designed with the help of the medical algorithm were originally intended specifically for simulating medical contingencies in a test environment – and therefore structured to employ story-telling for the purposes of demonstrating the need for a robust medical capability for deep space missions, the detail of these clinical scenarios and the narratives embedded within them have proved useful for systems engineering modeling and for answering specific engineering centered questions. An example of this "medical algorithm - story telling - systems engineering modeling" pathway was carried out to determine the upper bound communication bandwidth requirements for a worst-case medical contingency scenario during a Mars Transit Design Reference Mission.

For the above-mentioned test case, the algorithm was used to provide detailed information for a particular medical scenario regarding a step-by-step approach to what data was gathered, when, by what method (via numerous camera positions, etc.), how that data was relayed to the ground, and the timing and content of the transmitted data sent, processed and analyzed, and then retransmitted back to the crew. This test case process was run specifically on two medical scenarios thought to be very data intensive and likely to represent, again, "worst-case" medical situations where timing of communications could play a critical role in mission success.

The first scenario was a medical contingency case and the other was focused on behavioral health. These themes were selected because they were assessed to represent potential "worst case" scenarios, of sufficient medical complexity, that would require high rates of transfer of medical data back and forth from ground. This would help inform an upper bound for data transfer rates needed to support critical, medical system intensive contingencies.

The medical scenario describes a case of impacted renal stone with the development of urosepsis. This specific scenario was chosen because of the plausibility of such a medical contingency during a deep space mission. Additionally, this scenario requires a high rate of medical data collection and transfer to the ground especially during the initial hours of the medical event when the patient needs to be stabilized and imaging data is collected, transmitted, analyzed and retransmitted to the crew with instructions for treatment.

The behavioral health case chosen involved the hypothetical death of a child of one of the crewmembers. This particular scenario was chosen because of its extreme complexity in terms of the emotional, behavioral, and logistical burdens placed on the affected crew member, the crew at large, the supporting ground team and the crew member's Earth-based family-support group. For this scenario, the key factors of practical consideration involve logistics and the large amount of communication bandwidth that would be needed among the affected crewmember and their family-support group, the ground communications team, and with the support of terrestrially-based behavioral health assets.

Once the narratives for these scenarios were fleshed out, the communications team was subsequently able to identify the discrete components of the scenario narrative and its resulting treatment plan, in particular those that involved communication transfer and storage. From that information an estimation was made of the needed data transmission and storage requirements for a vehicle utilized for a Mars Transit DRM. To determine these requirements certain assumptions were made regarding which data types would be utilized based on their sources, as well as length, transmission time, and data transfer rates. For example, each Just In Time Training module utilized was assumed to be roughly 20 minutes in length and consist of a 1440 x 1080p high-definition video transmitted at 30fps, which equals roughly 7.5 MB/sec data transfer rates required to exchange the data within a 10 min period (All assumptions for data file sizes and transfer rates can be found in the communications paper referenced below).

For these worst-case test scenarios, assumptions regarding data file sizes and transfer rates were combined with the sections within the narrative where data transfer was identified as needed. This allowed estimates of data transfer requirements (including burst rates, overall storage needs and data transfer rates) for specific periods within the selected medical contingency. Once determined, these data estimates can be used to inform future vehicle requirements for data storage and data transfer rate needs. This ensures that future vehicles will have the ability to include a robust medical capability for deep space missions.

This example case highlights the potential power of this tool to inform future engineering design questions, such as the communications question described above. Such tools will make it possible to integrate future medical systems seamlessly into vehicle design to ensure that the needed medical capabilities are included. In so doing, this will help protect against the risk that has historically existed where human health, performance, and medical capabilities are incorporated more or less as an afterthought when finalizing vehicle designs and mission parameters, resulting in insufficiently robust capabilities to manage a medical contingency should it occur during a deep space mission. Ensuring that human health, performance, and medical capabilities are adequately robust will become increasingly important as we move to longer and longer duration deep space missions where the probability of medical events over the course of the mission increase dramatically. This will be especially important as medical evacuation becomes increasingly difficult and eventually impossible.

3.0 ALGORITHM

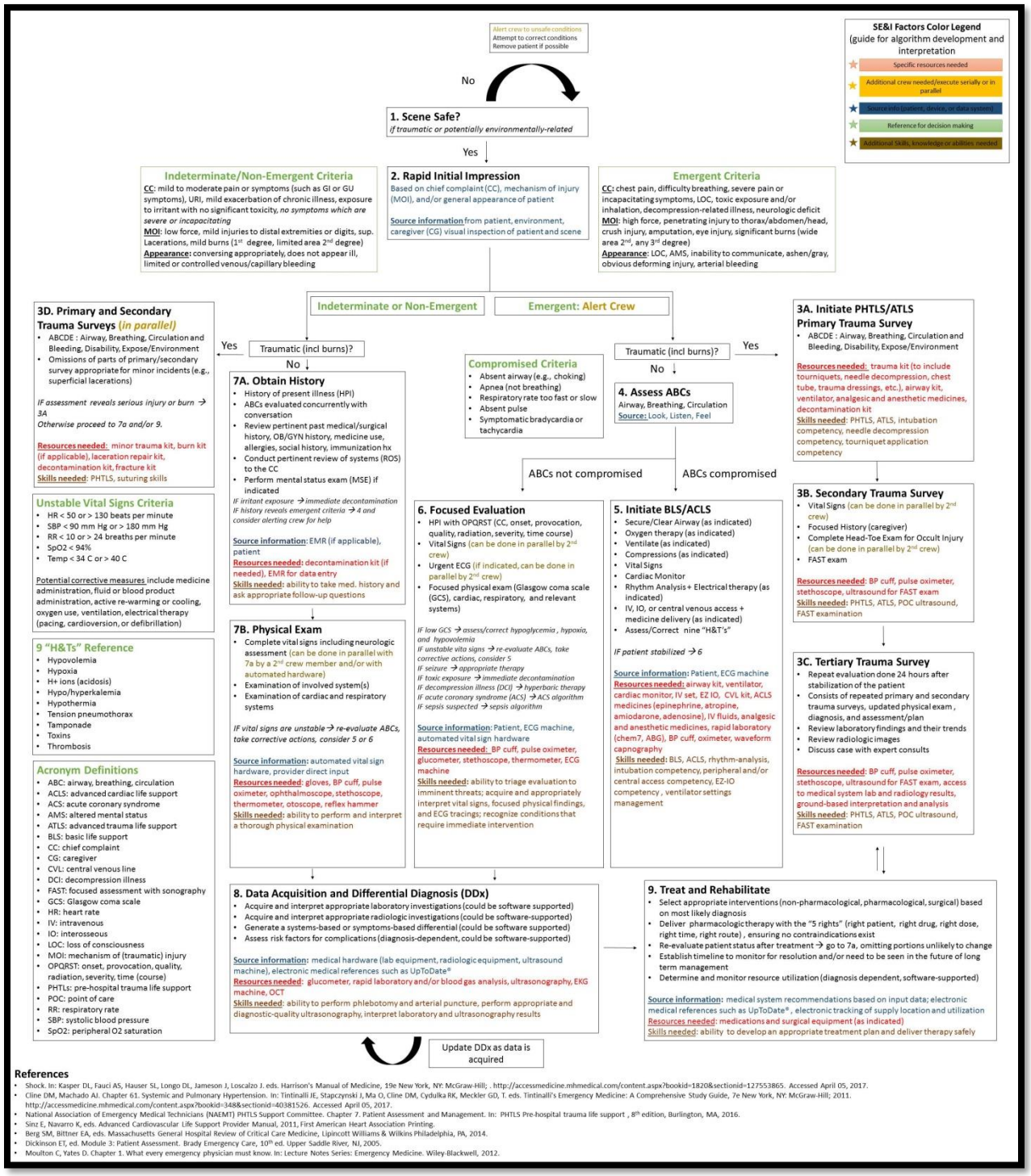

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FIGURE 1 ALGORITHM STEPS

4.0 EXERCISE

Mission Phase	Level of Care	Occurrence	Operation
Transit – IVA	V- Autonomous	Planned	Self-Care

4.1 EXERCISE SCENARIO NARRATIVE

The medical system sends an alert to a crewmember's personal monitor that she has an upcoming scheduled exercise session on the treadmill. She changes into her workout clothes and moves to the treadmill in the exercise module. The crewmember activates the medical system via the treadmill user interface, which uses biometric analysis to identify her and display her personal exercise prescription. After donning her treadmill harness and attaching the loading mechanisms, she notifies the medical system that she is ready to begin her exercise.

After the loading devices reach their set point, the treadmill belt starts moving and she starts running. Sensors embedded into the treadmill and harness measure her physical exertion, including running speed, step force exerted on the treadmill, and her vital signs. Upon completion of her exercise session, the medical system stores this data in her personal health record. She disconnects the loading mechanism and stows the treadmill harness. She then heads back to the hygiene station to get cleaned up and continue with the rest of her workday.

Upon receipt of the crewmember's exercise-related data, the medical system processes the information and generates a personalized interpretation, which is also stored within the crewmember's health record. The medical system detects a change in the crewmember's heart rate data but determines that it is within normal limits. No action is required, but a flag is placed in her record for the caregiver to read at his next crew status review.

The medical system coordinates with the vehicle's communication system to downlink the crewmember's updated health record and synchronize the onboard and ground electronic health systems.

4.1.1 EXERCISE ALGORITHM APPLICATION

Block 1 – Scene Safe - Skip (not applicable)

Block 2 – Rapid Initial Impression -Skip (not applicable)

Block 3 – Primary Surveys -Skip (not applicable)

Block 7A – Obtain History - Skip (not applicable)

Block 7B - Physical Exam – Skip (not applicable)

Block 8 – Data Acquisition and Differential Diagnosis	
Summary	Crewmember is prompted to perform an exercise prescription, which is recorded.

Decision	Heart rate variation is noted during exercise; although not emergent, a flag is placed in the chart for the caregiver to review
Info. Source	• Exercise equipment • Hardware for remote vital sign analysis
Resources	• Exercise prescriptions to counteract the effects of weightlessness appropriate to each crewmember (and how to design such an exercise program) • References on exercise physiology
Functionality	• Medical system scheduling system integrated with crew exercise • Medical system integrated with exercise equipment • Medical system integrated with remote vital sign monitoring during exercise sessions • Medical system stores variables related to exercise • Medical system can place flags for exercise-related measurements for physicians to review • Exercise prescription entry → schedule alerts for crewmembers
Training	• Interpretation of exercise related variables • Proper form and technique for prescribed exercises • Exercise equipment use and maintenance

Block 9 – Treat and Rehabilitate - Skip (not applicable)

4.1.2 EXERCISE REFERENCE INFORMATION

Exercise Prescription Error! Reference source not found.,Error! Reference source not found.	
Exercise	• Aerobic: Running, Cycling, Rowing, Elliptical, Stepping • Resistance: Squats, Deadlifts, Presses, Pulls
Duration Sets & Reps	• Aerobic: Time, often in intervals (for example, first 7 minutes of 30 minutes) • Resistance: # of sets and # of repetitions ("reps") per set • Heavy: 4 sets, 6 repetitions • Medium: 4 sets, 8 repetitions • Light: 4 sets, 12 repetitions
Intensity	• Aerobic: Expressed in % VO_2max, maximum HR, or METS (see below) • Resistance: Expressed in % 1 RM (see below)
Frequency	The number of times per week the exercise routine is to be performed.

Exercise Concepts Error! Reference source not found.,Error! Reference source not found.	
VO_2	Oxygen uptake, measured in liters per minute (L/m). Oxygen is necessary for efficient metabolic production of energy used by exercising muscles.
VO_2max	The highest rate of oxygen that can be taken up and utilized by the body. VO_2max is often used to represent the cardiorespiratory fitness of an individual. VO_2max increases with physical fitness training. Exercise requiring VO_2 just below VO_2max can be sustained for relatively long times.

Maximum HR	The predicted maximum heart rate an individual can achieve based on age. Maximum HR does not generally change as a result of physical fitness training, although resting HR does. $\mathbf{Maximum\ HR = 208 - (0.7 * age)}$ **Error! Reference source not found.**
# RM	Maximum number of times a load can be lifted before fatigue. 1 RM would mean one repetition before fatigue; **%** 1 RM is percent of total resistance an individual can lift one time. 1 RM is usually measured before beginning an exercise routine, although it needs to be periodically re-evaluated to account for strength increase during training.
METS	Metabolic equivalent used to estimate oxygen requirement per kg per minute, baselined to the resting metabolic requirement of 3.5 mL O_2/kg body weight/minute. 1 MET is considered resting, 2 METs is level walking at 2mph, 4 METS is level walking at 4 mph.**Error! Reference source not found.**
LT	Lactate threshold: the point at which aerobic consumption of oxygen is insufficient to meet metabolic energy demand, driving pyruvate → lactic acid production.

Table VIII. NASA's Expeditions 18–25 Sample ARED Exercise Protocols.

A. ARED macro cycle.*

RESISTANCE (% 1 RM)	HEAVY (4 × 6)	LIGHT (4 × 12)	MEDIUM (4 × 8)	HEAVY (4 × 6)	LIGHT (4 × 12)	MEDIUM (4 × 8)
70	1	2	3	2	3	1
75	3	1	2	1	2	3
80	2	3	1	3	1	2
85	1	2	3	2	3	1
90	3	1	2	1	2	3
95	2	3	1	3	1	2
100	1	2	3	2	3	1
105	3	1	2	1	2	3
110	2	3	1	3	1	2
115	1	2	3	2	3	1
120	3	1	2	1	2	3
125	2	3	1	3	1	2

*The numbers 1, 2, and 3 refer to the individual exercise sessions listed in Table VIIIB.

B. Cycle of ARED exercises sessions where each session represents an individual exercise period.

SESSION 1	SESSION 2	SESSION 3
Back Squat	Sumo Squat	Single Leg Squat
Heel Raise	Heel Raise	Sumo Deadlift
Deadlift	Deadlift	Romanian Deadlift
Romanian Deadlift	Shrug	Upright Row
Shoulder Press	Bench	Bicep Curl
Bent-over Row	Tricep Extension	Single Arm Row

FIGURE 2 EXAMPLE RESISTANCE EXERCISE PROTOCOLERROR! REFERENCE SOURCE NOT FOUND.

5.0 DENTAL EXAMINATION

Mission Phase	Level of Care	Occurrence	Operation
FD365 (unknown)	**V - Autonomous**	**Planned**	**Passive - Directed**

5.1 DENTAL EXAMINATION SCENARIO NARRATIVE

Having just passed the FD365 mark, Flight Engineer 1 (FE1) is notified via the Medical system that he is due for an annual dental exam. FE2, as the CMO is also notified that this exam is required. FE1 and FE2 plan a mutually agreeable time for the exam and meet in the medical bay.

5.1.1 DENTAL EXAMINATION ALGORITHM APPLICATION

Block 1 – Scene Safety	
Summary	There is an upcoming, planned visit without a preceding acute event
Decision	Scene is safe, proceed to rapid initial assessment (**Block 2**)
Info. Source	CP situational awareness
Resources	None
Functionality	MS schedule functionality and notification
Training	• Triage • Scheduling

Block 2 – Rapid Initial Assessment	
Summary	Planned medical visit for an annual dental examination and the CM has no complaint
Decision	Based on chief complaint, this is in-determinant/non-emergent → proceed to H&P (**Block 7A and 7B**)
Info. Source	Reference criteria for emergent/non-emergent conditions
Resources	None
Functionality	None
Training	Triage

5.2 DENTAL EXAMINATION SCENARIO NARRATIVE:

FE2 queries the medical system for information about past dental exams and treatments. He interviews FE1 about oral health and asks if there have been any problems with his mouth or teeth since the last exam and then documents the history in the medical system.

5.2.1 DENTAL EXAMINATION ALGORITHM APPLICATION

Block 7A – Obtain History	
Summary	• The chief complaint (“CC: scheduled dental examination”) and history of present of illness are obtained from the patient and appropriately documented. • CP reviews dental history and last dental exam.

	• CP reviews PMHx, PSHx, FMHx, current medications, medication allergies. • CP conducts an appropriate Review of Systems (ROS).
Decision	• There is no history of irritant exposure or evidence of emergency, thus the CP remains in the non-emergent section of the algorithm. • After necessary data is obtained and recorded, CP proceeds to physical examination (**Block 7B**).
Info. Source	• Patient verbal account of his symptoms as prompted by CP questions. • Prior medical encounters. • Prior intraoral photography. • Prior radiologic evaluation (x-rays including full mouth series – FMS/FMX – and most recent bitewing – BW – views and their "readings"). • Other historical data. • Standardized forms for routine dental evaluation for an exploration mission.
Resources	• Suggested questions/data to elicit from the CM for a dental-related history. • Dental reference texts. • Dental radiology reference material.
Functionality	• MS opens new encounter for the CM for a dental examination. • MS provides easy access to historical document review. • MS records interview and displays it in the encounter and allows CP to manually edit voice-to-text input. • MS suggests provides reference material for suggested/required information to gather from the patient.
Training	• History taking. • Data entry into medical system. • Interpretation of dental radiologic evaluation. • Familiarity with standard dental notation.

Block 7A, continued– Appropriate Questions and Review of Systems Error! Reference source not found.Error! Reference source not found.Error! Reference source not found.،Error! Reference source not found.	
CC	The chief complaint for a planned visit is often just "follow up for (visit reason)" or "scheduled visit for (visit reason)." However, the patient may have decided to delay reporting acute symptoms until their planned visit. This may require the provider to ask questions regarding their acute symptoms as well as questions regarding the reason the visit was originally scheduled for.
Dental-related history taking	General Dental HPI: • Any specific dental concerns? • Any pain? • Any sores? • Any swelling?

	• Temperature sensitivity? • Difficulty opening or closing jaw? • Popping or clicking sensations? • Broken or chipped teeth? • Trauma or injury to the jaw, teeth, or face? • Change in taste? • Teeth grinding? Review of current dental hygiene habits – brushing, flossing, fluoride use, mouth wash (and document if any hygienic habit causes pain or bleeding). Dental history: • Last dental appointment? • History of cavities? • History of gum disease? • History of/current use of bisphosphonates? • History of/current use of NSAIDs or aspirin? • History of wisdom teeth extraction?
ROS	Fevers? Chills? Headache? Dizziness? Dry eye? Dry mouth? Sore throat? Difficulty or painful swallowing? Hoarseness or loss of voice? Sinus congestion or drainage? Ear pain? Easy bleeding?

5.3 DENTAL EXAMINATION SCENARIO NARRATIVE

Next, FE2 inspects the oral cavity and teeth and records results in the Medical System. Still images of the oral cavity, teeth and gums are captured and uploaded to the Medical System.

