Optimizing Training Methods for Exploration Medical Crew: An Assessment of the Current Gaps

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Overview

- The current status of Exploration Medical Capability (ExMC) Gap 3.01
- Updated assessment and analysis of the training gaps
- Validation of training programs
- Metrics for quantification of training effectiveness
- What else do we know?
- Lessons learned so far
- Areas for future investigation
ExMC Gap 3.01

“We do not know the optimal training methods for in-flight medical conditions identified on the Space Medicine Exploration Medical Condition List [SMECL] taking into account the Crew Medical Officer’s clinical background.”
ExMC Gap 3.01 – Why is it important?

- Majority of historical in-flight medical problems were minor
- Though all crews undergo training in more advanced emergency medical procedures, these skills remain untested in a real-life incident
  - e.g., Advanced cardiac life support (ACLS)
- How can we be sure our training procedures are effective?

The need for medical preparation

- “Historically, the difficulties associated with illness and injury have accounted for the failures of more expeditions on Earth’s frontiers than any other single technical or environmental reason.”
- It is only a matter of time before there is a more severe medical emergency in space
  - Integrated Medical Model (IMM) helps predict incidence rates and incidence proportions

A paradigm shift

- Exploration missions will require a paradigm shift in medical preparation due to new limitations and unknown risks
  - Current mission planning:
    - Real-time ground support
    - Evacuation to Earth contingencies
  - Future mission planning:
    - Communication delay
    - Need to treat to definitive resolution or stabilization
Can we design a theoretical way to measure training effectiveness?

Targets:
- Identify a necessary skill-set based on SMEMCL
  - Determine the best training method for each skill
- Validate current and proposed training methods for both crew and ground support (flight surgeons and biomedical engineers [BMEs])
Current gap approach

- Develop a metric to quantify the effectiveness of training methods
- Integrate lessons learned from rigorous testing into exploration training methodology
Outlines current training flows for astronaut candidates, crew medical officer (CMO), surgeon, and BME

- Identifies limitations imposed on training algorithms by exploration missions
  - Lack of knowledge about medical conditions specific to spaceflight
  - Microgravity
  - Problems pertaining to knowledge and skill retention
- Current training methods are not adequate for exploration missions

Aiming for perfection

- The best possible medical training for crew
- The best possible preparation for ground support
- The best medical technology and equipment
- In-flight medical autonomy (ideally)
Where are we going, and how do we get there?
A new approach to the old gap

1. Existing gap report reviewed
2. Limited literature search performed
3. Areas of training defined
4. Extrapolation of a comprehensive list of questions regarding training
5. Identification of subject matter experts (SME) in training
6. Initial SME interviews to further improve questionnaire
Training gaps questionnaire

- Who better to help answer questions about training than experts in training?
  - What would we ask those experts...?
- In general, what are the tried and true best methods of medical education?
- How should we teach each specific piece of medical knowledge or individual skill?
Optimization of Training: Strategizing Closure of Gap 3.01

Validation
- How are education and training validated in general?
- How are medical education and medical training validated?
  - How are medical objective standardized clinical examinations (OSCEs) designed and validated?
  - How are interactive case-based simulations, educational tools, and assessments created and validated (e.g., United States Medical Licensing Exams)?
- How can we use the standards established in the validation of medical education teaching and evaluation methods to validate training methods for exploration class missions?
- How can we validate training methods prior to implementation of a training program for an exploration class mission?

Metrics/Quantification
- What metric do we use to assess the effectiveness of our training programs, strategies, and techniques?
- How do outside groups (e.g., EMTs, military) certify CREW and GROUND SUPPORT?
- How do we design studies to test the following:
  - The best training methods and techniques for a defined skill/topic?
  - The effectiveness of our training programs?
  - The metrics with which we evaluate our training programs?
Training gaps questionnaire

**Training Methods – Telemedicine**
- What are the gold standards for training users of telemedicine in a terrestrial environment?
- How can we adapt the current terrestrial gold standards to the limitations of our training environment?

**Training Methods – Just-in-Time Training**
- What are the gold standards for just-in-time training programs in a terrestrial environment?
- How can we adapt the current terrestrial gold standards to the limitations of our training environment?

**Training Methods – Dental**
- What are the gold standards for dental-focused training in a terrestrial environment?
- How can we adapt the current terrestrial gold standards to the limitations of our training environment?

**Training Methods – Medical Knowledge**
- What are the gold standards for medical knowledge training in a terrestrial environment?
- How can we adapt the current terrestrial gold standards to the limitations of our training environment?