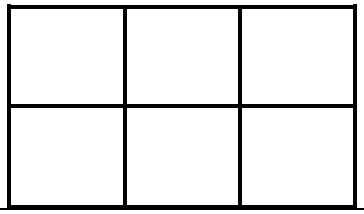
5.3.1 DENTAL EXAMINATION ALGORITHM APPLICATION

Block 7B – Physical Exam Error! Reference source not found.,Error! Reference source not found.	
Summary	After appropriate subjective data acquisition, the CP decides to proceed with the examination. Appropriate physical examination in this scenario includes the following: • Vital signs • General mental status (whether the patient is alert and oriented to person, place, and time) Extra-oral examination: skin, face, lymph nodes, salivary glands, thyroid, TMJ, cranial nerves Intra-oral examination: • Periodontal examination utilizing periodontal screening and recording system (PSR – see references) if time-limited or full periodontal charting if requested by ground or PSR is positive (see references), examination of the teeth for caries • Occlusal examination and maximum jaw opening diameter (in cm) • Additional examinations could include cardiovascular and pulmonary systems.
Decision	Routine dental examinations are generally incomplete without appropriate data acquisition (especially imaging) → proceed to data acquisition (**Block 8**)
Info. Source	• Automated import of vital signs

	• CP interpretation of the physical exam and subjective history given by the patient and reviewed on the medical system
Resources	• Dental examination references • Caries detection aides (if applicable, for example, trans-illumination and/or fluorescence) • Dental kit, Stethoscope, Penlight, tools needed for manual vital signs acquisition in event of automated vital sign acquisition failure
Functionality	• MS in appropriate data entry mode for dental examination • MS has templates for dental examination findings • Voice-to-text for medical encounter documentation • MS can receive, record, and display automated vital signs but allows for editing if needed by the CP
Training	• General physical examination • HEENT and Dental examination • Appropriate dental notation

5.3.2 DENTAL EXAMINATION REFERENCE INFORMATION

NOTE: This documentation uses Universal Numbering System for designating tooth number. Other systems exist, such as the ISO system, but are predominantly used internationally.**Error! Reference source not found.**

Periodontal Screening and Recording Error! Reference source not found.,Error! Reference source not found.
R  **L**
• Codes are entered for each box from the right (patient's right) to leftmost boxes. • Only the highest code is recorded for each sextant. • Top row is for the maxillary jaw (right sextant, central sextant, left sextant) and bottom row is for the mandible (right sextant, central sextant, left sextant). • The right and left sextants contain 5 teeth (2 premolars and 3 molars) and the central sextant contains 6 teeth (2 central incisors, 2 lateral incisors, 2 cuspids). • Screening is considered positive if any sextant has a code 3 or 4; positive screens require full mouth periodontal examination. • Asterisks should be addressed in the "treat and rehabilitate" section. • Code 0: No bleeding, no subgingival calculus, no defective margins, sulcus < 3.5 mm • Code 1: Bleeding occurs after probing, no subgingival calculus, no defective margins, sulcus < 3.5 mm

- Code 2: Subgingival calculus and/or defective margins are present. Sulcus < 3.5 mm
- Code 3: Sulcus 3.5 mm – 5.5 mm
- Code 4: Sulcus > 5.5 mm
- Asterisk (*): asterisk added to any code if there is furcation involvement, tooth mobility, mucogingival problems, or recessions extending > 3.5 mm
- X: patient is edentulous in this sextant (no teeth)

Complete Periodontal Examination **Error! Reference source not found.Error! Reference source not found.**

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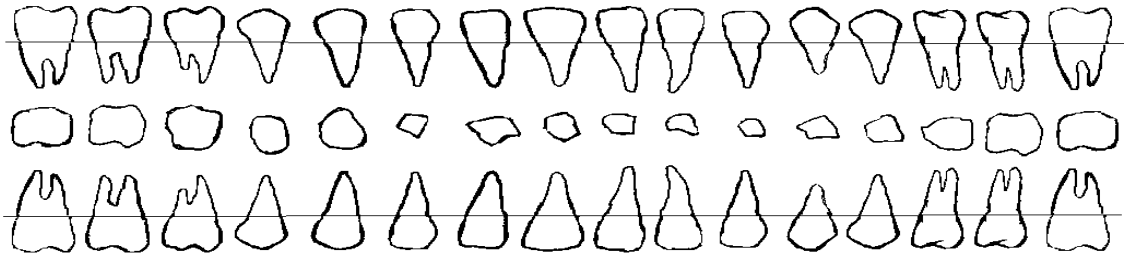

Lingual

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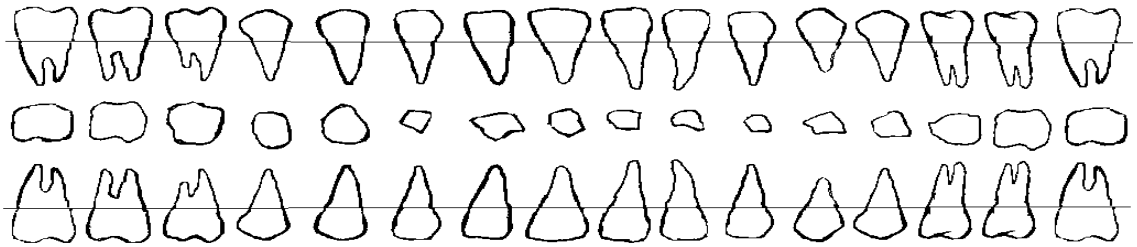
Buccal																
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PD																
CAL																
BOP																
M																

***PD**: Probe/pocket depth. Three measurements per side (buccal/lingual) for total of 6 per tooth. Recorded in millimeters.*
***CAL**: Clinical attachment level. Distance from the cementoenamel junction (CEJ) to base of sulcus. Calculated as PD + recession. Three measurements per side. Reported in millimeters.*
***BOP**: Bleeding on probe, reported as yes or no.*
***M:** Mobility, reported by grade. Grade I is slight, Grade II is moderate, grade III is severe facial-lingual mobility plus apical displacement.*
***F**: Furcation, meaning bone loss among multi-rooted teeth. Grade I is incipient, Grade II is probeable bone loss, Grade III is through-and-through, Grade IV is gingival recession and through-and-through (marked directly on roots)*

International Caries Detection and Assessment System (ICDAS)Error! Reference source not found.	
General Location	**Severity Codes**
• Pits and fissure • Smooth surface • Caries adjacent to restorations and sealants (CARS) • Root	• Code 0 – sound tooth surface • Code 1 – first visual change in enamel • Code 2 – distinct visual change in enamel • Code 3 – localized breakdown without visible dentin • Code 4 – underlying dentin or shadow visible • Code 5 – distinct cavity with visible dentin • Code 6 – extensive distinct cavity with visible dentin

5.3.3 DENTAL EXAMINATION ALGORITHM APPLICATION

Block 8 – Data Acquisition and Differential Diagnosis	
Summary	The physical examination is only remarkable for a need for routine cleaning. The CP however needs to preform imaging for complete documentation.
Decision	Obtain appropriate imaging → thereafter proceed to treatment (**Block 9**)
Info. Source	• CP interpretation of subjective (history) and objective (physical exam, images, labs) data • Appropriate reference material • Ultrasound, photography, x-ray (if available)
Resources	Appropriate reference texts, including medical, dental, and pharmaceutical references
Functionality	• MS provides guidance on imaging appropriate for a routine dental examination • MS can import imaging and ultrasound into the encounter
Training	• Dental imaging • Interpretation of routine dental examination findings

5.4 DENTAL EXAMINATION SCENARIO NARRATIVE

FE2 removes tartar and plaque and then finally polishes the teeth, records the treatment in the medical system. Later that day, the medical system transmits the updated information to the ground.

5.4.1 DENTAL EXAMINATION ALGORITHM APPLICATION

Block 9 – Treat and Rehabilitate	
Summary	The CP recognizes the need for routine dental cleaning
Decision	Proceed with intervention
Info. Source	• CP knowledge/training of dental screening and therapy • Dental references
Resources	• Dental kit • Appropriate References
Functionality	• MS system open to “assessment and plan” section of the encounter • MS saves encounter after provider completes documentation and saves it for transmission and future viewing
Training Error! Reference source not found.	Oral diagnosis, pain control, local dental anesthesia, dental infection therapy, placement of temporary fillings, tooth extraction, and bleeding control

5.5.1 DENTAL EXAMINATION REFERENCE INFORMATION

Sample Dental Kit[7]	
• Anesthesia aspirating dental syringe • Anesthesia carpule – 3% mepivacaine HCl, 4% articaine HCl with 1:100,000 epinephrine • Anesthesia syringe needle 27-gauge long • Cavity filling material (suggested Cavit-G) • Capping material (suggested Dycal) • COGSWELL-A elevator • Cotton balls, rolls, and pliers • Examination gloves • Excavator	• Explorer • Extraction elevator no. 301 • Extraction forces no. 150 and 151 • Front surface dental mouth mirror • Gauze/sponge • Handheld light • Instrument disinfection packets • Periodontal scaler • Woodson plastic instruments

6.0 HEADACHE

Mission Phase	Level of Care	Occurrence	Operation
Transit – IVA	**V- Autonomous**	**Unplanned**	**Self-Care**

6.1 HEADACHE SCENARIO NARRATIVE

For the past few hours, a crewmember has been experiencing a headache of moderate intensity that he recognizes as typical of those he has had in the past. Given that he has no other symptoms, he decides that there is no need to involve the CMO and will self-treat with acetaminophen, as he had for the previous headaches. He accesses the medical system and logs his current problem and his desire for acetaminophen. The medical system quickly cross-checks the vehicle's inventory system and determines that the acetaminophen supply is adequate and verifies that it is not contraindicated for this patient. It then dispenses the proper acetaminophen dose to the patient, who secures and swallows the pills and washes them down with some water from a drink bag. The medical system updates the patient's health record with this new event, logs the medication administered, and updates the vehicle's inventory tracking system. It also coordinates with the vehicle's communication system to downlink the patient's updated health record and synchronize the onboard and ground electronic health systems.

6.1.1 HEADACHE ALGORITHM APPLICATION

Block 1 – Scene Safety	
Summary	A CM has been having a headache for a few hours; he has had this headache before, believes it does not require physician attention, and proceeds to the medical system to enter request for acetaminophen.

Decision	In this scenario, the scene is safe but the decision is made by the CM and the MS and not the CMO. For certain complaints that could be related to environmental conditions, such as headache, the MS could record environmental parameters.
Info. Source	• Environmental monitoring and alarm system • CM self-assessment of condition
Resources	Reference material for chief complaints commonly related to environmental conditions
Functionality	MS checks chief complaint against environmental parameters to determine scene is safe and no action is needed; if environmental parameters have changed (even if still within normal limits), it makes sense to log this for physician review.
Training	• CM access to and use of the MS • CM training on what symptoms to report urgently to physician

Block 2 - Skip (not applicable)

Block 3 - Skip (not applicable)

Block 7 - Skip (not applicable)

Block 9 – Treat and Rehabilitate	
Summary	After logging his condition, verifying supply, and ensuring no contraindication exists, the CM is given access to the requested medication
Decision	Approve over the counter acetaminophen
Info. Source	• Medication tracker • CM logged medical complaint • List of contraindications for medications available
Resources	None
Functionality	• Medical system tracks medication supply • Medical system allows appropriate access to medications to CM without physician oversight • Medical system logs CM use of medical system • Medical system can check contra-indications, maximum daily dose prior to dispensing • Medical system can provide CM information on dose and frequency of over the counter medications
Training	CM access and use of the MS

6.1.2 HEADACHE REFERENCE INFORMATION

Acetaminophen Dose – Contraindications Error! Reference source not found.	
FDA boxed warning	"Risk of medication errors and hepatotoxicity (injection): • Take care when prescribing, preparing, and administering acetaminophen injection to avoid dosing errors that could result in accidental overdose and death. In particular, be careful to

	ensure the following: the dose in milligrams and milliliters is not confused; the dosing is based on weight for patients less than 50 kg; infusion pumps are properly programmed; and the total daily dose of acetaminophen from all sources does not exceed maximum daily limits. • Acetaminophen has been associated with cases of acute liver failure, at times resulting in liver transplant and death. Most of the cases of liver injury are associated with the use of acetaminophen at doses that exceed the maximum daily limits, and often involve more than 1 acetaminophen-containing product."
Dosing (Adult)	• Regular strength: 650mg q4-6 hours. Maximum daily dose: 3250 mg • Extra strength: 1000mg q6 hours. Maximum daily dose: 3000mg • Extended-release: 13000mg q8h. Maximum daily dose: 3900mg
Contraindications	Allergy to acetaminophen

Headache 'Red Flags' Error! Reference source not found.,Error! Reference source not found.
• Vision changes including vision loss, blurry vision, or double vision • Sudden onset, severe headache • Nausea or vomiting • Fever or chills • Weakness • Changes in sensation • Headache is unlike prior headaches • Cough worsens the headache

7.0 URINARY TRACT INFECTION (UTI)

Mission Phase	Level of Care	Occurrence	Operation
Transit	**V**	**Unplanned**	**Contingency - Directed**

7.1 UTI SCENARIO NARRATIVE

For a few days, a crewmember had been experiencing burning with urination, bladder/pelvic discomfort, fatigue, and an increase in urination frequency. Concerned, he tracks down the Physician Astronaut, explains his problems, and requests an appointment. The two head over to the medical bay and the Physician Astronaut grabs the medical display, which uses biometric analysis to identify her as the caregiver and grants her access to her patient's health record in the Medical System.

7.1.1 UTI ALGORITHM APPLICATION

Block 1 – Scene Safety

Summary	Ambulatory patient with no history of acute injury or exposure
Decision	Scene is safe, proceed to rapid initial assessment
Info. Source	CP situational awareness
Resources	None
Functionality	None
Training	Triage

Block 2 – Rapid Initial Impression	
Summary	• The CM's chief complaint is described as "low-level" and no individual complaint is alarm-provoking (no chest pain, no difficulty breathing, no eye injury, etc.) • No mechanism of injury involved (non-traumatic) • Patient appears conversant and ambulatory
Decision	Based on CC and appearance, this indeterminate or non-emergent and non-traumatic → proceed to obtaining history (**Block 7A**)
Info. Source	Reference criteria for emergent/non-emergent conditions
Resources	None
Functionality	None
Training	Triage

7.2 UTI SCENARIO NARRATIVE

The crewmember explains his symptoms in more detail. The Physician Astronaut decides to perform an exam, so she directs the Medical System to initiate a medical encounter, which prompts the system to record all medical interaction between the caregiver, patient, and Medical System. The Physician Astronaut starts the exam off by gathering the appropriate history from the crewmember. The Medical System prompts, records, reviews, and summarizes the interview in the patient's medical record. The Physician Astronaut references the vehicle's historical environment data and her patient's health record via the Medical System but finds no correlation with the vehicle environment or some other external issue. Thus, the affected crewmember's urinary symptoms are likely due to a current underlying medical issue. The Physician Astronaut makes an entry of the crewmember's symptoms and chief complaint in the crewmember's health record.

7.2.1 UTI ALGORITHM APPLICATION

Block 7A – Obtain history	
Summary	The chief complaint (dysuria, increased frequency and urgency) prompts the CP to create a new medical encounter in the MS. ABCs are assessed concurrently with the history. Appropriate history taking and records/systems review for this encounter would be: • History of Present Illness

	• Review of PMHx, PSHx, FMHx, current medications, medication allergies • Review of Systems (ROS)
Decision	• There is no history of irritant exposure or evidence of emergency, thus the CP proceeds in the non-emergent section of the algorithm. • After necessary data is obtained and recorded, proceed to physical examination – **Block 7B**
Info. Source	• Patient verbal account of his symptoms as prompted by CP questions • Historical record review on the MS • Summary of historical data for the patient provided by the MS • Environmental data import
Resources	Suggested questions/data to elicit from the CM for GU-related complaints
Functionality	• MS opens new encounter for the CM for a medical chief complaint • MS provides easy access to historical document review • MS records interview and displays it in the encounter and allows CP to manually edit voice-to-text input • MS suggests needed data to the CP
Training	• History taking • Knowledge of routine medical complaints and required questions to ask of the patient to "rule in" or "rule out" potential etiologies

Block 7A (continued) – Appropriate Questions and Review of Systems	
Chief-complaint agnostic	The chief complaint for an unplanned event is often the predominant symptom, such as "increased urination." Questions to gather more details comprise the "history of present illness" and include: • When did the condition start? • Under what circumstances? • How has it changed or progressed? • How would you describe the pain/discomfort (if applicable)? • Does the pain/discomfort radiate (if applicable)? • Does anything make it better? • Does anything make it worse? • Is the condition constant? If not, how often does it recur and how long does it last? • Has this or anything related occurred to you before? • (OPQRST – onset, provocation and palliation, quality, radiation, severity, time course)
GU-related Error! Reference source not found.	General: • Have you noticed any changes in urination? • How frequently are you urinating? • Any change in the color of urine? • Any pain while urinating, and if so, when?

	• Malodorous urine? • Any discharge not related to urination? • Any blood in the urine? • Any difficulty urinating? • Any suprapubic or pelvic pain? • Recent sexual contacts? • Dyspareunia? Red flags for complicated UTI: • Any recent catheterizations? • Tampon use? • Any recent antibiotic use? • Prior history of kidney stones? • Prior history of frequent UTI? • Prior history of GU related conditions?
ROS	Any recent fevers? Weight changes? Fatigue? Shortness of breath? Chest pain? Flank pain? Abdominal pain? Hematuria?

7.3 UTI SCENARIO NARRATIVE

The Medical System then prompts the Physician Astronaut to collect vital signs from the crewmember. She gathers the equipment for measuring blood pressure, heart rate, oxygen saturation, temperature, and respiratory rate and places them on her patient. She calls out the results as they are gathered, and the Medical System automatically saves them to the crewmember's health record using voice recognition technology. The Medical System displays the data back to the physician, who proceeds with the physical exam of the crewmember, populating her findings in the Medical System template. She finds that the crewmember has a little suprapubic tenderness on his abdominal exam, as well as some right sided tenderness in the costo-vertebral angle.

7.3.1 UTI ALGORITHM APPLICATION

Block 7B – Physical Exam	
Summary	After appropriate subjective data acquisition, the CP decides to proceed with the examination. Appropriate physical examination in this scenario includes the following: • Vital signs • General mental status (whether the patient is alert and oriented to person, place, and time) • Examination of the potentially involved systems: GU, testicular, prostate, and abdomen • Additional examinations could include cardiovascular and pulmonary systems.
Decision	• Vital signs are stable • After documentation of the exam → proceed to data acquisition and differential diagnosis (**Block 8**)

Info. Source	• Automated import of vital signs • CP interpretation of the physical exam and subjective history given by the patient and reviewed on the medical system
Resources	• Medical references • Hardware to obtain and import vital signs into the MS (HR, BP, SpO_2, temperature) • Digital stethoscope
Functionality	• MS in appropriate data entry mode for general medical evaluation • For non CMO, MS recommends appropriate physical examination and techniques • MS can interpret vital signs as normal or abnormal
Training	• General physical examination • GU examination

7.4 UTI SCENARIO NARRATIVE

Based on the physical exam findings and vital signs, the Medical System produces a differential diagnosis and presents it to the Physician Astronaut, who disregards the low-risk conditions and focuses on the higher risk conditions. Each suggested condition contains a link to additional information, such as variation in presentation, diagnostic approach, and treatment modalities, all stored within the Medical System and accessible to the physician if desired. The Physician Astronaut knows that the most likely diagnosis is that the crewmember has a urinary tract infection (UTI), but she needs additional data to confirm the diagnosis and to make certain there are no other medical issues, such as kidney stones or pyelonephritis (kidney infection).

7.4.1 UTI ALGORITHM APPLICATION

Block 8 – Data Acquisition and Differential Diagnosis	
Summary	Incorporating history (age, gender, symptom of dysuria, risk factors) and exam findings (suprapubic tenderness, CVA tenderness), an appropriate systems or symptoms-based differential (see box below) is generated
Decision	Based on the differential, select appropriate further evaluation: ultrasonography, urinalysis, complete blood count before proceeding with treatment
Info. Source	• CP interpretation of subjective (history) and objective (physical exam, images, labs) data • Ultrasound imagery • Laboratory results
Resources	• Appropriate reference texts, including medical and pharmaceutical references • "Just in time training" (JITT) or easy-to-follow instructions for ultrasound of kidneys and bladder • Blood draw supplies, urine sample supplies • Laboratory equipment
Functionality	• MS provides access to appropriate references • MS provides ultrasound training on demand

	• MS has some ultrasound imaging interpretation capability • MS is integrated with lab hardware to download and interpret lab values • MS provides and updates a differential diagnosis based on input data • MS can locate needed supplies
Training	• Handheld use of ultrasound • Blood draws • Lab hardware use • Formulating a differential diagnosis

7.4.2 UTI REFERENCE INFORMATION

Differential Diagnosis: Urinary Urgency and Increased Frequency in Male Error! Reference source not found.
Urinary tract infection (UTI) **Cystitis:** infection of the bladder presenting with dysuria, frequency, and/or urgency **Pyelonephritis:** infection of the kidney presenting with fever, malaise, and costovertebral-angle pain **Uncomplicated:** non-pregnant, female, no anatomic abnormalities, no recent instrumentation **Complicated:** all others not described in the uncomplicated section (including male) Etiology generally from E. coli, S. saprophyticus, Klebsiella, Proteus, and EnterococcusError! Reference source not found.
Urethritis: Infection of the urethra presenting with dysuria and occasionally discharge. Generally caused by sexually transmitted agents: n. gonorrhea, c. trachomatis, mycoplasma, urea plasma, trichomonas, and HSV.**Error! Reference source not found.**

Prostatitis: Infection of the prostate presenting with dysuria, frequency, and pelvic pain; generally presents with fever and obstructive symptoms (difficulty with urination). [19]
Nephrolithiasis: Kidney stones presenting with urinary colic. Generally calcium-based. Stones can allow for urinary tract colonization and infection, and thus may present as a complicated UTI.**Error! Reference source not found.**
Epididymitis: Infection of the epididymis, presenting with testicular pain, dysuria, urgency, and/or fevers. Often caused by c. trachomatis and n. gonorrhea in younger males and e. coli or pseudomonas in older males.**Error! Reference source not found.**

Laboratory Tests for Frequency in Males

Urine dipstick	Point of care test used to evaluate for leukocyte esterase (marker for pyuria) and nitrite (marker for enterobacteriaceae) which together constitute a screening test for UTI; positive leukocyte esterase and nitrite has a sensitivity and specificity of 75% and 66%, respectively, for UTI.**Error! Reference source not found.Error! Reference source not found.**
Urine microscopy	Laboratory test used to count white blood cells (pyuria is defined as >10/high power field (hpf) and examine for presence/absence of bacteria (bacteriuria).
Urine culture	Clean-catch voided urine is collected and incubated in cases of suspected complicated UTI to make a determination on causative species and antibiotic sensitivities.
CBC	Laboratory test used to assess blood counts and leukocyte differential. Disorders of any of the parameters would suggest a more serious issue than a localized, un-complicated UTI.
BMP	Laboratory test used to assess kidney function, electrolytes, and glucose. Disorders of any of the parameters would suggest a more serious issue than a localized, un-complicated UTI.

Radiologic Tests for Frequency in Males	
Ultra-sonography	Point-of-care radiologic examination, which could be used in this case to evaluate for the presence or absence of nephrolithiasis (sensitivity 63-85, specificity 79-100)**Error! Reference source not found.** pyelonephritis, hydronephrosis, and epididymitis.

7.5 UTI SCENARIO NARRATIVE

With this new data, the initial list of differential diagnosis provided by the Medical System is reduced. The Physician Astronaut updates the Medical System to indicate that a urinary tract infection is the most likely condition and inform her patient as such. She then develops a treatment plan that includes antibiotics. The Medical System crosschecks the antibiotic prescription with the crewmember's health record to verify that there are no contra-indications for that particular medication. The treatment plan is logged into the Medical System, which displays the entered information for review. The Medical System then coordinates with the vehicle's communication system to downlink the patient's updated health record and synchronize the onboard and ground electronic health systems.

7.5.1 UTI ALGORITHM APPLICATION

Block 9 – Treat and Rehabilitate	
Summary	The CP enters the assessment as "complicated UTI" and initiates empiric treatment. Given the lack of culture, antibiotic selection must cover the most common causative agents.
Decision	Prescribe antibiotics at the appropriate dose, interval, and route to the CM, taking into account the patients' medical history and allergies (see below). Schedule appropriate follow up for monitoring.
Info. Source	• Pharmaceutical reference • Antibiotic/infectious disease reference • List of available antibiotics on the vehicle, location, and previous utilization

Resources	• Medication list • References as above
Functionality	• MS tracks medication supply and updates estimates of supply availability for the rest of the mission • MS tracks medication usage and can project shortages • MS will re-schedule the patient for follow up visit • MS saves encounter after CP finishes data entry and prepares it for submission/synchronization with the ground
Training	• Resource utilization • Use and monitoring of prescription drugs • Selection appropriate treatment regimen based on a diagnosis

7.5.2 UTI REFERENCE INFORMATION

Antibiotic Selection for Acute UTI/Complicated by Male Gender Error! Reference source not found.Error! Reference source not found.		
Fluoroquinolones	• Ciprofloxacin 500mg bid PO 7-14 days • Levofloxacin 750 mg qd PO 5-7 days	• Not for fluoroquinolone allergic. • Monitor for tendinitis and tendon rupture, peripheral neuropathy, and CNS effects (boxed warning).
Trimethoprim-sulfamethoxazole	Bactrim DS (800mg sulfamethoxazole, 160mg trimethoprim) bid PO 7-14 days	• Not for sulfa allergic. • Only if “local resistance” is <20% and did not take in last 3 months. • Monitor for nephrotoxicity, skin reactions, and hyperkalemia.
Nitrofurantoin	NOT for use in males for UTI.	NOT for use in males for UTI.

8.0 DENTAL ABSCESS

Mission Phase	Level of Care	Occurrence	Operation
Transit – IVA	**IV- Semi autonomous**	**Unplanned**	**Directed**

8.1 DENTAL ABSCESS SCENARIO NARRATIVE

For a few days, a crewmember has been experiencing a toothache on the left side. Concerned, she tracks down the physician astronaut to explain her problems. The two head over to the medical bay and the physician astronaut grabs her display, which uses biometric analysis to identify her as the caregiver and grants her access to her patient's health record in the medical system.

8.1.1 DENTAL ABSCESS ALGORITHM APPLICATION

Block 1 – Scene Safety	
Summary	Minor symptoms have been going on for a few days
Decision	Scene is safe, proceed to rapid initial assessment
Info. Source	Situational Awareness
Resources	None
Functionality	None
Training	Triage

Block 2 – Rapid Initial Impression	
Summary	A crewmember has been having a toothache for "a few days"
Decision	Based on chief complaint, this is non-emergent (there is MOI and appearance is assumed to be normal)
Info. Source	Reference criteria for emergent/non-emergent conditions
Resources	None
Functionality	None
Training	Triage

8.2 DENTAL ABSCESS SCENARIO NARRATIVE

The patient explains her symptoms in more detail. The physician astronaut decides to perform an exam and directs the medical system to initiate a medical encounter, which prompts it to record all medical interaction between the caregiver, patient, and the medical system. The physician astronaut starts the exam off by gathering the appropriate history from the patient. The medical system prompts, records, reviews and summarizes the interview in the medical record for the physician astronaut. As the physician astronaut scans the automated entry, she

sees something that should be updated and edits the note. The medical system then prompts the physician astronaut to review the vehicle's historical environment information and the patient's health records. The medical system records and reports these actions taken by the physician astronaut.

8.2.1 DENTAL ABSCESS ALGORITHM APPLICATION

Block 7A – Obtain History	
Summary	The chief complaint (left-sided toothache) prompts the CP to create a new medical encounter in the MS. ABCs are assessed concurrently with the history. Appropriate History for this encounter would be: • History of Present Illness • Review of dental history and last dental exam • Review of PMHx, PSHx, FMHx, current medications, medication allergies • Review of Systems (ROS)
Decision	• There is no history of irritant exposure or evidence of emergency, thus the CP proceeds in the non-emergent section of the algorithm. • After necessary data is obtained and recorded, proceed to physical examination **(Block 7B)**
Info. Source	• Patient verbal account of her symptoms as prompted by CP questions • Historical record review on the MS • Summary of historical data for the patient provided by the MS
Resources	• Suggested questions/data to elicit from the CM for dental-related complaints • Dental reference texts
Functionality	• MS opens new encounter for the CM for a dental chief complaint • MS provides easy access to historical document review • MS records interview and displays it in the encounter and allows CP to manually edit voice-to-text input • MS suggests needed data to the CP
Training	• History taking • Knowledge of appropriate dental complaints and required questions to ask of the patient to "rule in" or "rule out" potential etiologies for the CM's complaint

Block 7A (continued) – Appropriate Questions and Review of Systems [44]	
Chief-complaint agnostic	The chief complaint for an unplanned event is often the predominant symptom, such as "left sided tooth pain." Questions to gather more details comprise the "history of present illness" and include: • When did the condition start? • Under what circumstances? • How has it changed or progressed?

	• How would you describe the pain/discomfort (if applicable)? • Does the pain/discomfort radiate (if applicable)? • Does anything make it better? • Does anything make it worse? • Is the condition constant? If not, how often does it recur and how long does it last? • Has this or anything related occurred to you before? (OPQRST – onset, provocation and palliation, quality, radiation, severity, time course) Always review PMHx, PSHx, medications, allergies; social history as needed; for dental cases, dental history and most recent dental evaluation; ROS.
Dental-related Error! Reference source not found.	General: • Facial redness or swelling? • Cold or hot sensitivity of the teeth? • Pain when eating? • Difficulty swallowing? • Pain when opening the jaw? • Numbness of the face, tongue, or jaw? • Any sores? • Any discharge? • Broken or chipped teeth?
ROS	Fevers? Chills? Headache? Dizziness? Dry eye? Dry mouth? Sore throat? Difficulty or painful swallowing? Hoarseness or loss of voice? Sinus congestion or drainage? Ear pain? Easy bleeding?

8.3 DENTAL ABSCESS SCENARIO NARRATIVE

The medical system prompts the physician astronaut to collect vital signs from the patient. She gathers the required equipment and places them on the patient. These devices are used to measure blood pressure, heart rate, oxygen saturation, temperature, and respiratory rate. The physician astronaut calls out the results as they are gathered, and the medical system automatically saves them to the patient's health record using voice recognition technology. The medical system displays information back to the physician astronaut, who proceeds with the physical exam of the patient, populating her findings in the medical system template. She finds that the patient has red, swollen gingival tissue near the left lower third molar and swelling on the left side of her face.

Block 7B – Physical Exam	
Summary	• After appropriate subjective data acquisition, the CP decides to proceed with the examination. • Appropriate physical examination in this scenario includes vital signs, general mental status, an extra-oral examination (skin, face, lymph nodes, salivary glands, thyroid, TMJ, cranial nerves, diameter of jaw opening) and an intra-oral examination (periodontal examination of the entire mouth as well as dental examination of the tooth/teeth identified as causing the pain). • Additional examinations could include cardiovascular and pulmonary systems.
Decision	Physical examination reveals red, swollen gingival tissue near left third molar (#17) and overlying facial edema and swelling. Proceed to data acquisition (image and lab) and differential diagnosis
Info. Source	• Automated vital signs acquisition • CP examination of the patient and verbal statements
Resources	• Dental examination references • Dental kit, Stethoscope, Penlight, Hardware for vital signs acquisition
Functionality	• MS in appropriate data entry mode for dental examination • MS has templates for dental examination findings • MS can take voice input to enter data into the medical encounter document • MS can receive, record, and display automated vital signs
Training	• General physical examination • HEENT and Dental examination

8.4 DENTAL ABSCESS SCENARIO NARRATIVE

At this point the physician astronaut opts to take a picture of the affected area. That picture is automatically downloaded into the physical exam portion of the encounter once the physician astronaut reviews and approves it. Based on the physical exam findings and vital signs, the medical system produces a differential diagnosis and presents it to the physician astronaut. Each suggested condition contains a link to additional information, such as variation in presentation, diagnostic approach, and treatment modalities, all stored within the medical system and accessible to the physician astronaut if desired. The physician astronaut suspects that her patient has a dental abscess, and she wants additional information to gain more confidence in the diagnosis. She reviews the additional diagnostic tests suggested by the medical system. She decides to activate the ultrasound within the medical system and deploys the broad band linear ultrasound probe from its stowage location. She informs the medical system of her intent to perform a soft tissue ultrasound scan of the neck and face. The medical system guides her to pick the appropriate preset, apply gel, and place the probe on the patients face on the unaffected side first. During scanning, it offers to guide her through the scanning process while identifying and measuring dark anechoic areas that may represent an abscess. Upon completing the ultrasound scan, all images and associated interpretations and calculations are stored to the patient's health record. After reviewing the ultrasound

information, the physician astronaut informs the patient that there is likely an infection in her tooth and gum tissue. The physician astronaut also wants to perform a blood analysis to check for signs of systemic infection, so she unstows the blood sampling hardware and collects a sample from her patient. She interfaces the blood sample with the laboratory analysis hardware, which is integrated with the medical system, and begins a blood analysis. Upon completion of the blood test, the lab analysis hardware transmits the results, which are displayed to the physician astronaut. After reviewing the laboratory information, she informs the patient that the lab results are normal, indicating that there are no signs of systemic infection. With this new information, the initial list of differential diagnoses provided by the medical system is reduced.

8.4.1 DENTAL ABSCESS ALGORITHM APPLICATION

Block 8 – Data Acquisition and Differential Diagnosis	
Summary	• The physical examination is concerning for an infection (swelling, erythema, and pain) but the CP is not an expert in this field of medicine. • Imaging and laboratory analysis should be undertaken, but the CP is unsure of what imaging and lab tests are needed and thus reviews a broad list of differential diagnoses, each with detailed information on clinical presentation and diagnostic approach.
Decision	Obtain appropriate imaging and laboratory tests for suspected diagnosis (infection). • For dental abscess, periapical x-ray (such as panorex) is the imaging modality of choice, although bedside ultrasound is feasible.
Info. Source	• CP interpretation of subjective (history) and objective (physical exam, images, labs) data • Medical and dental reference material appropriate for the chief complaint of tooth pain • Ultrasound imagery • Laboratory results
Resources	• Appropriate reference texts, including medical, dental, and pharmaceutical references • “Just in time training” or easy-to-follow instructions for ultrasound of the face for dental abscesses • Blood draw supplies • Laboratory equipment
Functionality	• MS provides access to appropriate references • MS provides ultrasound training on demand • MS has some ultrasound imaging interpretation capability • MS is integrated with lab hardware to download and interpret lab values • MS provides and updates a differential diagnosis based on input data
Training	• Handheld use of ultrasound • Blood draws • Lab hardware use • Formulating a differential diagnosis

8.4.2 DENTAL ABSCESS REFERENCE INFORMATION

Differential Diagnosis for Adult Dental Pain Error! Reference source not found., Error! Reference source not found.
• Odontogenic: caries, pulpitis, cracked tooth syndrome, periapical (dental) abscess or facial space infection, Ludwig's angina • Periodontal: gingivitis, gingival abscess, periodontal abscess, acute necrotizing gingivostomatitis • Non-dental infection: candidiasis, HSV1/2, VZV, mumps, saladenitis, sinusitis, parotitis, osteomyelitis • Neurogenic or MSK origin: trigeminal neuralgia, Bell's palsy, TMJ disorder, dental or alveolar fracture, bisphosphonate-induced osteonecrosis of the jaw • Miscellaneous: aphthous ulcers, stomatitis, mucositis, vitamin deficiency, radiation-related mucositis, glossitis, pyogenic granuloma, lichen planus, erythema multiforme, malignancies, referred pain from cardiovascular infarction

Ultrasound for Diagnosis of Periapical Abscess Error! Reference source not found.
• Patient sits upright • CP uses 5-10 or 5-12 MHz linear transducer • CP sweeps affected areas of face in 2 orthogonal planes • Abscess defined as an "irregular or round, localized, compressible, anechoic or hypoechoic fluid collection" • Cellulitis defined as "increased echogenicity of skin and subcutaneous tissues or hypoechoic or anechoic strands traversing the subcutaneous tissue or cobblestone appearance of the subcutaneous tissues"

8.5 DENTAL ABSCESS SCENARIO NARRATIVE

The physician astronaut updates the medical system to indicate that a dental abscess is the most likely condition. She prescribes a course of oral antibiotics and pain medication as the initial treatment. She also elects to seek specialty consult with a ground dentist and oral surgeon. Her request for a consultation is recorded in the medical system and then synchronized with the vehicle's communication system for transmittal to the ground. The patient's health record is downlinked along with the request. Upon review of the downlinked patient health record, the ground medical support team concurs with the dental abscess diagnosis and modifies the treatment plan to include drainage. The ground uplinks the treatment plan to the medical system. The physician astronaut reviews the plan and cross-checks her antibiotic prescription with the patient's health record to verify that there are no contraindications for that particular medication. She then logs the treatment plan into the medical system. The medical system again coordinates with the vehicle's communication system to downlink the patient's updated health record and synchronize the onboard and ground electronic health systems.

8.5.1 DENTAL ABSCESS ALGORITHM APPLICATION

Block 9 – Treat and Rehabilitate	
Summary	The CP enters the assessment as "dental abscess" and stabilizes the condition with antibiotics. She requests expert consult for further details.
Decision	Prescribe antibiotics at the appropriate dose, interval, and route to the CM, taking into account the patients' medical history and allergies (see below).
Info. Source	• Pharmaceutical reference • Antibiotic/infectious disease reference
Resources	• Medication list • References as above
Functionality	• MS tracks medication supply and updates estimates of supply availability for the rest of the mission • MS can flag an encounter for ground review to solicit expert consultation; experts can transmit their recommendations in a way that is recorded to the patient's medical chart and readable by the CP • MS will re-schedule the patient for follow up visit
Training	• Resource utilization • Use and monitoring of prescription drugs

8.5.2 DENTAL ABSCESS REFERENCE INFORMATION

Oral Antibiotics for Dental Space Abscess [29, 31, 32]		
Penicillin VK ± Metronidazole	• PVK: 500mg q6-8h PO • MTZ: 250-500 mg PO q8h	• PVK not for penicillin-allergic • Disulfiram-like RXNs with MTZ
Amoxicillin-clavulanate	875/125 mg q12h PO	• Not for penicillin-allergic patients • Adjustment in renal impairment • Monitor for diarrhea
Clindamycin	300-450mg q8h PO	• Not for clindamycin-allergic, but can be used in penicillin allergic patients • Monitor for diarrhea
Selection of antibiotic will depend on contra-indications and severity of condition. Definitive therapy is incision and drainage (with expert consultation) and appropriate periodontal debridement and cleaning. Consider oral chlorhexidine and/or saline rinses.		

9.0 ARM INJURY

Mission Phase	Level of Care	Occurrence	Operation
Transit/Orbit	**V – Autonomous**	**Unplanned**	**Contingency - Directed**

9.1 ARM INJURY SCENARIO NARRATIVE

Tianna had reached with her unencumbered arm to try to push the door open. Realizing she needed to try something else she tried to reach to the release switch on the far side of the doorframe. It was an awkward maneuver and one she immediately regretted - resulting in her arm being pinned by the door just below the wrist at an angle. She cries out and a few blood drops floated into the cabin off her arm. She was pinned in place.

9.1.1 ARM INJURY ALGORITHM APPLICATION

Block 1 – Scene Safety	
Summary	Unsafe scene due malfunctioning door
Decision	Correct unsafe conditions, thereafter proceed to **Block 2**
Info. Source	CP situational awareness
Resources	None
Functionality	None
Training	Triage

9.2 ARM INJURY SCENARIO NARRATIVE

Moments later the door started opening with Duane immediately grabbing her arm to try to stop the blood dome from expanding on her forearm. Tianna screamed with pain. It wasn't clear how much damage had been done to her arm; the blood would need to be cleared out of the way. Duane though that she might have a 3-4 inch laceration that seemed to wrap around the skin and appeared to go deep. The blood continued to flow. At this point Duane realized that they were going to need some help and told Jose to initiate an emergency sequence with the ship's medical system.

9.2.1 ARM INJURY ALGORITHM APPLICATION

Block 2 – Rapid Initial Assessment	
Summary	The CM has a crush type-mechanism of injury with an unknown and uncontrolled source of bleeding
Decision	Based on CC and appearance, this is an emergent scenario related to a traumatic injury → proceed to Primary Trauma Survey (**Algorithm 3A)**
Info. Source	Reference criteria for emergent/non-emergent conditions
Resources	None
Functionality	None
Training	• Triage • Parallel tasks: one crew to maintain pressure to prevent blood loss, another to help transport and set up medical system

9.3 ARM INJURY SCENARIO NARRATIVE

Xavier floated into the cabin and as the crew medical officer he assumed control as he addressed the medical system: "Computer, this is Xavier Daniels, please activate the medical bay emergency protocol for trauma. Perform automatic power up now and activate crew Tianna Foo's internal biosensor package on my authority… [Any emergency activation by the crew medical officer or commander were immediately logged]. … Duane held pressure on the wound but there it was seeping blood and it was becoming apparent that there was a mixture of brighter red blood that indicated a possible arterial injury… "Computer, please identify the location of the tourniquets in the medical bay and please identify the location of the gauze." Computer responded "The drawer containing the tourniquets has been illuminated with a red light and opened. The drawer containing the sponge and gauze supplies has been illuminated with a green light and opened."

9.3.1 ARM INJURY ALGORITHM APPLICATION

Block 3A – Initiate PHTLS/ATLS (Primary Trauma Survey)	
Summary	The primary survey (ABCDE) is completed. Airway and breathing are intact. Circulation and bleeding requires pressure and a tourniquet for control. Disability (neurologic function of the crushed limb) will be assessed after bleeding is controlled. The patient's injury is appropriately exposed for evaluation.
Decision	After assessing the ABCDEs and intervening as necessary, proceed to Secondary Trauma Survey (**Block 3B**)
Info. Source	• CP witnessed the event and appropriately focuses the exam and history • The medical system identifies required resources
Resources	Trauma medical supplies
Functionality	• MS opens new encounter and has an emergency mode for unstructured queries and data retrieval • MS provides easy access to historical document review • MS logs emergency entries for priority transmission and to highlight the need for ground review and feedback
Training	• Emergency patient evaluation: BLS, ACLS (for CMO), PHTLS, and ACLS (for CMO) • Each of the survey system (ABCDE) could be addressed in parallel by multiple crew members under the direction of a single medical provider/leader

9.3.2 ARM INJURY REFERENCE INFORMATION

Primary Trauma Survey [33]	
Airway	Check for airway patency. Assess for obstruction. If uncertain, perform chin-lift or jaw-thrust maneuver and insert an airway device to relieve tongue/soft tissue obstruction. If needed, cricothyroidotomy and/or intubation.
Breathing	Determine the rate and depth of breathing; if inadequate provide supplemental oxygen and assist with ventilations. Inspect the neck and chest for tracheal deviation, unilateral chest

	motion, and percuss the chest for dullness or hyper resonance. Relieve tension pneumothorax with needle decompression.
Circulation (and bleeding)	Identify sources of external and internal bleeding. Assess pulse. Apply direct pressure, tourniquets to control hemorrhage; obtain large bore IV catheter access for volume resuscitation.
Disability	Assess pupils for reactivity. Determine GCS. Assess for spinal cord injuries.
Expose/Environment	Undress the patient to accurately assess for injuries. Prevent hypothermia. Draw blood for laboratory analysis including ABG, CBC, BMP, CMP, pregnancy test, ABO type and screening; attach ECG, insert urinary catheter for strict urine output monitoring.

9.4 ARM INJURY SCENARIO NARRATIVE

At this point Xavier asked the medical system for the heart rate and blood pressure so he would know a baseline. Computer responded "Tianna Foo heart rate 115 beats per minute. Blood pressure 130 over 80 mm Hg." [Bleeding control is performed]. "Duane will start an IV in your right arm… After that I'm going to check a neurologic exam of your hand to see if you've sustained a nerve injury. The color of your blood suggests to me that you have probably damaged your ulnar artery and we will need to ligate the artery to stop the bleeding." Duane had asked the system to locate the blood pressure cuff and stethoscope. Once he found them in the lighted drawer, he checked it on the unaffected arm. Unfortunately, it was a little lower than her implant was noting. He proceeded to don the glasses that would help him identify where her veins were and got an IV start kit from the drawer that Computer indicated. He quickly walked through the sensory and motor portions of the physical examination and spoke his findings to Computer. "Computer, start an event note and document this date and time for Tianna Foo. Start dictation: Section History of Present Illness: Crew Tianna Foo sustained a laceration of left upper extremity in what appears to be a hatch malfunction at time and date shown. No other trauma noted, no head injury, no loss of consciousness. Injury was witness and compression begun on the wound are to attempt to minimize loss of blood. End Dictation." A subset of the monitor opened and an event note was created automatically by the computer. Xavier's dictation showed up on the screen. Xavier continued, "Computer, please import past medical history, medications and allergies from Tianna Foo's file into the note. Please list Review of Systems as deferred. Section Physical Exam: Please import current vital signs. Start Dictation. Extremity examination: Left upper extremity with 4 cm laceration with active bleeding and slightly macerated appearance about 5 cm below the wrist on the lateral side of the arm. Bone is exposed on inspection but no fractures or foreign bodies apparent on exam. Motor function intact for digits 1-3, decreased strength in flexion and extension for digits 4 and 5 at 1 out of 5 respectively. Unable to spread fingers, sensation decreased over digits 4 and 5. Wrist flexion and extension 5 out of 5, sensation intact over the back of the hand. End dictation."

9.4.1 ARM INJURY ALGORITHM APPLICATION

Block 3B – Secondary Trauma Survey	
Summary	After the primary survey is complete, a focused history (if needed), vital signs, and a detailed head-to-toe physical assessment is performed; because of the witnessed event and limited body area of injury, much of this is skipped.
Decision	After assessing the ABCDEs and intervening as necessary, proceed to Secondary Trauma Survey (**Block 3B**)
Info. Source	• CP witnessed the event and appropriately focuses the exam and history • The medical system identifies required resources
Resources	• Trauma medical supplies including IV start kit • Equipment for vital signs acquisition
Functionality	• Automated vital signs acquisition • Voice-to-text and text-to-voice • MS can follow commands to open new encounter and record dictated notes • MS automatically imports PMHx, PSHx, current medications, and allergies into the encounter dictation.
Training	• Emergency patient evaluation: BLS, ACLS (for CMO), PHTLS, and ACLS (for CMO) • Peripheral IV placement • Manual vital signs acquisition • Neurologic examination/assessment

9.4.2 ARM INJURY REFERENCE INFORMATION

Secondary Trauma Survey (ATLS) [33]	
History Taking and Vital Signs	OPQRST and/or AMPLE format
Head	Inspect, auscultate, and palpate for lacerations, contusions, fractures, thermal injury; evaluate eyes and remove contact lenses, evaluate cranial nerve function, ears and nose for CSF leak, inspect mouth for bleeding and broken teeth, carotid bruits, carotid pulses
C-spine, neck	Inspect and palpate for tracheal deviation, tenderness, deformity, swelling, subcutaneous emphysema, tracheal deviation, pulse symmetry, bruits; maintain cervical immobilization
Chest	Inspect, auscultate, palpate, and percuss for: appropriate bilateral breath sounds and heart sounds, penetrating injury, subcutaneous emphysema, tenderness, crepitation, hyper resonance or dullness
Abdomen	Inspect, auscultate, palpate, and percuss for: blunt and penetrating injury, bowel sounds, rebound tenderness, guarding, gravid uterus, and/or FAST. Obtain pelvic x-rays and apply pelvic compression binder if indicated.

Perineal, Rectum, Vagina	Assess for contusions, hematomas, lacerations, and urethral bleeding. Check for anal sphincter tone and prostate position (if indicated). Check for blood in vaginal vault and for lacerations (if indicated).
Musculoskeletal	Inspected UE and LE for blunt and penetrating injuries. Palpate for tenderness, crepitation, abnormal movement, and sensation. Palpate all peripheral pulses. Assess pelvis for stability. Inspect and palpate thoracic, lumbar spines. Apply splinting devices as indicated. Maintain spinal immobility. Apply pelvic binder (if indicated). Administer tetanus immunization. Consider compartment syndrome.
Neurologic	Re-check GCS and pupils. Evaluate UE and LE motor and sensory function.

9.5 ARM INJURY SCENARIO NARRATIVE

Xavier requests help in setting up for the nerve block]. "Computer, please project the ultrasound image directly onto screen 1. Adjust settings for nerve exam. Please highlight the left extremity axillary nerve in these images. [The system provides instructions for ultrasound placement]. Xavier followed the directions. [He injects the anesthetic agent]. "Alright, we'll give that a few minutes. You should start getting relief momentarily."

Xavier said. "Computer, please calculate what class of hemorrhage Tianna's vital signs indicate." Computer replied: "Heart rate, blood pressure and respiratory rate all indicate a class 2 hemorrhage suggesting between 750-1000 ml of blood loss. Suggest 2 liter IV fluid for resuscitation." [Crew discusses how to start the IV and deliver the fluids. They also request the medical system make more medical-grade fluid in case they need it.]

"Commander, I'd like to have Jose on standby for our walking blood-bank procedures. Can you please have him available for MedBay?" Xavier asked. "Ok, Jose will be on standby if you need to activate him." The Commander replied.

"What do we do now?" Duane asked Xavier. "Ligation" said Xavier. Duane went to one of the screens and accessed the medical database – it was a reference resource similar to Up-to-Date or emedicine – and looked up ligation and artery. [CMO discusses procedure with patient]. Xavier says "Computer, please activate medical suction and identify location of hemostats, needle driver, and vicryl sutures #5 size. Jose, can you please be ready to deal with any errant blood that floats away?" Jose nodded yes as he hooked up the medical suction device to the vac-port. [Xavier performs ligation procedure]. "We'll need to washout the wound and close it. For now, I'll use the cold plasma device to sterilize the wound after washing and before we loosely close the area. We'll need to prepare some pictures and questions for the flight surgeons back home so we can get some guidance on how to proceed, but at least we have time now and can take off the tourniquet."

After successfully cleaning, sterilizing and closing the wound, Xavier asked Computer to contact Mission Control and provide them with a status of the situation and request recommendations as well as start working on a rehab plan to minimize the impact to mission objectives. "Shall I input the rehab plan into the Tianna's personal countermeasures profile?" asked Computer.

"Yes please, Computer", replied the CMO. "Computer, please also provide the commander and Mission Control with a mission impact assessment. Assume pain medication will be needed for the next two weeks, and we will need to monitor for possible infection of the wound site as well. She is likely to have diminished function in her left hand for the duration of the mission." Computer also calculated the projected disability of crewmember Tianna, likely mission impacts of best- and worst-case scenarios, mission alternatives, and changes in the ship's stock of medical and life supporting consumables.

9.5.1 ARM INJURY ALGORITHM APPLICATION

Block 9 – Treat and Rehabilitate	
Summary	The ulnar artery has been lacerated and its corresponding nerve has been potentially injured. The artery will need to be ligated to prevent bleeding; the procedure will require a nerve block to perform.
Decision	• After completing secondary survey, the following treatments are performed: nerve block and arterial ligation for definitive source control, volume resuscitation ± blood transfusion, wound cleaning and sterilization, wound closure • A rehabilitation plan is requested for the injury from the ground
Info. Source	• Electronic reference material • Just in time training for nerve block, arterial ligation
Resources	• Suture kit, anesthetic agent • Wound cleaning and sterilization supplies • IV fluids, blood collection containers, blood transfusion kits • Ultrasound
Functionality	• MS provides access to electronic resources for medical and surgical procedures • Vehicle has hardware capable of producing on-demand fluids safe for intravenous use • Software and required laboratory equipment in place to utilize a walking blood bank • MS can estimate blood loss in trauma based on vital signs • MS can interpret ultrasound imagery
Training	• Vascular ligation • Wound closure and care • Ultrasound use and identification and relevant anatomical structures

9.5.2 ARM INJURY REFERENCE INFORMATION

Classification of Shock Due to Blood Loss [33, 34]				
	Class I	**Class II**	**Class III**	**Class IV**
Blood loss (mL)	< 750	750 – 1500	1500 – 2000	>2000
Blood loss (%)	< 15 %	15-30%	30-40%	>40%
Pulse / HR	< 100	100-120	>120	>140

Systolic Blood Pressure	Normal	Normal	Decreased	Decreased
Pulse pressure	Normal/increased	Decreased	Decreased	Decreased
Respiratory rate	14 – 20	20-30	30-40	>35
Urine output (mL/hr)	> 30	20-30	5-15	Negligible
Mental status	Mildly Anxious	Anxious	Anxious, confused	Confused, lethargic
Initial fluid replacement	Crystalloid	Crystalloid	Crystalloid + blood	Crystalloid + blood

Suture Materials [35, Error! Reference source not found.]		
Absorbable	**Polyglactin 910 (Vicryl)**	• Tensile strength for 3-4 weeks for subcutaneous sutures and vessel ligation • Takes 90 days to resorb • Minimal tissue inflammation
	Poliglecaprone 25 (Monocyrl)	• Tensile strength for max. 2-3 weeks • Often used for facial lacerations and subcutaneous soft tissue approximation • Absorbed 90 days • Minimal tissue inflammation
	Polyglycolic acid (Dexon)	• Braided filament with tensile strength 2-3 weeks • Absorbed by 60-90 days • For subcutaneous approximation and vessel ligation
	Polydioxanone (PDS II)	• Tensile strength 2-4 weeks • Absorbed by 180-210 days • Useful for subcutaneous soft tissue approximation when prolonged closure is needed
	Polytrimethylene carbonate (Maxon)	• Monofilament with tensile strength 2-4 weeks • Absorbed by 180 days • Useful for subcutaneous soft tissue approximation when prolonged closure is needed
	Catgut, Chromic gut	• Tensile strength for 7-28d days • Useful for oral mucosal sutures • Absorbed in 70-90d
	Fast Absorbing Gut	• Tensile strength for 5-7 days • Useful for facial wounds and skin grafts • Absorbed in 21-42 days
	Coated polyglactic 910 (Vicryl Rapide)	• Tensile strength for 5-10 days • Absorbed by 42 days

		• For skin approximation
Non-absorbable	**Silk**	Low tensile strength, often used for securing percutaneous lines; can cause inflammatory reactions
	Nylon (Ethilon, Dermalon)	High tensile strength but requires a large number of knot throws to remain in place, low tissue inflammation.
	Polypropylene (Prolene)	High tensile strength but requires a large number of knot throws to remain in place; can be colored and so easily found in a surgical field; least amount of tissue reactivity.
	Polyester (Mersilene, TiCron)	Braided and monofilament with high tensile strength and minimal tissue reactivity; often used for tendon repair
	Polybutester (Novafil)	Monofilament with high tensile strength and minimal tissue reactivity
Suggested Sizes (for lacerations)		• Scalp: 3-0 or 4-0 • Face: 6-0 • Trunk: 4-0 • Extremities: 4-0 • Digits: 5-0

9.5.3 ARM INJURY ALGORITHM APPLICATION

Block 3C – Tertiary Trauma Survey	
Summary	Repeat primary and secondary surveys (usually indicated in multi-system traumatic patient) after stabilization, usually done 24 hours after initial injury; done in conjunction with consultants and appropriate review of imaging. In this case, it would be ideal to perform after ground had responded with their input into the case.
Decision	• Wound is monitored for infection, the neurologic status of the hand is monitored, and feedback from the ground and appropriate expert consults. • Rehabilitation plan is received and reviewed
Info. Source	• Ground transmission of their review and recommendations • Provider review of recorded notes and images from the initial encounter
Resources	Medical references
Functionality	• MS provides appropriate access to prior recordings • MS provides access to the ground-transmitted review and recommendations
Training	• Physical examination • Wound care • Physical therapy and rehabilitation of a traumatic nerve injury

9.5.4 ARM INJURY REFERENCE INFORMATION

Tertiary Trauma Survey[45]	
Head	GCS
Scalp	Inspect and palpate for laceration/abrasion, swelling, ecchymosis, fractures
Face	Inspect and palpate for laceration/abrasion, swelling, ecchymosis, fractures
Eyes	Assess eye movement, pupils, and visual acuity
Mouth	Assess occlusion, teeth, and for CSF leak.
Neck	Inspect for lacerations/abrasion, hematomas, swelling, subcutaneous air, tenderness; determine if C-spine is cleared clinically or radiographically
Chest	Inspect for lacerations/abrasion, swelling, ecchymosis, subcutaneous air and palpate for tenderness or deformity in the ribs, sternum, clavicle; assess for flail and paradoxical movement. Review CXR.
Abdomen	Inspect for lacerations/abrasion, swelling, ecchymosis; palpate for tenderness/guarding and masses; assess pelvis for stability.
Back	Log roll to inspect back and neck for lacerations/abrasion, swelling, ecchymosis; palpate vertebral column for tenderness and/or deformity.
Extremities	Assess for lacerations/abrasions, swelling, ecchymosis; check all peripheral pulses; assess for tenderness and instability
Peripheral nerves	Assess motor and sensory nerves

10.0 DECOMPRESSION SICKNESS (DCS)

Mission Phase	Level of Care	Occurrence	Operation
Transit – IVA	V- Autonomous	Unplanned	Undirected

10.1 DCS SCENARIO NARRATIVE

Due to a micrometeoroid impact to the vehicle that caused a breach in the hull, the internal vehicle pressure begins to drop. A brief search for the breach is unfruitful; because the pressure continues to drop, the commander orders all crew into pressure suits. The physician astronaut does not don his suit in time and passes out. After the other crewmembers finish donning their suits, the commander orders one crewmember to put the physician astronaut into his suit while the other crewmembers search for the breach.

10.1.1 DCS ALGORITHM APPLICATION

Block 1 – Scene Safety	
Summary	The atmospheric pressure has dropped, threatening both the vehicle and the life of the physician astronaut.
Decision	• The scene is unsafe and the conditions need to be corrected before proceeding to definitive medical care. • One crewmember is ordered to help the physician astronaut, and the others attempt to fix the breach in the vehicle.
Info. Source	• Situational awareness • Environmental monitoring and alarm system
Resources	• Pressure suits • Breach patch material
Functionality	The medical system has yet to be activated, although it should be able to passively monitor and log environmental data, such as atmospheric pressure
Training	• Triage and resource/crew management in emergency scenarios • Pressure suit donning and doffing • Vehicle repair in setting of pressure loss/hull breach

10.2 DCS SCENARIO NARRATIVE

The crewmember quickly gets the physician astronaut into his suit, closes the visor, and powers the suit on in order to provide normal levels of pressure and oxygen. After a few minutes, the commander and other crew are able to find and successfully patch the breach, and the atmospheric pressure begins to rise. The unconscious physician astronaut is carried to the medical bay and the medical system is activated in an emergency mode. As part of the emergency protocol, the medical system then activates the patient's biosensor and starts to collect vital signs, which are recorded to the patient's encounter and displayed for review. Although the physician astronaut has not yet fully

recovered consciousness, he has begun to occasionally move his extremities and water vapor is seen on the inside of his visor."

10.2.1 DCS ALGORITHM APPLICATION

Block 2 – Rapid Initial Assessment	
Summary	The physician astronaut has lost consciousness in the setting of reduced atmospheric pressure.
Decision	This scenario is emergent by criteria: loss of consciousness and potentially decompressive illness.
Info. Source	• Crew knowledge of events leading to medical incapacitation (decompression) • Patient appearance, chief complaint, mechanism of injury
Resources	None
Functionality	• Medical system has an emergency mode which can be activated by any crew (consider automatic activation if environmental alarms are activated) • Medical system recognizes user is not the physician and tailors interface appropriately; additionally, recognizes or gathers input that the patient is the physician astronaut • Medical system logs emergency mode activations for priority transmission
Training	• Triage of medical complaints in order of acuity • Ability to recognize emergency scenarios, especially ones that are included in the Integrated Medical Model (IMM)

Block 3 – Skip – (not traumatic)

Block 4 – Assess ABCs	
Summary	• ABCs: airway, breathing, and circulation • The patient has lost consciousness and has been placed in a pressure suit. It will be difficult to accurately assess the ABCs, however, the crew assessing the patient should look for water vapor condensation on the inside of the mask, look and feel for chest rise and fall, and, if the patient is wearing a remote vital signs and cardiac monitor, check the data feed from the monitor.
Decision	The patient appears to have "intact" ABCs, and so BLS/ACLS is not initiated
Info. Source	• Provider assessment of patient • Medical system display of vital signs and cardiac monitor
Resources	Hardware for remote vital signs and cardiac rhythm monitoring
Functionality	In emergency mode, vital signs and cardiac monitor should be prominently displayed for desired crew members and/or easily accessed by the crew medical provider
Training	• Triage • Pressure suit donning and doffing, vehicle repair

10.3 DCS SCENARIO NARRATIVE

The medical system assesses the collected vital signs and makes a suggested diagnosis of hypoxic-hypoxia with probable decompression sickness (DCS) and provides relevant reference information to the backup medical officer. It then recommends a treatment plan of recompression therapy and suggests performing a myringotomy first to prevent uncontrolled tympanic membrane rupture because the suit will be pressurized to 60ft of sea water. The backup medical officer agrees and uses the medical system to locate the appropriate medical supplies.

10.3.1 DCS ALGORITHM APPLICATION

Block 5 - Skip – not BLS/ACLS

Block 6 – Focused Evaluation	
Summary	• History of present illness in this situation can be recorded after treatment has been initiated, and it would be written solo by the crew medical provider as the patient cannot provide it himself • Vital signs and remote cardiac monitor are already assessed in this scenario • Focused physical exam is not currently possible given the patient is still in the pressure suit and cannot cooperate with the exam • Given the constellation of symptoms and circumstances leading to the scenario, the provider should proceed with immediate therapy for decompression illness
Decision	Decompression illness → proceed with appropriate therapy
Info. Source	• The crew medical provider assessment of the situation • The medical system assessment of the situation, incorporating a variety of data streams (provider input, vital signs, environmental data, etc.) • Medical system "knowledge support" for non-physician provider regarding therapy for decompression illness
Resources	• Hardware for remote vital signs monitoring • Surgical tools for myringotomy
Functionality	• In emergency mode, vital signs and cardiac monitor should be prominently displayed and/or easily accessed by the crew medical provider • For non-physician users of the medical system, prominent "knowledge support," which in this case includes information about decompression illness and treatment guidelines • Provide "just in time" training for a surgical procedure
Training	• Ability to perform a focused history and physical • Interpretation of vital signs and cardiac monitor • Familiarity with pressure suit functionality • Familiarity with surgical equipment

Block 7 - Skip – not applicable

Block 8 - Skip – not applicable

10.4 DCS SCENARIO NARRATIVE

Now that the atmospheric pressure has stabilized, the backup medical officer removes her helmet and gloves and restrains the patient to facilitate treatment. The medical system guides the backup medical officer through the myringotomy protocol and, when complete, she replaces the patient's helmet and powers the patient's suit once again. The medical system guides her through the processes of increasing and decreasing the pressure of the suit to treat the DCS and providing oxygen to treat the hypoxia. Meanwhile, the medical system records the procedures being performed and continuously collects and displays the patient's vital signs. As the stabilization treatment comes to a completion, the patient regains consciousness, and the medical system prompts a physical exam to be logged. It guides the backup medical officer through the physical exam, during which the patient conveys that he is having difficulty hearing.

10.4.1 DCS REFERENCE INFORMATION

Decompression Illness [37, 38]	
Type 1 decompression sickness (DCS)	Syndrome resulting from reduction in ambient pressure leading to bubble formation in body tissues; type 1 is considered less serious and involves joint-pain, cutaneous symptoms (itching), and/or lymphatic symptoms (swelling) only. For DCS type 1 as a result of altitude exposure (no recent exposure to pressures greater than one atmosphere) that resolves on descent, initial treatment is 2 hours of oxygen therapy at one atmosphere. If symptoms persist on descent or recur at any time during oxygen therapy, proceed to recompression therapy following **Treatment Table 5**.
Type 2 decompression sickness (DCS)	Syndrome resulting from reduction in ambient pressure leading to bubble formation in body tissues; type 2 is considered severe and is diagnosed based on neurologic symptoms (loss or alteration of consciousness, numbness, weakness, vertigo, thoraco-abdominal pain); cardiopulmonary symptoms (chest pain, difficulty breathing); and certain skin findings such as marble discoloration. Recompression therapy follows **Treatment Table 6**.
Arterial gas embolism (AGE)	Blockage (embolism) resulting from the transit of bubbles from tissues and veins into the arterial circulation, leading to reduced or absent blood flow to critical organs, particularly the brain (→ stroke like symptoms) and the spine (→ numbness and paralysis). Differentiation between DCS type 2 and AGE is often not possible in the immediate clinical setting. Initial recompression therapy follows **Treatment Table 6**.

Decompression Sickness Indications for Treatment Tables[37]	
5	Type 1 DCS. Once at depth, a neurologic exam is done and if any abnormalities are noted, the patient should be treated following treatment table 6.
6	AGE, type 2 DCS, and type 1 DCS if symptoms persist after 10 minutes of treatment table 5 or if neurologic exam is abnormal.

6A	AGE (or type 2 DCS) if symptoms persist or worsen after reaching 60 feet seawater (initial treatment table 6A).

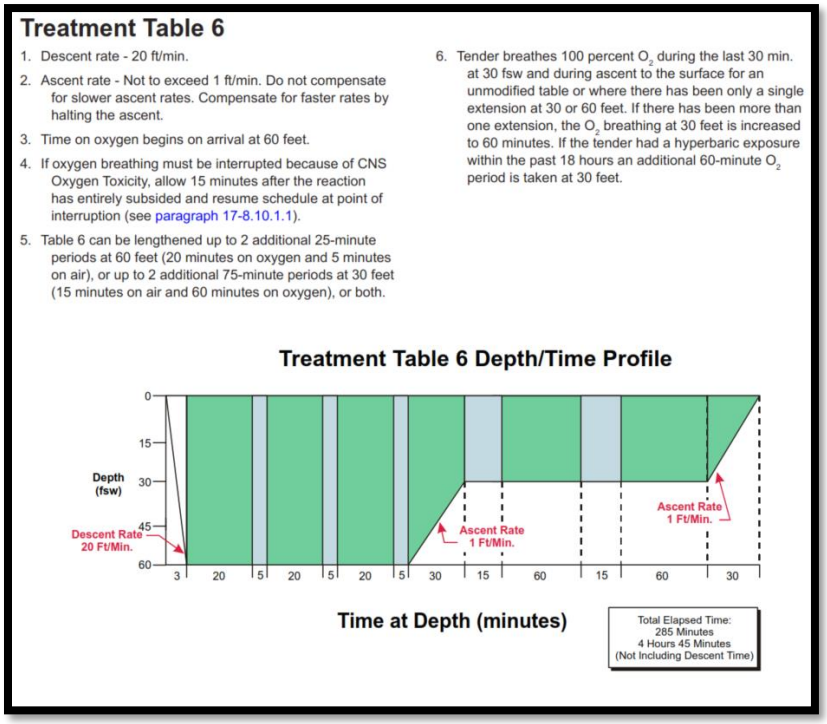

FIGURE 3 TREATMENT TABLE 6.[37]

10.5 DCS SCENARIO NARRATIVE

The backup medical officer performs a hearing test to assess the degree of hearing loss. She then requests that the medical system calculate the projected disability of the patient and provide a recommended rehabilitation plan for his compromised hearing, which was affected due to the myringotomy. She also requests a mission impact statement, taking into account the crew's health, the unexpected use of resources, and the state of the vehicle. With this information, the medical system recommends a long-term treatment plan for the patient, records and updates the patient's health record, and displays the information for the backup medical officer. The medical system then coordinates with the vehicle's communication system to downlink the patient's updated health record and synchronize the onboard and ground electronic health systems.

10.5.1 DCS ALGORITHM APPLICATION

Block 9 – Treat and Rehabilitate	
Summary	• After initial evaluation for ABCs and preparation for recompression therapy for decompression illness, the patient is taken to 60 feet sea water according to treatment table 6 for presumed type 2 DCS.

	• At depth, neurologic examination is performed, although this will be limited by consciousness of the patient and by the pressure suit separating the examiner from the patient. • As expected, the patient complains of hearing loss after myringotomy and recompression therapy.
Decision	Treated empirically for type 2 DCS
Info. Source	• Evaluation of patient – neurologic exam and subjective complaints • Medical system reference material regarding complications of myringotomy and recompression therapy
Resources	Suit interface to guide recompression therapy
Functionality	• Medical system monitors system resources • Medical system logs event for transmission • Medical system provides appropriate reference material for non-physician provider • Medical system schedules follow up for patient evaluation • Medical system can estimate mission impact based on supply usage and astronaut impairment
Training	• Management of suit for recompression therapy • Patient examination, particularly neurologic and auditory

11.0 ACUTE RADIATION SYNDROME (ARS)

Mission Phase	Level of Care	Occurrence	Operation
Transit	**V – Autonomous**	**Unplanned**	**Contingency - Directed**

11.1 ARS SCENARIO NARRATIVE

A SPE has hit the ship and the crew is bunkered in the radiation shelter; however, an emergency (a fire) means that some astronauts must leave the shelter

11.1.1 ARS ALGORITHIM APPLICATION

Block 1 – Scene Safety	
Summary	Unsafe scene due to high radiation flux and shipboard fire
Decision	Attempt to correct unsafe conditions (fire) and reduce impact of conditions that cannot be changed (bunker in radiation shelter); crew medical officers are held in reserve/safety to maintain medical capacity unless absolutely required.
Info. Source	• Radiation and fire alarms • Communication from ground
Resources	• Firefighting resources • Waste management and isolation resources for radiation shelter
Functionality	• MS must be aware of radiation measurements and have appropriate alarms

	• MS must be aware of environmental measuring system for fire byproducts and have appropriate alarms
Training	Triage, fire-fighting, biological waste management

11.2 ARS SCENARIO NARRATIVE

The commander and engineer extinguish the fire and instruct the environmental system to increase filtration to clear the fire by-products from the atmosphere. However, their in-suit dosimeters register life-threatening radiation exposure – approx. 2 Gy.

11.2.1 ARS ALGORITHM APPLICATION

Block 2 – Rapid Initial Assessment	
Summary	Two astronauts have had acute high-dose radiation exposure (estimated ~2 Gy)
Decision	Acute radiation exposure is an emergency, thus proceed to ABC assessment (**Block 4**)
Info. Source	• Reference criteria for emergent/non-emergent conditions • Dosimetry and MS tissue model
Resources	MS can model dosimetry for each crewmember
Functionality	None
Training	Triage

11.3 ARS SCENARIO NARRATIVE

Once the CME has passed, the crew leaves the shelter and those exposed move to the medical bay. One affected crewmember vomits.

11.3.1 ARS REFERENCE INFORMATION

Symptoms in Acute Radiation Sickness Based on Acute Whole-Body Exposure (GY)[39]					
	Vomiting onset (% incidence)	**Diarrhea Onset (% incidence)**	**Headache Onset (% incidence)**	**AMS Onset**	**Temperature Onset (% incidence)**
Mild (1-2 Gy)	2h (10-50)	None	Slight	None	Normal
Mod. (2-4 Gy)	1-2h (70-90)	None	Mild	None	Increased 1-3h (10-80)
Severe (4-6 Gy)	<1h (100)	Mild 3-8h (<10)	Moderate >24h (50)	None	Fever 1-2h (80-100)
V.S. (6-8 Gy)	<30m (100)	Heavy 1-3h (>10)	Severe 3-4h (80)	Possible AMS	High fever <1h (100)
Lethal (>8 Gy)	<10m (100)	Heavy in minutes (100)	Severe 1-2h (80-90)	AMS in seconds (>50Gy)	High fever <1h

11.3.2 ARS ALGORITHM APPLICATION

Block 3A – Skip - (not traumatic)

Block 4 – Assess ABCs	
Summary	Airway, breathing, and circulation are intact in appropriately conscious, responding individuals
Decision	Proceed to focused evaluation (**Block 6**)
Info. Source	Provider assessment of patients
Resources	None
Functionality	None
Training	Medical triage and evaluation

Block 6 – Focused Evaluation [40]	
Summary	• A rapid overview of current symptoms, vital signs, and focused physical exam is performed on two astronauts who have developed symptoms related to an acute radiation exposure. • Appropriate questions in this case would include ones detailing nausea and vomiting, diarrhea, abdominal pain, skin changes, headache, weakness, fatigue and the time course associated with each symptom as measured from exposure • CP reviews PMH, PSHx, medications, allergies • Appropriate physical examination would include vital signs including temperature, neurologic status, thorough skin examination for blistering, erythema, petechial, hair loss, desquamation, ulcer/necrosis; extremity examination for swelling, abdominal examination, cardiovascular examination and volume status, and pulmonary examination.
Decision	After appropriate history and physical, proceed to data acquisition and differential diagnosis (**Block 8**)
Info. Source	• CP interview and examination of the patient • CP review of the MS records • CP review of dosimetry
Resources	Reference material
Functionality	• MS has automated vital signs acquisition • MS has automated dosimetry data acquisition • In the encounter, MS automatically imports historical data such as PMHx, PSHx, current medications, and allergies.
Training	Medical history taking and physical examination

Block 8 – Data Acquisition and Differential Diagnosis	
Summary	Given the relatively accurately known exposure (2 Gy), degree of symptoms, and time delay from exposure to symptom onset, the exposed crew is diagnosed with ARS (Score 2, European Consensus Scoring System, section 10.3.3)

Decision	For the first 48 hours, obtain required measurements and labs from the exposed crew (see Laboratory Analysis in section 10.3.3); thereafter, reassess the patients based on the METREPOL organ score (section 10.4.4)
Info. Source	• Electronic reference material (pharmaceuticals, ARS diagnosis and therapy) • CP interpretation of dosimeter, signs and symptoms, and laboratory analysis
Resources[1]	Laboratory analysis – complete blood count (CBC), complete metabolic profile (CMP), phosphorous, magnesium, ionized calcium, amylase – and appropriate medical supplies (collection tubes, butterfly syringes, alcohol swabs, etc).
Functionality	MS recording and display of laboratory analysis
Training	• Diagnosis and triage of acute radiation syndrome • Laboratory draw and analysis

11.3.3 ARS REFERENCE INFORMATION

European Consensus Conference Scoring System (First 48 Hours)[42]			
	1	**2**	**3**
Delay before symptoms	<12 h	<5h	<30m
Cutaneous erythema	-	+/-	+++ (before 3 hours)
Asthenia	+	++	+++
Nausea	+	+++	++++
Vomiting (# emesis per 24h)	≤1	1-10 episodes	>10 episodes
Diarrhea (# stools in 24h)	≤3 bulky	2-9 soft	>10 watery
Abdominal pain	Minimal	Intense	Excruciating
Headache	0	++	Excruciating
Temperature	<38 C	38-40C	>40C
Blood Pressure	Normal	+/- normal	<80 SBP
Temporary Loss of Consciousness	0	0	+/- coma
Blood lymphocytes (24/48h, uL)	(>1500/>1500)	(<1500/<1500)	(<500/<100)

Laboratory Evaluation (First 48 Hours)[43]	
Spaceflight	• CBC with differential and reticulocyte count every 4-8 hours for the first 24 hours, then every 12 to 24 hours • "Standard biochemical tests" (CMP, calcium, magnesium, phosphorous) **+** amylase
Terrestrial (either not needed or unavailable)	• Chromosome aberration analysis on blood lymphocytes *(not available but also unnecessary)*

	• Red cell group typing (likely done pre-flight but will need to be available in the EMR) • Freeze samples of serum and cells for future HLA typing *(unnecessary – for bone marrow transplant)*

11.4 ARS SCENARIO NARRATIVE

The crew is treated according to a Score 2 guideline for Acute Radiation Sickness. Additionally, the CP consults an expert on the ground for input.

11.4.1 ARS ALGORITHM APPLICATION

Block 9 – Treat and Rehabilitate	
Summary	• After drawing the appropriate laboratory analysis, the CP treats the sickened astronauts with bone marrow support, antibiotics, fluids, and symptomatic care as needed (Section 10.4.2) • 48 hours after exposure and in consultation with ground experts, patients will be re-evaluated based on METREPOL criteria (Section 10.4.2)
Decision	Treatment of ARS (Score 2) and appropriate continued surveillance and re-evaluation
Info. Source	• Electronic reference material • Ground medical support
Resources	• IV fluids and ability to generate IVF on-demand • Blood collection containers, blood transfusion kits • Appropriate medicines (Section 10.4.2) • Waste management (emesis, diarrhea, isolation kits)
Functionality	• MS tracks medication usage • MS has walking blood bank functionality (if required) • MS can store and display ground communications in the patient chart
Training	• ARS therapy • Biologic waste management

11.4.2 ARS REFERENCE INFORMATION

Treatment of ARS Based on ECCSS [41, 42]	
Score 1	Clinical monitoring and symptomatic treatment
Score 2	• Reverse isolation • Cytokines (G-CSF 5ug/kg sc qday or GM-CSF 5-10 ug/kg/d) for 2-3 weeks if dose between 30-10 Gy or fall in ALC below baseline or until ANC >1000uL • Ondansetron (8mg IV q8h) for nausea and emesis • Loperamide (4mg followed by 2mg, max 16mg/24h, [*not if fever is present]*) or octreotide for diarrhea • Irradiated platelet transfusion if <20,000

	• Antibiotics:
	  ○ Asymptomatic neutropenia: oral fluoroquinolone (levofloxacin 750mg PO qd) only if expected to be prolonged
	  ○ Neutropenic fever and low risk symptoms: oral fluoroquinolone (as above) **+** amoxicillin-clavulanate (500mg/125mg PO TID)
	  ○ Neutropenic fever and high risk symptoms: IV 4th generation cephalosporin, macrolide, or piperacillin/tazobactam
	• Consideration for antibiotics for PCP prophylaxis if risk >6% (trimethoprim-sulfamethoxazole)
	• Antivirals for varicella-zoster outbreak: acyclovir
	• Antifungal prophylaxis if prolonged neutropenia: fluconazole 400mg qd
	• IV or PO electrolyte replacement solutions

Score 3	Score 2 **+** palliative care measures

Re-Evaluation Based on METREPOL (After 48 Hours) [40]				
Response Category (RC) System [40] is based on the highest degree of the following evaluated systems (neurovascular, hematopoietic, cutaneous, and gastrointestinal).				
NEUROVASCULAR SYSTEM				
	Degree 1	**Degree 2**	**Degree 3**	**Degree 4**
Nausea	Mild	Tolerable	Intense	Excruciating
Vomiting	Occasional (1/d)	Intermittent (2-5/d)	Persistent (6-10/d)	Refractory (>10/d or requires TPN)
Anorexia	Able to eat	Decreased PO intake	No significant intake	Requires TPN
Fatigue syndrome	Able to work	Decreased activity	Needs some assistance for self-care	Needs total assistance
Fever	<38C	38-40C	>40C <24h	>40C for >24h
Headache	Minimal	Tolerable	Intense	Excruciating
Hypotension	None	BP<100/70	BP<90/60 transient	BP<80/? Persistent
Neuro deficits	Barely detectable	Easily detectable but low severity	Prominent with interference with activities	Life threatening (AMS, LOC)
Cognitive deficits	Minor loss of memory, judgement	Moderate loss of memory, reasoning, and/or judgement	Major intellectual impairment	Complete memory loss
HEMATOPOIETIC SYSTEM				
	Degree 1	**Degree 2**	**Degree 3**	**Degree 4**

Lymphocyte changes	>1.5 e9	1-1.5 e9	0.5-1 e9	<0.5 e9
Granulocyte changes	>2 e9	1-2 e9	0.5-1 e9	<0.5 e9 or initial granulocytosis
Thrombocyte changes	>100 e9	50-100 e9	20-50 e9	<20 e9
Infection	Local (no therapy required)	Local (topical abx only)	System (PO abx)	Sepsis (IV abx)
Blood loss	Petechiae, normal Hb	Mild blood loss <10% decrease	Gross loss 10-20% decrease	Spontaneous bleeding or blood loss >20%
CUTANEOUS SYMPTOMS				
	Degree 1	**Degree 2**	**Degree 3**	**Degree 4**
Erythema	Minimal or transient	Moderate; patches <10cm^2	Marked, isolated patches or confluent 10-40% BS	Severe, isolated patches or confluent >40% of BS
Sensation/itching	Pruritus	Slight and intermittent pain	Moderate and persistent pain	Severe and persistent pain
Swelling/edema	Present, asx	Symptomatic	Symptomatic and causing dysfunction	Total dysfunction
Blistering	Rare with sterile fluid	Rare with hemorrhagic fluid	Bullae with sterile fluid	Bullae with hemorrhage
Desquamation	Absent	Patchy dry	Patchy moist	Confluent moist
Ulcer/necrosis	Epidermal only	Dermal	Subcutaneous	Muscle/bone
Hair loss	Thinning	Patchy	Complete	Complete
Onycholysis	Absent	Partial	?	Complete
GASTROINTESTINAL SYSTEM				
	Degree 1	**Degree 2**	**Degree 3**	**Degree 4**
Diarrhea Frequency	2-3 stools/d	4-6 stools/d	7-9 stools/d	>10 stools
Consistency	Bulky	Loose	Sloppy	Watery
Mucosal loss	Intermittent	Intermittent but large volume	Persistent	Persistent with large volume
Bleeding	Occult	Intermittent	Persistent	Gross hemorrhage
Abdominal cramps/pain	Minimal	Tolerable	Intense	excruciating

*METREPOL: Medical Treatment Protocols for radiation accident victims

12.0 IMPACTED RENAL STONE, HYDRONEPHROSIS, AND UROSEPSIS WITH SEPTIC SHOCK

Mission Phase	Level of Care	Occurrence	Operation
Transit	**V – Autonomous**	**Unplanned**	**Contingency - Directed**

12.1 SEPSIS SCENARIO NARRATIVE

Despite nominal health up to this point, the Physician Astronaut starts to develop left-sided low back (costovertebral angle) pain and tenderness that radiates to the groin. The pain quickly ramps up to a 9/10 pain, and is followed by nausea and vomiting. These events were witnessed by the ship's Crew Medical Officer (CMO) who stops to assist the Physician Astronaut. The two head over to the medical bay and the CMO asks the ship's computer to access the Medical System. The system identifies the CMO and allows him access to the Physician Astronaut's, now patient's, health record."

12.1.1 SEPSIS ALGORITHM APPLICATION

Block 1 – Scene Safety	
Summary	Ambulatory patient with no history of acute injury or exposure
Decision	Scene is safe, proceed to rapid initial assessment
Info. Source	CMO situational awareness
Resources	None
Functionality	None
Training	Triage

Block 2 – Rapid Initial Assessment	
Summary	• Patient's pain level is described as "severe". • This is corroborated by objective data of nausea and vomiting from the pain. • No mechanism of injury involved (non-traumatic) Patient appears conversant and ambulatory, though uncomfortable.
Decision	This meets criteria for an Emergent Medical Condition based on severe pain, but is non traumatic $\rightarrow$ proceed to assessing ABCs (**Block 4**).
Info. Source	Reference criteria for emergent/non-emergent conditions; patient's knowledge.
Resources	None
Functionality	None
Training	Triage

12.2 SEPSIS SCENARIO NARRATIVE

Patient appears to be in pain, but is still speaking with CMO, suggesting that she is maintaining her airway and is breathing appropriately and that her blood pressure is sufficient for brain perfusion. The Medical System prompts the CMO to collect vital signs. He gathers the equipment for measuring blood pressure, heart rate, oxygen saturation, temperature, and respiratory rate and places them on patient. He calls out the results as they are gathered, and the Medical System automatically saves them to the patient's health record using voice recognition technology. The Medical System displays the data back to the CMO. At this time, blood pressure is 155/90, pulse is 110, respiratory rate is 18, temperature is 99.0°F, and oxygen saturation is 99%.

12.2.1 SEPSIS ALGORITHM APPLICATION

Block 4 – Assess ABCs	
Summary	• The severe nature of the pain prompts the CMO to assess the ABCs of the patient to ensure the patient is stable, as part of the Emergency Medical Condition protocol • This is done in part through observation of the patient (is she talking, labored breathing, etc.) and in part with vital signs • As a part of this, the CMO also creates a new medical encounter in the MS
Decision	• Patient's ABCs appear to be uncompromised based on observation and vital signs • After necessary data is obtained and recorded, proceed to Focused Evaluation (**Algorithm 6**)
Info. Source	• CMO observations that patient is talking and breathing unlabored • Automated import of vital signs • CMO interpretation of vital sign data
Resources	• Hardware to obtain and import vital signs into MS (HR, BP, SpO_2, temperature) • MS can interpret vital signs as normal or abnormal.
Functionality	MS in appropriate data entry mode for general medical evaluation.
Training	Triage (able to assess patient's airway protection and breathing as appropriate).

12.3 SEPSIS SCENARIO NARRATIVE

Because of the level of discomfort of the patient, the CMO decides to give the patient an initial dose of pain medication. Directed by the patient and after checking medication allergies, the CMO gives patient 4mg morphine, which eases her pain. The patient then explains her symptoms in more detail, as well as the time course over which they occurred. The CMO decides to perform an exam, so he directs the Medical System to initiate a medical encounter, which prompts it to record all medical interaction between the caregiver, patient, and Medical System. The CMO starts the exam off by gathering the appropriate history from the patient. The Medical System prompts, records, reviews, and summarizes the interview in the patient's medical record. The CMO references the vehicle's historical environment data and his patient's health record via the Medical System.

12.3.1 SEPSIS ALGORITHM APPLICATION

Block 6 – Focused Evaluation	
Summary	• After appropriate subjective data acquisition, the CMO decides to proceed with the examination • Appropriate physical examination in this scenario includes the following: • Updated vital signs • General mental status (whether the patient is alert and oriented to person, place, and time) • Examination of the potentially involved systems: back, abdomen, GU • Additional examinations could include cardiovascular and pulmonary systems
Decision	• Patient is tachycardic with mildly elevated BP secondary to pain • Patient has tenderness over left flank with radiation to groin • This improves with administration of pain medication • Vital signs and exam are stable • After documentation of the exam, proceed to data acquisition and differential diagnosis (**Algorithm 8**)
Info. Source	• Automated import of vital signs • CMO interpretation of the physical exam and subjective history given by the patient and reviewed on the Medical System (with or without aid in interpretation by patient)
Resources	• Medical references • Hardware to obtain and import vital signs into the MS (as above). • Digital stethoscope
Functionality	• MS in appropriate data entry mode for general medical evaluation • MS can recommend appropriate physical examination and techniques • MS can interpret vital signs as normal or abnormal
Training	• General physical examination • GU examination

12.4 SEPSIS SCENARIO NARRATIVE

Based on the physical exam findings and vital signs, the Medical System produces a differential diagnosis and presents it to the CMO, who disregards the low-risk conditions and focuses on the higher risk conditions. Each suggested condition contains a link to additional information, such as variation in presentation, diagnostic approach, and treatment modalities, all stored within the Medical System and accessible to the medical provider if desired.

The CMO can see based on this information that the most likely diagnosis is that the crewmember has a kidney stone, but needs additional data to confirm and further characterize the diagnosis (such as determine size of the stone and evaluate for hydronephrosis) and to make certain there we no other medical issues, such as acute kidney injury, superimposed infection, or any other surreptitious abdominal, chest, or cardiac issue. This data is synchronized with the Earth Medical System so the

Crew Surgeons and SME's are aware and can provide their input and guidance to the CMO*. The medical team on Earth relays an initial diagnostic and treatment plan to the ship's CMO by both audio channels and via the Medical System.

***First notification and communication with Earth**

12.4.1 SEPSIS ALGORITHM APPLICATION

Block 8 – Data Acquisition and Differential Diagnosis	
Summary	Incorporating history (age, gender, severe flank pain, risk factors) and exam findings (CVA tenderness with radiation to groin), an appropriate systems or symptoms-based differential (see box below) is generated.
Decision	Based on the differential, select appropriate further evaluation: ultrasonography, urinalysis, complete blood count, complete metabolic panel, cardiac enzymes, EKG before proceeding with treatment.
Info. Source	• CMO interpretation of subjective (history) and objective (physical exam, images, labs) data (with or without the help of patient). • Ultrasound imagery • Laboratory results • Interpretation of subjective and objective data from Earth-based SMEs.
Resources	• Appropriate reference texts, including medical and pharmaceutical references. • "Just in time training" (JITT) or easy-to-follow instructions for ultrasound of kidney and bladder* (**may already available on the vehicle, or uploaded from Earth*) • Blood draw supplies, urine sample supplies. • Laboratory equipment. • Vehicle to Earth communication and data-transfer capability.
Functionality	• MS provides access to appropriate references • MS provides ultrasound training on demand • MS has some ultrasound imaging interpretation capability • MS is integrated with lab hardware to download and interpret lab values • MS provides and updates a differential diagnosis based on input data • MS can locate needed supplies. • MS is integrated with vehicle electronic and communication systems to enable audio and video communication data transfer, as well as data transfer of laboratory data (including video) to Earth.
Training	• Handheld use of ultrasound • Blood draws • Lab hardware use • Formulating a differential diagnosis • Ground communication and data transfer procedures

12.5 SEPSIS SCENARIO NARRATIVE

With this new data, the initial list of differential diagnoses provided by the Medical System is reduced. The CMO updates the Medical System to indicate that a kidney stone is the most likely condition, as well as a probable superimposed urinary tract infection based on the results of the urinalysis, and a possible pyelonephritis based on signs of infection on the complete blood count. All of this information was also communicated to the patient. With the help of the Physician Astronaut and now patient, the CMO develops a plan for further diagnosis and initial treatment that includes drawing blood and urine cultures, then treating with antibiotics for a urinary tract infection, and giving medications for pain control.

The Medical System cross-checks the antibiotic and pain medication with the crewmember's health record to verify that there are no contra-indications for that particular medication. The Medical System also receives communication back from Earth-based SMEs regarding recommendations for nephrostomy tube placement given the large size of the stone and the improbability of passing it. These components of the treatment plan are logged into the Medical System, which displays the entered information for review. The Medical System then coordinates with the vehicle's communication system to synchronize the onboard and Earth electronic health systems. The augmented reality JITT for nephrostomy tube placement is uploaded to the Medical System from the Earth. The CMO administers more pain medication for the patient, draws blood and urine for cultures, starts antibiotics, watches the JITT training video for nephrostomy tube placement, then proceeds to perform tube placement procedure using the augmented reality feature. The procedure is video recorded from several angles, and from the CMO's perspective and is sent to the medical team on Earth. Following tube placement, patient has sizeable relief and urine is seen to drain from tube. CMO repeats kidney ultrasound to confirm appropriate placement of tube and visual confirmation of kidney decompression. The ultrasound images are sent to Earth to confirm appropriate placement by the Crew Surgeons and SMEs. They send back an audio communication confirming that they agree with catheter placement.

12.5.1 SEPSIS ALGORITHM APPLICATION

Block 9 – Treat and Rehabilitate	
Summary	The CMO enters the assessment as "impacted stone with hydronephrosis and possible urinary tract infection" and initiates treatment. Given the lack of culture results, antibiotic selection must cover the most common causative agents. Nephrostomy tube is placed and appropriate placement confirmed by both CMO and Earth SME.
Decision	Prescribe pain medications and antibiotics at the appropriate dose, interval, and route to the patient, taking into account her medical history and allergies (see below). Place and maintain nephrostomy tube so as to ensure kidney decompression. Monitor as appropriate (including culture results to further tailor antibiotic treatment). Can refer back to **Algorithms 7A** or **4** if clinical condition changes, depending on the severity of the change
Info. Source	• Pharmaceutical reference • Antibiotic/infectious disease reference

	• List of available antibiotics/pain medications on the vehicle, location, and previous utilization • Interpretation of subjective and objective data from Earth-based SMEs
Resources	• Medication list • References as above • Augmented reality, "Just in time training" (JITT) instructions for ultrasound of kidney and bladder • Augmented reality, "Just in time training" (JITT) instructions for percutaneous nephrostomy tube placement • Blood draw supplies, urine sample supplies • Culture laboratory equipment • Nephrostomy tube procedure kit supplies • Vehicle to Earth communication and data-transfer capability
Functionality	• MS tracks medication supply and updates estimates of supply availability for the rest of the mission • MS tracks medication usage and can project shortages • MS can locate needed supplies • MS provides procedure training on demand • MS has some ultrasound imaging interpretation capability • MS is integrated with vehicle electronic and communication systems to enable audio and video communication data transfer, as well as data transfer of laboratory data (including video) to Earth • MS will re-schedule the patient for follow up visit. • MS saves encounter after CMO finishes data entry and prepares it for submission/synchronization with the Earth
Training	• Resource utilization • Use and monitoring of prescription drugs. • Selection of appropriate treatment regimen based on a diagnosis • Blood draws • Lab hardware use • Procedure performance • Ground communication and data transfer procedures

12.6 SEPSIS SCENARIO NARRATIVE

The patient's clinical status is rechecked by CMO a short time after initial management is concluded and patient is started on antibiotics and pain medications. At that time, patient is found to be "clammy" and toxic-looking. Her breathing appears to be more labored. Because of an apparent worsening clinical status, CMO decides to reevaluate the patient based on the medical management algorithm. Because of the potentially severe medical implications of the new physical exam findings, CMO decides to proceed with **Block 4** for further management of the patient. He again gathers the equipment for measuring vital signs and places them on the patient. He calls out the results as they

are gathered, and the Medical System automatically saves them to the patient's health record using voice recognition technology. The Medical System displays the data back to the CMO. At this time, blood pressure is 90/50, pulse is 122, respiratory rate is 24, temperature is 99.0°F, and oxygen saturation is 96%."

12.6.1 SEPSIS ALGORITHM APPLICATION

Block 4 – Assess ABCs	
Summary	The potentially worsening clinical status prompts the CMO to assess the ABCs of the patient to ensure the patient is stable, as part of the Emergency Medical Condition protocol. This is done in part through observation of the patient (is she talking, labored breathing, etc.) and in part with vital signs. As a part of this, the CMO an addendum to his original medical encounter in the MS.
Decision	• Patient's ABCs appear to be possibly compromised based on observation and vital signs. • After necessary data is obtained and recorded, proceed to Initiate BLS/ACLS (**Block 5**).
Info. Source	• CMO observations that patient's clinical status is "worsening" with more labored breathing and decreased sensorium. • Automated import of vital signs. • CMO interpretation of vital sign data.
Resources	Hardware to obtain and import vital signs into MS (HR, BP, SpO_2, temperature)
Functionality	• MS in appropriate data entry mode for general medical evaluation. • MS can interpret vital signs as normal or abnormal.
Training	Triage (able to assess patient's airway protection and breathing as appropriate).

12.7 SEPSIS SCENARIO NARRATIVE

Based on the physical exam findings and vital signs, the Medical System indicates to the CMO that patient has potentially compromised ABCs and that the CMO should consider initiating BLS and/or ACLS. The CMO does so by beginning to visually inspect the patient's airway, which currently looks patent with no obstruction. He continues by observing the patient's breathing, which appears mildly labored, but does not seem to be concerning for imminent collapse. As a part of this breathing observation, the CMO auscultates the patient's lungs and hears fine crackles in the bases bilaterally consistent with new fluid.

Based on the new vitals and exam information, the patient's condition is concerning for early septic shock. The CMO begins two antecubital IV's in the patient's arms and starts an infusion of normal saline solution. After 2 liters of IV fluids, patient's vitals are rechecked and patient's blood pressure is found to be 73/42. At this point, the CMO decides to start a vasopressor drug. He communicates with the Earth SME to ensure that this is an appropriate action and to receive further instruction on how to perform such a task. Once receiving communication with the Earth-based Crew Surgeon, he places an intraosseous access device (IO)* and a peripheral arterial line and starts the new medication.

Note: *IO is placed because the CMO will be well trained in its use. A central line would be more challenging and require augmented reality or JITT or other.

He also places a Foley catheter into the patient's bladder in order to monitor urine output as a measure of adequate circulation. With the start of the vasopressors, patient's blood pressure begins to improve to 91/53. The CMO checks an arterial blood gas, a chest x-ray, a lactic acid level, cardiac enzymes, and an EKG to assess the patient's peripheral circulatory and overall clinical statuses and to assess proper placement of the IO. CMO relays all information on blood work results, clinical status, and procedure course back to the Earth Crew Surgeon and SMEs for assessment and further recommendations.

12.7.1 SEPSIS ALGORITHM APPLICATION

Block 5 – Initiate BLS/ACLS	
Summary	The CMO modifies treatment based on the new vitals and clinical exam findings. New treatment is focused on more emergent ABC management. Patient is given IV fluids and started on vasopressors drugs. This is done in consultation with Earth Crew Surgeon and SMEs. Medical Encounter is updated
Decision	Administer IV fluids and vasopressors drugs at the appropriate dose, interval, and route to the patient, taking into account her medical history and allergies (as before). Monitor as appropriate, including consultation with Earth. Will reassess clinical status and consider reinitiating algorithm based on patient's clinical course.
Info. Source	• Pharmaceutical reference • List of available IV fluids and vasopressor medications on the vehicle, location, and previous utilization • Interpretation of subjective and objective data from Earth-based SMEs.
Resources	• Medication list • References as above Augmented reality, "Just in time training" (JITT) instructions for intraosseous access device placement** *(this basic procedure should be a part of the Medical System already)* • Blood draw supplies • Arterial line kit • Central venous catheter kit • Vehicle to Earth communication and data-transfer capability.
Functionality	• MS tracks medication supply and updates estimates of supply availability for the rest of the mission • MS tracks medication usage and can project shortages • MS can locate needed supplies • MS provides procedure training on demand • MS provides procedure training on demand • MS is integrated with vehicle electronic and communication systems to enable audio and video communication data transfer, as well as data transfer of laboratory data (including video) to Earth
Training	• Resource utilization

	• Use and monitoring of prescription drugs • Selection of appropriate treatment regimen based on a diagnosis. • Blood draws • Lab hardware use • Procedure performance • Ground communication and data transfer procedures

12.8 SEPSIS SCENARIO NARRATIVE

The patient's clinical status is checked again a short time after initiating a vasopressor agent. Her breathing appears to be more labored with use of accessory muscles. Because of an apparent worsening clinical status, CMO again decides to reevaluate the patient based on the medical management algorithm. Because of the potentially severe medical implications of the new physical exam findings, CMO again decides to proceed with **Block 4** for further management of the patient. He gathers the equipment for measuring vital signs and places them on the patient. He calls out the results as they are gathered, and the Medical System automatically saves them to the patient's health record using voice recognition technology. The Medical System displays the data back to the CMO. At this time, blood pressure is 96/57, pulse is 106, respiratory rate is 35, temperature is 102.3°F, and oxygen saturation is 92%."

12.8.1 SEPSIS ALGORITHM APPLICATION

Block 4 – Assess ABCs	
Summary	The potentially worsening clinical status prompts the CMO to assess the ABCs of the patient to ensure the patient is stable, as part of the Emergency Medical Condition protocol. This is done in part through observation of the patient (is she talking, labored breathing, etc.) and in part with vital signs. As a part of this, the CMO an addendum to his original medical encounter in the MS.
Decision	• Patient's ABCs appear to be possibly compromised based on observation and vital signs. • After necessary data is obtained and recorded, proceed to Initiate BLS/ACLS (Block 5).
Info. Source	• CMO observations that patient's clinical status is "worsening" with more labored breathing and decreased sensorium. • Automated import of vital signs. • CMO interpretation of vital sign data.
Resources	Hardware to obtain and import vital signs into MS (HR, BP, SpO_2, temperature)
Functionality	• MS in appropriate data entry mode for general medical evaluation. • MS can interpret vital signs as normal or abnormal.
Training	Triage (able to assess patient's airway protection and breathing as appropriate).

12.9 SEPSIS SCENARIO NARRATIVE

Based on the physical exam findings and vital signs, the Medical System indicates to the CMO that patient has potentially compromised ABCs and that the CMO should consider initiating BLS and/or ACLS. The CMO does so by beginning to visually inspect the patient's airway, which again looks patent with no obstruction. He continues by observing the patient's breathing, which appears more labored presently, and concerning that the patient may tire herself out. The CMO auscultates the patient's lungs and hears worsening crackles throughout the entire lung fields bilaterally consistent with worsening fluid.

CMO decides to proceed with intubating the patient for airway protection and prevent of respiratory collapse. He begins by ventilating the patient by hand while communicating current clinical status, labs and vitals with the Earth-based Crew Surgeon and SMEs to confirm the appropriateness of this plan and to receive recommendations on how to proceed. He then initiates rapid sequence intubation with anesthetic and paralytic medications. He places the patient on a ventilator after endotracheal tube placement and places the patient on a maintenance anesthetic, under guidance of the Medical System. He follows up tube placement with an arterial blood gas, chest x-ray, cardiac enzymes, EKG, lactic acid, and coagulation factors to assess proper tube placement and to assess current circulatory status.

The patient's clinical status is relayed to the Earth Crew Surgeon and SMEs for assessment, and further recommendations. At this point the decision is made, in consultation with the Earth to proceed with ultrasonic dissolution of the obstructing stone. Augmented reality, JITT guidance for the procedure is uploaded to the ship from the Earth. The CMO successfully performs the procedure under augmented reality guidance. Video of the procedure is relayed to the Earth. Subsequent to this, a repeat ultrasound is performed to ensure that the stone is adequately broken up. These images are relayed to Earth for confirmation.

12.9.1 SEPSIS ALGORITHM APPLICATION

Block 5 – Initiate BLS/ACLS	
Summary	The CMO modifies treatment based on the new vitals and clinical exam findings. New treatment is focused on more emergent ABC management. Patient is intubated with rapid sequence intubation and given anesthetic and paralytic medications. Patient is placed on a ventilator following intubation for maintenance of respiratory function. Following this, ultrasonic dissolution is performed to break up the patient's stone. This is all done in consultation with Earth. Medical record is updated and sync'd to the Earth.
Decision	Administer anesthetic/paralytic drugs at the appropriate dose, interval, and route to the patient, taking into account her medical history and allergies (as before). Monitor as appropriate, including consultation with Earth. Will reassess clinical status and consider reinitiating algorithm based on patient's clinical course.
Info. Source	• Pharmaceutical reference. • List of available anesthetic/paralytic medications on the vehicle, location, and previous utilization. • Interpretation of subjective and objective data from Earth-based SMEs.
Resources	• Medication list

	• References as above
	• Augmented reality, "Just in time training" (JITT) (already a part of the Medical System) for:
	  ○ rapid sequence intubation
	  ○ ultrasonic dissolution
	  ○ ultrasound of kidney and bladder
	• Blood draw supplies
	• Intubation kit, including suction and oxygen source
	• Vehicle to Earth communication and data-transfer capability

Functionality	• MS tracks medication supply and updates estimates of supply availability for the rest of the mission • MS tracks medication usage and can project shortages • MS can locate needed supplies • MS provides procedure training on demand • MS provides ultrasound training on demand • MS has some ultrasound imaging interpretation capability • MS is integrated with vehicle electronic and communication systems to enable audio and video communication data transfer, as well as data transfer of laboratory data (including ultrasound and video) to Earth. • MS saves encounter after CMO finishes data entry and syncs with the Earth.
Training	• Hand held ultrasound use • Resource utilization • Use and monitoring of prescription drugs. • Selection of appropriate treatment regimen based on a diagnosis. • Blood draws • Lab hardware use • Procedure performance • Ground communication and data transfer procedures

12.10 SEPSIS SCENARIO NARRATIVE

Following intubation and ultrasonic dissolution of the stone, the patient's clinical status stabilizes. CMO was initially performing updated vital signs on the patient every hour with updated labs (complete blood count, complete metabolic panel, magnesium, phosphorus) to monitor clinical status every 4 hours. This information was relayed to the Earth base medical team every hour for situational awareness and for any recommendations should they occur. Chest x-rays and arterial blood gas analysis were performed every 24 hours and this information was also relayed to the Earth. The patient was monitored in this way for approximately 48 hours.

At this time, the patient's blood pressure improved and she is able to wean off the pressor. Her respiratory status also improved and her oxygen requirements are titrated down on the ventilator. She is given a breathing trial and is then successfully extubated. Her vital sign checks are spaced further

out over the next 96 hours, first to every 4 hours and then to every 8 hours. Her blood draws are spaced out to twice a day and then to once a day. Chest x-rays and arterial blood gases are stopped. Synchronization of the Medical System with Earth is extended to every 4 hours, then to every 8 hours initially. As the patient slowly improves communication is twice daily for a week, then then daily for two more weeks, then sync'd as needed. The Medical System and Earth medical team develop a rehabilitation plan for the patient, which is communicated to the CMO. Patient is started on physical therapy and incentive spirometry to regain her strength and further improve her respiratory status. The patient eventually recovers and is returned to duty as the ship's physician.

13.0 DEATH OF CREW FAMILY MEMBER

Mission Phase	Level of Care	Occurrence	Operation
Transit – IVA	**IV- Semi autonomous**	**Unplanned**	**Assisted**

13.1 FAMILY MEMBER DEATH SCENARIO NARRATIVE

One month out from Martian orbital insertion of flyby mission. Crew member receives notice via spouse and flight surgeon that 11 year old child admitted to hospital for difficulty breathing.

13.1.1 FAMILY MEMBER DEATH ALGORITHM APPLICATION

Block 1 – Scene Safety	
Summary	Mild symptoms of guilt and helplessness in CM
Decision	Scene is safe, proceed to initial assessment
Info. Source	Situational Awareness
Resources	None
Functionality	None
Training	Triage

Block 2 – Rapid Assessment	
Summary	CM child is in the hospital for breathing difficulties
Decision	This is non-emergent but resources to assist CM should be mobilized
Info. Source	Criteria for emergent/non-emergent conditions
Resources	CMO, FS, BHP office, store and forward video comm, e-mails, BHP self-help modules for CM, BHP review modules for CMO
Functionality	None
Training	Triage

13.2 FAMILY MEMBER DEATH SCENARIO NARRATIVE

BHP arranges store and forward video communication in CM child's hospital room and facilitates any needed adjustments to CM schedule. BHP sends email to CM offering support and offering to assist with family on earth as needed. FS and spouse hold store and forward video conferences as requested by CM over next week (every 2-3 days) with nightly email updates on child's status from the FS and spouse. CMO meets with CM to establish supportive relationship as needed. CMO communicates with BHP and FS with updates as needed (1-2/week).

After a few days, child's respiratory status has worsened. The child is intubated and placed on a ventilator in the ICU. FS/BHP sends email to CMO, and commander notifying them of situation and suggesting CMO utilize Just in Time Training software to strengthen skills needed for counseling. Comm between Spouse and CM increases to nightly while FS meets with CM as needed to help with any medical questions. FS/BHP again messages CM offering support, and recommends regular meetings with CMO on as needed bases. FS/BHP offers support to CMO and prepares any needed resources for uplink. FS/BHP assists with CM schedule changes and arranges comm with family. FS/BHP continues to reach out to spouse to offer support as needed (q3-4 days). BHP notifies CM to observe fitness for duty in CM and need to modify schedule.

13.2.1 FAMILY MEMBER DEATH ALGORITHM APPLICATION

Block 7A – Obtain History	
Summary	• Past psych history of CM: no chronic or acute problems • PMH: no acute or chronic problems • CM exhibits significant feelings of helplessness, anxiety, and frustration, lapses of concentration • CM concerned over not being there for family • CM would like continue to work as this is therapeutic but appreciates efforts to allow time in schedule for family conferences
Decision	• Continue with as needed FS/BHP conferences (q3-4d) • Continue with daily family conferences in hospital • Continue with PRN Q3-4d meetings with CMO for counseling • Continue weekly BHP—> CMO emails and PRN conference (q weekly) • Continue ground support of family via BHP/FS • BHP support self-assessment of CM as fit for duty, but continue to monitor via commander, CM, and CMO
Info. Source	• Patient verbal account • CMO • Patient emails • Family members • Commander account • FS accounts • Store and forward video

	• Other CM
Resources	• JITT for CMO • CMO • store and forward video conference capability to hospital • Store and forward video conference to private conference rooms • Store and forward video conference to home with spouse • Email capability • FS • BHP staff • JITT for CM self help
Functionality	• MS opens new encounter for the CM for a psychiatric chief complaint • MS provides easy access to historical document review • MS records interview and displays it in the encounter and allows CMO/FS/BHP to manually edit voice-to-text input • MS suggests needed data to the CMO
Training	• Psychological monitoring, surveillance, mental status • Knowledge of appropriate listening and counseling techniques for grief and helplessness feelings

Block 7A (continued) – Appropriate Questions and Review of Systems	
Chief-complaint agnostic	The chief complaint for an unplanned event is often the predominant symptom. Feelings of helplessness, grief, and frustration are common. Family will also need significant assistance on ground. In this case questions are less important than listening and responding. Using frameworks for therapy of grief and guilt may be helpful but most communication is informal self-care and buddy care. Review of family structure, dynamics, location, and status is also helpful. Always review: PMHx, PSHx, PPHx, ROS, medications, allergies; social history as needed
Psych related	General: • Mood • Mental status • Family structure
ROS	Mood, affect, activity level, sleep amount, eating amount, thoughts on current situation.

13.3 FAMILY MEMBER DEATH SCENARIO NARRATIVE

Over the next several days, the child's respiratory status continues to worsen and she is requiring increasing levels of oxygen and is finally placed on ECMO. During this time, the blood pressure starts

to drop and requires several liters of IV fluids and ultimately the child is placed on vasopressors. During this time, the CM continues to receive updates and discuss with FS/BHP/Spouse on the same as needed schedule.

After more than a week in the hospital, the child's blood pressure and breathing status begin to stabilize, but her renal function appears to be worsening because of ischemia and acute tubular necrosis from the previous low blood pressure. The CM, who has been in regular contact with the treating physician, makes the decision with the spouse to start the child on dialysis. The patient improves and is ultimately weaned off vasopressors and ECMO.

However, after a week and a half in the ICU, the child's breathing status starts to worsen. The child's blood pressure begins to drop again and she starts spiking fevers. The child is started on antibiotics and pan-cultured, which grows MRSA from the blood, presumably from a dialysis catheter infection. The child's blood pressure continues to drop despite adding a second and then a third vasopressor. After about 2 weeks in the ICU, the child goes into PAE cardiac arrest. She is resuscitated, but is found to have bilateral middle cerebral watershed infarcts. During this time, CM store and forward video communication will need to be increased and CMO check ins will need to be more frequent (daily). BHP will arrange to suspend CM's duties and provide resources for communication and family support as the child's condition deteriorates. BHP will have daily conferences with CMO to begin anticipatory guidance and extra training for an anticipated negative outcomes. BHP will provide continuous support to the ground based family along with FS presence in the hospital to facilitate timely updates to the CM and carry out any requests the CM has regarding the patient.

The child is found to be without spontaneous respirations and has no corneal reflex and does not withdraw to pain off sedation. At this point BHP would request 1-2 crew initiated direct store and forward video link to assist with support as medical team is no longer able to offer primary support. Over the next 48 hours, the CM is in communication with spouse, FS, and child's medical team as often as comm delays allow to discuss what to do from an end of life standpoint. The decision is ultimately made to withdraw care. BHP would also have twice daily store and forward video linked conferences with CM, and multiple e mails to CM, CMO, and commander. Multiple hours of store and forward video comm between CM and family/friends with BHP supporting will be the bulk of communications.

13.3.1 FAMILY MEMBER DEATH ALGORITHM APPLICATION

Block 7B – Physical Exam	
Summary	After appropriate subjective data acquisition
Decision	Intense symptoms of grief, helplessness and acute depressed mood signify an acute grief reaction. CMO, BHP and Commander support crew member and will shift critical duties from CM to others as needed. Non critical tasks may still be performed by CM as the CM desires or shifted to others. Non critical comm will cease to free up space for comm with BHP, family, spouse, friends and CM.

Info. Source	• Patient verbal account • CMO • Patient emails • Family members • Commander account • FS accounts • Store and forward video • Other CM
Resources	• JITT for CMO • CMO • Store and forward video conference capability to hospital • Store and forward video conference to private conference rooms • Store and forward video conference to home with spouse • Email capability • FS • BHP staff • JITT for CM self help
Functionality	• MS in appropriate data entry mode for psychological examination • MS has templates for psych examination findings • MS can take voice input to enter data into the medical encounter document • MS can receive, record, and display automated assessments
Training	• Psychological assessment • Acute grief reaction management

13.4 FAMILY MEMBER DEATH SCENARIO NARRATIVE

Following the death of the child, the CM increases the frequency of communicating with family and the BHP group will help support spouse and the rest of ground family. A store and forward video link to memorial service will be provided. BHP will likely have tapering communications as needed with CM, spouse and CMO starting with 2/week and tapering off to baseline (once every 2 weeks) over the course of about 2 months. The latter session may be linked with PMCs to facilitate a team approach as grief reaction stabilizes over time. BHP will continue to provide support for ground family and spouse as needed. CMO will meet with crew member once weekly, likely coordinated with BHP store and forward video uplinks and provide email/store and forward video updates to BHP throughout this period. Gradually CM duties will be reinstated as tolerated and as CM adapts to new circumstances and as work focus and vigilance, is restored.

13.4.1 FAMILY MEMBER DEATH ALGORITHM APPLICATION

Block 8 – Data Acquisition and Differential Diagnosis	
Summary	The psychological diagnosis of acute grief reaction is made and the CMO must use various therapy frameworks to assist with stabilizing CM emotional status. Ground assistance from BHP in store and forward video comm, CMO guidance and BHP aid to ground based family members will be critical.
Decision	Obtain appropriate assessments, reassessments and therapeutic interventions to maximize feelings of control, minimize feelings of helplessness, guilt, and to provide as much availability of CM and family to each other as possible.
Info. Source	• Patient verbal account • CMO • Patient emails • Family members • Commander account • FS accounts • Store and forward video • Other CM
Resources	• JITT for CMO • CMO • Store and forward video conference capability to hospital • Store and forward video conference to private conference rooms • Store and forward video conference to home with spouse • Email capability • FS • BHP staff • JITT for CM self help
Functionality	• MS provides access to appropriate references • MS provides psych assessment training on demand • MS has some psych assessment interpretation capability • MS provides and updates a differential diagnosis based on input data • MS provides suggested frameworks for therapy
Training	• Psychological assessments • Counseling • Collection and documentation of relevant information for e mail downlink to BHP personnel • Formulating a differential diagnosis

13.4.2 FAMILY MEMBER DEATH REFERENCE INFORMATION

Differential Diagnosis for Bereavement

- Uncomplicated Bereavement
- Complicated Bereavement
- Major Depressive Disorder
- Major Depressive Episode
- Suicidality
- Homicidally
- Depression
- Anxiety

High Risk Features
• Suicidal thoughts • Functional impairment • Aggressive behavior • Guilt about things other than actions taken or not taken by the survivor at the time of the death; • Thoughts of death other than the survivor feeling that he or she would be better off dead or should have died with the deceased person; • Morbid preoccupation with worthlessness; • Significant psychomotor retardation (e.g., it's hard to get moving, and what movements there are slow); • Prolonged and serious functional impairment; and • Hallucinatory experiences other than thinking that he or she hears the voice of, or transiently sees the image of, the deceased person.

13.5 FAMILY MEMBER DEATH ALGORITHM APPLICATION

Block 9 – Treat and Rehabilitate	
Summary	The CMO enters the assessment as "uncomplicated bereavement" and stabilizes the condition with therapy and communication based interventions. Expert consultation requested as needed for further details.
Decision	Institute therapeutic frameworks as needed
Info. Source	• DSM V • BHP ground personnel • Medical team for CM child
Resources	• Store and forward video Comm • References as above • Virtual Reality gear

Functionality	• MS tracks medication supply and updates estimates of supply availability of medications for the rest of the mission • MS can flag an encounter for ground review to solicit expert consultation; experts can transmit their recommendations in a way that is recorded to the patient's medical chart and readable by the CMO • MS will re-schedule the patient for follow up visit
Training	• Resource utilization • Use and monitoring of mental status, mood, and prescription drugs

13.5.1 FAMILY MEMBER DEATH REFERENCE INFORMATION

MEDICATION FOR DEEP SPACE DEPRESSIVE EPISODE/BEREAVMENT	
ANXIOLYTICS	**TBD**
ANTIDEPRESSANTS	**TBD**
Selection of medication will depend on contra-indications and severity of condition. In general Bereavement is self-limited and medications should be reserved only for short term sedation of dangerous behavior that threatens well-being of afflicted CM or remaining crew or prolonged reactions concerning for major depressive disorder.	

APPENDIX A: ACRONYMS AND ABBREVIATIONS

ABC	Airway, Breathing, Circulation
Abx	Antibiotics
ABG	Arterial Blood Gas
AED	Automatic External Defibrillator
AC	Ante Cibum
ACLS	Advanced Cardiac Life Support
ACS	Acute Coronary Syndrome
AGE	Arterial Gas Embolism
ALC	Absolute Lymphocyte Count
AMS	Altered Mental Status
ANC	Absolute Neutrophil Count
ARS	Acute Radiation Sickness (or Syndrome)
ATLS	Advanced Trauma Life Support
A&O	Alert and Oriented
BCx	Blood culture
BID	Bis in die
B/L	Bilateral
BLS	Basic Life Support
Blood gas	Arterial Blood Sample
BMI	Body Mass Index
BMP	Basic Metabolic Panel
BOP	Bleeding on Probe
BW	Bitewing
BP	Blood Pressure
BVM	Bag Valve Mask
CAD	Coronary Artery Disease
CAL	Clinical Attachment Level
CBC	Complete Blood Count
CC	Chief Complaint
CE	Cardiac Enzymes
CEJ	Cementoenamel Junction
CG	Caregiver
CP	Chest Pain
CPR	Cardiopulmonary Resuscitation
CMO	Crew Medical Officer
CMP	Complete Metabolic Profile
CN	Cranial nerves
CNS	Central Nervous System
CrCl	Creatinine Clearance
C-spine	Cervical Spine
CSF	Cerebrospinal Fluid
CT	Computed Tomography
CVA	Costovertebral Angle
CVA	Cerebral vascular Accident
CVL	Central venous line
CXR	Chest Xray
DCI	Decompression Illness
DCS	Decompression Sickness

DDx	Differential Diagnosis
DPL	Diagnostic Peritoneal Lavage
DBP	Diastolic Blood Pressure
DVT	Deep Vein Thrombosis
D/C	Discontinue
EBL	Estimated Blood Loss
ECG (or EKG)	Electrocardiogram
ECCSS	European Consensus Conference Scoring System
EMR	Electronic Medical Record
EOM	Extraocular Movements (intact)
ETCO2	End-Tidal Carbon Dioxide
ETT	Endotracheal Tube
FAST	Focused Assessment with Sonography for Trauma
FMH (or FMHx)	Family Medical History
FMS (or FMX)	Full Mouth Series
GCS	Glasgow Coma Scale
G-CSF	Granulocyte Colony Stimulating Factor
GI	Gastrointestinal
GFR	Glomerular Filtration Rate
GM-CSF	Granulocyte-Macrophage Colony Stimulating Factor
GU	Genitourinary
GYN	Gynecology
Gtt	Guttae
HBO	Hyperbaric Oxygen
HEENT	Head, Ears, Nose, and Throat
HLD	Hyperlipidemia
HPI	History of Present Illness
H&H	Hemoglobin and Hematocrit
HR	Heart rate
H&P	History & Physical
HTN	Hypertension
HSV	Herpes Simplex Virus
ICP	Intracranial Pressure
I&D	Incision & Drainage
IM	Intramuscular
INR	International Normalized Ratio
IV	Intravenous (line)
IVD	Intervertebral Disc
IO	Intraosseous (line)
IOP	Intraocular Pressure
I&Os	Ins & Outs
IU	International Units
JVP	Jugular Venous Pressure
K	Potassium
LE	Lower Extremity
LLQ	Left Lower Quadrant
LMP	Last Menstrual Period
LOC	Loss of Consciousness
LP	Lumbar Puncture
LUQ	Left Upper Quadrant
MCV	Mean Corpuscular Volume

MET	Metabolic Equivalent
MI	Myocardial Infarction
MOI	Mechanism of Injury
MSE	Mental Status Exam
MSK	Musculoskeletal
NKDA	No Known Drug Allergies
NGT	Nasogastric Tube
NPA	Nasopharyngeal Airway
NPO	Nil Per Os
NSAID	Non-Steroid Anti-Inflammatory Drug
OB/GYN	Obstetrics and Gynecology
OCT	Optical Coherence Tomography
OD	Oculus Dexter
OPA	Oropharyngeal airway
OPQRST	Onset, Provocation or Palliation, Quality, Radiation, Severity, Time course
OS	Oculus Sinister
OU	Oculi Uterque
PCP	Primary Care Physician or Provider
PD	Probing Depth
PE	Physical Exam
PE	Pulmonary Embolus
PEA	Pulseless Electrical Activity
PERRL(A)	Pupils Equal, Round, and Reactive to Light (and Accommodation)
PMH (or PMHx)	Past Medical History
PNA	Pneumonia
PHTLS	Pre-Hospital Trauma Life Support
PO	Per Os
POC	Point of Care
PRN	Pro Re Nata
PP	Pulse Pressure
PSH (or PSHx)	Past Surgical History
PSR	Periodontal Screening and Recording
PT	Physical Therapy
PT	Patient
PTX	Pneumothorax
PVC	Premature Ventricular Contraction
QD	Quaque Die
QHS	Quaque Hora Somni
ROM	Range of Motion
ROS	Review of Systems
RLQ	Right Lower Quadrant
RR	Respiratory Rate
RSI	Rapid Sequence Intubation
RUQ	Right Upper Quadrant
R/G/M (or M/R/G)	Rubs/Gallops/Murmurs
SBP	Systolic Blood Pressure
SBO	Small Bowel Obstruction
SD	Spatial Disorientation
SI/HI	Suicidal Ideations/Homicidal Ideations
SL	Sublingual
SOB	Shortness of Breath
SpO_2	Peripheral O_2 Saturation

Tension PTX	Tension Pneumothorax
TBI	Traumatic Brain Injury
TID	Ter In Die
TIVA	Total IV Anesthesia
TM	Tympanic Membrane
TMJ	Temporomandibular Joint
UA	Urinalysis
UE	Upper Extremity
US	Ultrasound
UTI	Urinary Tract Infection
V/Q	Ventilation/Perfusion
VS (V/S)	Vital Signs
WBC	White Blood Cell
WNL	Within Normal Limits
XR	X-Ray
YO	Year Old

Airway, Breathing, Circulation	A mnemonic to remind care providers to address imminently life-threating conditions first during emergencies. Airway: ensure that no obstruction exists to the flow of air from the mouth to the lungs. If the airway is obstructed, the provider will need to clear it or intubate (insert a breathing tube into the trachea). Breathing: ensure the patient is breathing adequately, which depends both on an open (not obstructed) airway and the appropriate rate and depth of each breath. If breathing is inadequate, the provider will need to ventilate the patient (manually or mechanically). Circulation: ensure an adequate flow of blood from the heart to the organs. This most often done by checking for a carotid (an artery in the neck) pulse. If a pulse is absent, cardiopulmonary resuscitation (CPR) is started.
Antibiotics	Medical shorthand for antibiotics.
Arterial Blood Gas	Laboratory analysis of an arterial blood sample which can be used to determine hemoglobin concentration, acid-base balance, electrolytes, and oxygenation status.
ABO	ABO is shorthand for laboratory assessment of the blood-group “type” of the patient in order to transfuse “matched” red blood cells.
Automatic External Defibrillator	A machine that autonomously interprets a heart rhythm to determine if an electric shock (defibrillation) is medically indicated (after being turned on and applied to a patient). It is for use by both the public and by care providers without advanced cardiac life support (ACLS) certification.
Ante Cibum	Medicine is to be taken before a meal.
Advanced Cardiac Life Support	A training program developed by the American Heart Association to train care providers in emergency resuscitation. Advanced care providers (doctors, nurses, paramedics) are usually required to take this training program every 2 years to maintain a certification. It goes beyond “basic” life support in that it trains and re-

	certifies providers in the use of medicines and manual electric pacing and/or defibrillation for abnormal cardiac (heart) rhythms.
Acute Coronary Syndrome	A group of clinical conditions that are often called “heart attacks.” Acute coronary syndromes are due to inadequate blood flow to heart muscle.
Arterial Gas Embolism	A type of decompression illness (DCI) in which gaseous bubbles have entered arterial circulation. In addition to DCI, it can also occur due to direct traumatic inoculation.
Absolute Lymphocyte Count	Can be calculated by multiplying the total number of white blood cells against the percentage of white blood cells which are lymphocytes. If the white blood cell count is 8000, and 20% of those white blood cells are lymphocytes, that means the absolute lymphocytes count would be 1600 (8000 x 0.2). This is a normal lymphocytes count.
AMPLE	A mnemonic to address certain details when obtaining the “History of Present Illness” (HPI) in an emergency. It stands for allergies, medications currently used, past illnesses/pregnancy, last meal, and events/environment related to injury. It is best used in a scenario that may require surgery (and thus anesthesia), such as trauma.
Altered Mental Status	Short hand notation for a change in alertness and orientation.
Absolute Neutrophil Count	A measure of the number of neutrophils in the blood. Neutrophils are a type of white blood cell that help the body fight infection. An absolute neutrophil count may be used to check for infection, inflammation, leukemia, and other conditions. The lower a person's absolute neutrophil count is, the higher the risk is of getting an infection.
Acute Radiation Sickness (or Syndrome)	A group of symptoms and related organ/tissue dysfunction due to exposure to large doses of radiation.
Advanced Trauma Life Support	A training program developed by the American College of Surgeons to train care providers in trauma care. It is designed for physicians who deal with trauma in the hospital setting (such as surgeons or emergency medicine physicians).
Apnea	Absent breathing (respiratory rate is zero).
Alert and Oriented	Common short hand to state patient is awake and responsive and oriented. Often oriented is followed by the number 3 (A&Ox3) which means the patient is oriented to self (they know who they are), place (they know where they are), and time (they know what year/month/day it is).
Blood Culture	A laboratory test that takes a blood sample and incubates it on a growth medium to allow for the growth of a bacteria or fungus to determine if there is an infection of the blood stream.
Bis in die	Medical abbreviated meaning to take the medicine twice a day.
Bilateral	Short hand for bilateral (i.e., both right and left sides).
Basic Life Support	A training program developed by the American Heart Association to train care providers of all backgrounds in the basic (no use of medicine) management of choking victims, use of an automatic defibrillator (AED) use, and performance of cardiopulmonary resuscitation (CPR).

Arterial Blood Sample	A sample of arterial blood (usually obtained from the radial artery in the forearm using an “arterial puncture” technique) used for rapid laboratory analysis in emergent or critical care settings to determine the blood count, electrolyte balance, and oxygenation status of the patient.
Body Mass Index	Calculated as weight (in kg) divided by height squared (in meters). A BMI > 25 is overweight and >30 is considered obese. It can be an inaccurate measurement in muscular individuals.
Basic Metabolic Panel	A laboratory test for electrolyte (sodium, potassium, chloride, bicarbonate) concentrations, glucose, and markers of kidney function (creatinine, blood urea nitrogen or BUN).
Bleeding on Probe	A yes/no response: do the gums bleed when probed during a dental exam?
Bradycardia	An abnormally slow heart rate.
Bitewing	A radiologic evaluation of the posterior (molar and premolar) crowns (top/exposed portion of a tooth) and their relation to the alveolar bone (tooth socket).
Blood Pressure	The pressure of the circulating blood and fluid in the arterial system. It is measured typically in millimeters of mercury and can be expressed in three numbers: systolic blood pressure (the maximum pressure achieved caused by contraction of the heart), diastolic blood pressure (the minimum pressure in the vessels in between contractions of the heart), and mean arterial blood pressure, which is roughly 2/3 * diastolic pressure + 1/3 * systolic pressure.
Bag Valve Mask	Handheld device which is applied over the patient’s mouth and nose (the mask portion), while the bag is squeezed to create positive pressure to force air into the patient’s lungs. A form of artificial ventilation. Sometimes called an Ambu-bag.
Coronary Artery Disease	Restriction in the blood flow in the arteries supplying oxygen to the heart.
Clinical Attachment Level	Clinical attachment level is the distance from the cementoenamel junction (CEJ) to base of sulcus. Calculated as PD + recession. Three measurements per side. Reported in millimeters.
Caries	Medical term for cavity (destruction of enamel).
Complete Blood Count	A laboratory test to determine the concentrations of hemoglobin, hematocrit, red blood cells, white blood cells, and platelets. Occasionally includes a differential, which includes information on the absolute amount of each type of white blood cell present (in cells per mL) and also a breakdown by percentage of the types of white blood cells present.
Chief Complaint	The reason(s) the patient sought care or is being seen by the care provider. It could be a symptom (“chest pain”) or a condition (“cellulitis”) and is sometimes qualified by whether it is new or whether it is follow-up
Cardiac Enzymes	Laboratory test often done to determine if a heart attack has occurred.
Cementoenamel Junction	Junction between the crown of the tooth and the root.
Caregiver	Whomever is assessing and treating the patient
Chest Pain	Shorthand for the symptom of chest pain.

Cardiopulmonary Resuscitation	Manual chest compression performed on patients without a pulse to mechanically contract the heart and push blood to the organs. During CPR, the patient is also ventilated to ensure an adequate oxygen supply.
Coags	Medical jargon for coagulation factors, a group of molecules the body produces to help stop bleeding.
Contusion	Bruise.
Crystalloid	Crystalloid refers to fluids with electrolyte compositions appropriate to be given to patients intravenously that are not transfused body fluids (i.e., fluids that are not blood or blood products). Examples of crystalloid include normal saline (NS) which can be full concentration, half-concentration (1/2 NS), or quarter concentration (1/4 NS); lactated ringers (LR); and dextrose solutions which can vary in concentration but are often 5% dextrose (D5) or 10% dextrose (D10) suspended in NS (D5NS), LR (D5LR), or sterile water (D5W).
Crew Medical Officer	Crew Medical Officer.
Complete Metabolic Profile	Laboratory test of electrolytes, kidney function, and liver function.
Cranial nerves	Medical shorthand for cranial nerves, of which there are twelve, usually written I-XII.
Central Nervous System	The brain and spinal cord.
Creatinine Clearance	A metric of kidney function. Creatinine clearance is an important consideration for determining the appropriate dose of medicine as medications are often eliminated from the body by the kidneys.
Cervical Spine	Shorthand for the cervical spine.
Crico-thyroidotomy	Surgical procedure to cut through the anterior portion of the neck to reach the trachea in order to secure the airway with an endotracheal tube.
Cerebrospinal Fluid	Fluid which bathes/surrounds the central nervous system; obtained by lumbar puncture (LP) for laboratory analysis and can leak out in traumatic head injuries.
Computed Tomography	Cross-sectional x-rays.
Costovertebral Angle	The anatomic region of the body defined by the angle where the 12^{th} rib meets the bony spine. CVA tenderness (CVAT) in this region is often due to inflammation of the kidney, as seen in pyelonephritis (infection of the kidney).
Cerebral vascular Accident	A clinical term sometimes used to describe a stroke.
Central venous line	A large catheter (“line”) placed into a large vein (found in the neck, groin, or upper arm, often under ultrasound guidance to prevent injury) to allow for delivery of large volumes of fluids or medicines that would be toxic to smaller veins. CVLs have a high rate of infection if left in place for prolonged periods of time and should be placed under sterile (surgical) conditions.
Chest Xray	Radiography of the chest

Decompression Illness	A group of related medical conditions caused by a reduction in the ambient atmospheric pressure of the environment, causing gaseous bubble formation and inflammation in organs and blood vessels.
Decompression Sickness	A type of DCI involving bubble formation and inflammation in the organs and venous system.
Differential Diagnosis	A list of the possible causes for the patient's symptoms, physical exam findings, and other objective data (such as labs and imaging).
Diagnostic Peritoneal Lavage	A surgical procedure in which a catheter is inserted into the lower abdomen in attempt to aspirate blood following trauma. It has largely been replaced by non-invasive ultrasound tests (see FAST).
Diastolic Blood Pressure	The blood pressure in the arteries during the relaxation phase of the heart. The "lower" number of the blood pressure in medical notation.
Deep Vein Thrombosis	A blood clot in veins which are not just below the surface of the skin. Can be in the lower or upper extremity.
Discontinue	Medical shorthand for plan to discontinue a therapy.
Estimated Blood Loss	Estimate in mL for total blood loss, usually made after a procedure which is expected to cause some loss of blood.
Electrocardiogram	A time-dependent tracing of the electric activity of the heart. Sometimes called EKG, meaning electro-kardio-graph, for historical reasons.
European Consensus Conference Scoring System	See Section 11.3.1 and reference #42.
Echo (or echocardiogram)	An ultrasound examination of the heart.
Electronic medical record	Digital medical record.
Extraocular Movements (intact)	Short hand for assessment of ocular movement. EOMI would suggest that ocular movements are intact (normal).
End-Tidal Carbon Dioxide	A measurement of carbon dioxide in exhaled air through a mask or endotracheal tube.
Endotracheal Tube	A tube inserted into the trachea and sealed in place with an inflatable cushion. Used to create an airway. Can be attached to a bag valve mask so medical providers can provide manual artificial ventilation, or to a mechanical ventilator.
Focused Assessment with Sonography for Trauma	Ultrasound examination used to assess trauma patients for free fluid inside the abdomen, pelvis, and around the heart; if free fluid is seen on the ultrasound image the FAST exam is considered "positive" and the patient often requires a surgical intervention. An "eFAST" exam is "extended" to assess the lungs for pneumothorax (a collapsed lung due to trapped air).
Family Medical History	History of medical conditions experienced by the patient's family.
Full Mouth Series	A complete radiologic evaluation of the teeth and supporting structures.

Fundoscope	Also called an ophthalmoscope, it is a device used to help examine the retina.
Furcation	The location on multi-rooted teeth where the separate roots meet together.
Glasgow Coma Scale	A numeric scale used to assess the neurologic (mental) status of a patient; often used after a head injury or a suspected stroke to assess the severity of the condition. It is scored from 3 (coma) to 15 (fully awake) and depends on eye movement, ability to make verbal communication, and ability to move extremities/follow commands.
Granulocyte Colony Stimulating Factor	A type of medication that stimulates the bone marrow to produce white blood cells, often given to patients on chemotherapy or who have been exposed to large doses of radiation.
Gastrointestinal	Shorthand notation for the gastrointestinal system, which includes the esophagus, stomach, small and large intestines.
Glomerular Filtration Rate	A metric of kidney function. GFR is an important consideration for determining the appropriate dose of medicine as medications are often eliminated from the body by the kidneys.
Granulocyte-Macrophage Colony Stimulating Factor	A substance that helps make more white blood cells, especially granulocytes, macrophages, and cells that become platelets. It is a cytokine that is a type of hematopoietic (blood-forming) agent.
Genitourinary	Short hand notation for the genitourinary system, which includes the kidneys, ureters, bladder, and urethra.
Gynecology	Medical exam of, or specialty for, dealing with the female reproductive system.
GxPxxxx	Short-hand for the gravidity (the number of times a woman has been pregnant) and parity (the outcomes of each of the pregnancies). One method to write parity is "TPAL" or # of term births, # of preterm births, # of abortions (whether spontaneous or induced), and # living children. For example, a never pregnant woman would be G0P0000 whereas as a thrice pregnant woman with three term births and three living children would be G3P3003.
Guttae	Short hand notation for a medicine that is to be infused intravenously at a certain drip rate (mL/hour), for example "heparin gtt."
Hyperbaric Oxygen	A treatment involving delivering oxygen at high partial pressures, usually given in the aerospace medical setting for decompression illness (DCI).
Head, Ears, Nose, and Throat	A portion of the physical exam addressing the referenced anatomic areas.
Hemostat	Surgical tool used to clamp a blood vessel.
	Hemodynamic instability, severe diarrhea, neurologic status changes, hypoxia, evidence of hepatic insufficiency, prolonged ANC<500
Hyperlipidemia	Short hand for elevated cholesterol.
History of Present Illness	A narrative that describes in detail the problem the patient has or the reason for the patient's current visit with the caregiver.
Hemoglobin and Hematocrit	Jargon to reference a laboratory analysis of the blood content of hemoglobin (molecule that carries oxygen) and hematocrit (ratio of blood cells to blood volume)

Heart rate	The number of beats/contractions of the heart in one minute. Also called pulse.
History & Physical	A term to describe how a medical encounter is structured: first, the history of the reason for the visit and second, the physical examination of the patient.
H&Ts	A group of differential diagnoses to consider when attempting an emergency resuscitation when the etiology of the condition is not known. It stands for: hypovolemia (too little blood or plasma volume), hypoxia (low oxygen), h+ ion (acidosis), hypo or hyperkalemia (too little or too much potassium), hypothermia, tension pneumothorax (trapped gas pushing on the heart), tamponade (trapped blood pushing on the heart), toxins, and thrombosis (clots in the heart or lung).
Hypertension	Shorthand for elevated blood pressure, whether systolic or diastolic.
Herpes Simplex Virus	Refers to two viruses (HSV type 1 and type 2) which often infect skin and mucosal surfaces and thereafter can become dormant in nerve ganglions.
Hypopnea	A term referring to a respiratory rate which is abnormally slow
Intracranial Pressure	A term for the measurement of the pressure inside the skull, usually measured by lumbar puncture (LP).
Incision & Drainage	Shorthand notation for the medical procedure of incising and draining an abscess (a pocket of infection that is unable to drain).
Intramuscular	Medication is to be injected into a muscle.
International Normalized Ratio	A laboratory test of clotting time. INR is often used to monitor warfarin therapy, but can be elevated in liver dysfunction.
Intravenous (line)	A small catheter (“line”) placed into a peripheral vein to deliver fluids and medicines. Peripheral veins are found in the arms, legs, hands, feet, and neck. Can also mean medicine is to be injected intravenously.
Intervertebral Disc	A disc (cartilaginous cushion) between vertebral bones. Can become displaced, causing impingement on the spine or nerves and thus pain and weakness, usually in the legs.
Intraosseous (line)	A small catheter (“line”) placed into the marrow space of a bone to deliver fluids and medicines; generally used in emergencies because there is pain associated with the use of a drill to place the catheter. Can also mean medicine is to be injected intraosseously.
Intraocular Pressure	Pressure of the contents of the eye, measured in millimeters of mercury (mm Hg). Is measured with a device called a tonometer.
Ins & Outs	Shorthand notation for the total amount of fluids intake and fluid output (in urine).
International Units	A measurement system for the doses of some medications.
Jugular Venous Pressure	A physical exam finding that estimates the venous blood pressure in the jugular vein (a vein in the neck) which is elevated in situations of resistance to blood flow from the jugular vein through the heart, such as in heart failure or tamponade.
Potassium	Shorthand for potassium concentration, usually measured on the basic metabolic panel (BMP) or complete metabolic panel (CMP).

Large Bore	Bore refers to the internal diameter of a vascular catheter. Because resistance increases dramatically with decreasing diameter, smaller catheters are inappropriate in situations which require rapid delivery of volume or medicine. Large bore catheters are appropriate in these scenarios and include catheters 16 gauge or less (the gauge measurement system is inversely related to diameter – so a 14 gauge has a larger internal diameter than 16g).
Lower Extremity	Short hand notation for legs/feet. Can be written as LLE for left lower extremity and RLE for right low extremity or BLLE for bilateral lower extremities.
Left Lower Quadrant	Medical shorthand for the leftmost lower quadrant of the abdomen.
Last Menstrual Period	Dated to the first day of menstrual flow.
Loss of Consciousness	Medical shorthand for a patient who has lost consciousness. In aerospace, often from excessive acceleration (G-LOC).
	ANC<500 not expected to be prolonged, no comorbidities, no hepatic and renal dysfunction
Lumbar Puncture	Medical procedure by which a needle is inserted through spaces in the vertebral column into the spinal canal to obtain cerebrospinal fluid (CSF).
Left Upper Quadrant	Medical shorthand for the leftmost upper quadrant of the abdomen. Pain in this region could be due to inflammation or injury of the colon, pancreas, or spleen.
Mean Corpuscular Volume	A measurement on the complete blood count (CBC), it represent the mean volume, in femtoliters (fL), of the red blood cells. If it is low, red blood cells are “microcytic.” If it is normal, red blood cells are “normocytic.” If it is high, red blood cells are “macrocytic.” This value is important when determining the cause of anemias (low blood counts).
Metabolic Equivalent	A ratio of the energy required to perform an exercise to some standard energy expenditure. METs are important when assessing a patient’s physical exercise capacity, cardiovascular capacity, or oxygen consumption. For example, a brisk walk would require 3.0 METS while jumping rope would require 10 METS.
Myocardial Infarction	Medical jargon for heart attack.
Mechanism of Injury	The physical process by which a patient was traumatically injured. This described in both general terms (penetrating, crushing, cutting, burning) and also in relation to the situation leading to the injury (motor vehicle crash, fall, assault)
Mental Status Exam	Psychiatric evaluation of a patient.
Musculoskeletal	Shorthand notation for the musculoskeletal system.
Nerve block	Term used for a procedure involving the injection of local anesthetic nerve a large trunk of a sensory nerve to produce a large area of anesthesia.
No Known Drug Allergies	Shorthand for a patient who reports no allergies to medicines.
Nasogastric Tube	Shorthand for a tube placed to allow for delivery of food, fluid, or medicine to the stomach or to allow for suctioning of the stomach contents.

Nasopharyngeal Airway	Device placed into the nares that helps create an airway from the nose to the pharynx, bypassing any obstructions in the mouth. Does not provide ventilation; it simply helps keep an airway open.
Nil Per Os	Medical abbreviation meaning the patient is to take nothing by mouth (no food or water).
Non-Steroid Anti-Inflammatory Drug	A type of analgesic (pain) medicine, usually available over the counter. Includes medicines such as naproxen and ibuprofen. Does usually NOT include aspirin or acetaminophen (Tylenol), although this is often confused.
Obstetrics and Gynecology	Medical specialty (or section of the medical history) related to childbirth and the female reproductive tract.
Occlusion	Occlusion refers to the relationship between the upper and lower jaw when they are closed together.
Optical Coherence Tomography	A type of medical imaging to produce high resolution images using long wavelength light; often used in the aerospace environment to evaluate the retina (back of the eye).
Oculus Dexter	The right eye
Oropharyngeal airway	Device inserted into the mouth to keep the airway open. Does not provide ventilation; it simply helps prop the airway open.
Onset, Provocation or Palliation, Quality, Radiation, Severity, Time course	A mnemonic used to aid the provider in gathering necessary details to create a "history of present illness" (HPI) narrative. Onset refers to when and in what conditions a symptom began, provocation and palliation refers to what helps or worsens the symptom, quality refers to the patient's description (e.g., "sharp" or "burning") of the symptom, severity is generally rated on a scale of 0 to 10, and time course refers to how has the symptom or complaint changed since it began until seeking medical care.
Otoscope	Device used to visual the external ear canal and tympanic membrane; often also used to examine the nasal turbinates.
Oculus Sinister	The left eye
Oculi Uterque	Both eyes
Papilledema	A finding on fundoscopy, ocular ultrasound, or OCT. It refers to fluid build-up and swelling (edema) behind the optic nerve, causing it to jut out.
Primary Care Physician or Provider	Medical provider who is the initial point of contact for, and manager of, continuing, non-emergent medical care.
Probing Depth	Depth with which a periodontal probe can reach in the space between the gingiva and the cementum of the tooth (normal is < 3.5 mm).
Physical Exam	The section of a history and physical dedicated to the recording of data related to examination of the patient, including vital signs.
Pulmonary Embolus	A clot in the arteries leading from the heart to the lung
Pulseless Electrical Activity	A heart rhythm not compatible with life and not responsive to defibrillation (shocking).

Peritoneal signs	Peritoneal signs are findings on physical examination that suggest that the internal lining of the abdomen (the peritoneum) is inflamed, which is concerning for a serious medical condition that may require surgery. These signs include guarding (patient's prevents examination of the abdomen due to pain), rigidity (involuntary contracture of the abdominal muscles), and rebound pain (there is pain when the examiner moves the hand off, rather than onto, the abdomen due to the rebound of the peritoneum back into place).
Pupils Equal, Round, and Reactive to Light (and Accommodation)	Short hand notation for the assessment of the pupils. PERRLA notation indicates that the pupils appear and behave normally.
Past Medical History	A list of the patient's previously diagnosed medical conditions.
Pneumonia	Medical shorthand for pneumonia, an infection of the lung parenchyma. If acquired outside the hospital, often abbreviated as "CAP" for community-acquired pneumonia.
Pre-Hospital Trauma Life Support	A training course and certification in the management of trauma outside of the hospital; usually required for emergency medical technicians (EMTs), and physicians in emergency medicine or aerospace medicine specialties.
Per Os	Medication is to be taken by mouth (swallowed).
Point of Care	A description for rapid laboratory or radiologic or ultra-sonographic assessment of the patient (at the point of their initial care, i.e., at bedside in the emergency room or the primary care office) *as opposed* to sending lab samples to a laboratory or having the patient move to a CT machine to get imaging.
Pro Re Nata	Medical abbreviation meaning the medicine is to be taken "as needed."
	7 days or more
Pulse Pressure	Defined as the difference between the systolic and diastolic blood pressures. This largely determined by the pumping function of the heart and the vascular resistance. A low PP is called a "narrow" PP and a large PP is called a "wide" PP.
Past Surgical History	A list of the patient's previous surgeries.
Periodontal Screening and Recording	Dental shorthand for a screening system for periodontal (gum) disease.
Physical Therapy	Treatment modality to improve strength and functioning.
Patient	Medical shorthand for patient.
Pneumothorax	A potentially life-threatening situation in which air is trapped between the chest wall and the lung; as pressure builds up in this region of trapped air, it compresses the lung and eventually the heart, preventing breathing and circulation of blood. If the trapped air becomes significant, this condition is known as a "tension" pneumothorax.
Premature Ventricular Contraction	A heart beat occurring before expected (a beat that was not triggered by an atrial impulse).
Quaque Die	Abbreviation meaning the medicine is to be taken every day.

Quaque Hora Somni	Abbreviation meaning the medicine is to be taken every night at bedtime.
See explanation	Quality refers to the patient's subjective experience and description of their pain. For example, burning, sharp, stabbing, crushing, etc.
Range of Motion	The range of a particularly joint to move; range of motion is tested to determine neurologic and musculoskeletal function.
Review of Systems	A section of a complete history and physical which consists of close-ended (yes or no) questions to obtain required details for each body system. These questions are asked as patients to ensure all needed information is gathered in the course of an interview.
Right Lower Quadrant	The lower right fourth of the abdomen on physical examination. Tenderness in this region may signify inflammation or injury of the appendix, colon, or ovary.
Respiratory Rate	The number of breaths in one minute.
Rapid Sequence Intubation	Anesthetic and intubation technique used to rapidly sedate and intubate a patient, as opposed to a more structured approach for planned surgical anesthesia.
Right Upper Quadrant	Medical shorthand for the upper right quadrant of the abdomen, assessed on physical examination. Tenderness in this region may signify inflammation or injury of the liver, biliary tree, pancreas, and/or stomach.
Rx	Shorthand notation for prescription medicine.
Rubs/Gallops/Murmurs	Medical shorthand for the categories of heart sounds, usually written in the context that there are no abnormal heart sounds (e.g., "no r/g/m").
Systolic Blood Pressure	The blood pressure in the arteries during contraction of the left ventricle, measured in millimeters of mercury (mm Hg). The "top" number of the blood pressure in medical notation.
Small Bowel Obstruction	A blockage in the small intestines, leading to pain, nausea, and vomiting.
Spatial Disorientation	A condition in which the pilot/operator of a vehicle misinterprets visual or vestibular cues as to their orientation and movement in 3-dimensional space, often leading to incorrect control input.
Sensitivity	A term from biostatistics in the evaluation of the "accuracy" of a diagnostic test. Sensitivity refers to the percent of patients who have a condition who test positive on a diagnostic test.
Shock	Shock is a physiologic state in which there is decreased oxygen and nutrient supply to the vital organs. Because this state cannot be easily assessed in a clinical situation, the patient's chief complaint, vital signs, and mental status are used as surrogates to determine if a patient is in shock. Shock can be due to a variety of conditions, including hypovolemic shock (low blood volume often due to blood loss), cardiogenic shock (heart failure due to intrinsic or extrinsic causes such as tamponade, infarction, and obstruction), neurogenic shock (loss of neural control of blood vessels), and septic shock (inflammatory damage to the circulation).
Suicidal Ideations/Homicidal Ideations	Medical shorthand for the assessment of a psychiatric patient to determine if they are thinking about suicide or homicide.

Sublingual	Medication is to be taken under the tongue.
Shortness of Breath	Shorthand for a common, patient-reported symptom.
Social History	Section of the medical history which includes details related to: occupational history, geographic history including recent travel, relevant substance use (tobacco products, alcohol, caffeine, illegal drugs), educational history
Specificity	A term from biostatistics in the evaluation of the "accuracy" of a diagnostic test. Specificity refers to the percent of patients who do not have a condition who test negative on a diagnostic test.
Peripheral O_2 Saturation	The percentage of hemoglobin in the blood bound by oxygen.
Tachycardia	An abnormally fast heart rate.
Tachypnea	An abnormally fast respiratory rate
Tension Pneumothorax	A life-threatening situation in which air is trapped between the chest wall and the lung; it compresses the lung and the heart, preventing breathing and circulation of blood.
Traumatic Brain Injury	Medical jargon for a head injury.
Ter In Die	Medicine is to be taken three times a day.
Total IV Anesthesia	The term applied to the scenario when anesthesia medicine for surgery is delivered solely through an IV; there is no inhaled gas anesthetic component.
Tympanic Membrane	The membrane separating the external ear canal from the middle ear space. Examined with an otoscope.
Temporomandibular Joint	Joint between the mandible (lower jaw) and the temporal bone (lower section of the skull).
Tonometer	A device that measures intraocular pressure.
Urinalysis	A laboratory test of urine to determine electrolyte concentrations and if protein, red blood cells, white blood cells, and byproducts of bacterial metabolism are present
Upper Extremity	Short hand for arms/hands.
Ultrasound	A medical imaging technique using high-frequency sound.
Urinary Tract Infection	Infection of the kidney, ureter, bladder, or urethra.
Ventilation	Ventilation refers to the artificial movement of air in and out of the lungs by application of pressure.
Vicryl	A tradename for a type of absorbable material used for suturing wounds.
Ventilation/Perfusion	Medical shorthand for the ratio of ventilated lung to the amount of blood flow to that portion of the lung.
Vital Signs	The vital signs of the patient: heart rate, blood pressure, oxygen saturation, temperature, and respiratory rate.
Walking Blood Bank	A type of "blood bank" in which the donors are selected beforehand and donate blood only at the time it is needed for transfusion. It is used in remote settings (such as Antarctica or the space program) when storing blood is not an option.

White Blood Cell	A category of blood cells involved in immune response.
Within Normal Limits	Medical shorthand for normal.
X-Ray	Medical shorthand for x-ray.
Year Old	Medical shorthand for age. Often combined with “m” for male or “f” for female (35 year old male → 35 yom; 35 year old female → 35 yof)

APPENDIX B: REFERENCES

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