**Training Methods – Medical Skills/Procedures**
- What are the gold standards for training in medical skills/procedures in a terrestrial environment?
Locating subject matter experts
Locating subject matter experts

- Internal organization (NASA and Wyle)
  - Current training leads and those already directly involved with training
- External experts
  - Previous participants in summits on training (e.g., dental)
  - SciVal Expert Locator ® (aka Collexis)
  - Literature search
- Resulted in a spreadsheet of contacts organized by area of expertise
Improving the questionnaire

- Initial meetings conducted with internal training experts for feedback on the questionnaire
  - Some modifications made to wording and specificity of questions
  - General consensus... a potentially useful approach
Addressing the questions...
VALIDITY

Does the test or measurement actually quantify the attribute it is intended to quantify?

“...a test is valid if it measures what it purports to measure...” (Kelly, 1927)

Validity is a *property* of a attribute
- Similar to the concept of truth
- i.e., Are our methods of training valid?

Validation is a *process* of theory testing to determine if an attribute possesses the characteristic of being valid
- i.e., How can we test our methods of training to determine their validity?

Reliability

- The consistency of measurement outcomes over multiple iterations of a test
- Quantifies the degree of variation in scores to determine if the test is *reproducible*
  - An assessment of the amount of random error
- Necessary but not sufficient for establishing validity

How can we validate or measure effectiveness of training methods?

- **Types of evaluations used in medical education**
  - Written assessment (knowledge/cognitive ability)
  - Rating of directly observed performance
  - Standardized performance-based evaluation
    - Observed standardized clinical encounters (OSCEs)
    - Simulated or standardized patients
    - Computer-based simulations

- **Other methods of evaluation**
  - Review of written documentation (e.g., notes, orders)
  - Other statistics (e.g., complications, mortality, awards)

Knowledge assessments

- Written test format (e.g., multiple choice questions)
  - One of the simplest of the medical evaluation tools
  - Relatively straightforward to establish moderate reliability and validity
  - Limited applications beyond basic assessment of knowledge acquisition and retention

Rating of directly observed performance

- An expert evaluation of clinical performance in a real-world setting (e.g., on the wards)
  - Oral examinations attempt to mimic clinical context
- Used to assess the following:
  - How the subject integrates knowledge and skill into behavior
  - Clinical judgment
  - Professional competencies
- Outcomes are expert ratings the performance of subject
  - Point scale (e.g., 1-5)
  - Dichotomous checklist
Limitations

- Competencies and behaviors are difficult to define and not easily measured
- High degree of variability
- Time intensive

Reliability and validity evidence in medical education literature moderate, but format widely used

Standardized performance-based evaluations

- Attempt to model a real-world expert evaluation while eliminating or controlling variables
  - Designed to assess similar attributes, behaviors, and competencies
- Examples:
  - U.S. Medical Licensing Exam Step 2 Clinical Skills
  - Primum Clinical Case Simulation ®
  - OSCE for board certification in Family Medicine
Standardized performance-based evaluations

- Limitations
  - Behaviors and competencies hard to define
    - Useful to assess demonstrable skills
  - Poor generalizability beyond specific skills tested
    - The broader the inference based on outcomes, the less valid
  - Time and cost intensive
- Reliability and validity evidence in medical education literature moderate, but format widely used

Applications to training for exploration spaceflight
What are we going to teach?

- Subcategories of training
  - Medical knowledge
  - Medical procedures and skills
    - Dental procedures and skills
  - Use of telemedicine
  - Just-in-time training
  - Hardware use
  - Behavioral health
Current medical training

- 2 CMOs from among the crewmembers for each International Space Station (ISS) mission
- No previous medical background
- Receive 40 hours of lecture and training
  - Medical diagnostics (4 hours)
  - Medical therapeutics (5.5 hours)
  - CPR and ACLS (10.5 hours)
- Optional clinical component

Medical training for exploration spaceflight

- Must adapt the current training paradigms for the limitations of exploration missions
  - Inability to return to Earth for evacuation
  - Communication delays and blackouts
  - Resource constraints
    - Time
    - Volume, mass, weight, power
    - Cost
  - As yet unperceived risks inherent in extended duration missions beyond low Earth orbit

Medical procedures and skills training

- Minor procedures currently incorporated into CMO training
- Ongoing investigations into how to best perform procedures in microgravity
Medical procedures and skills training for exploration spaceflight

- Define a list of procedures and skills necessary for each condition on the SMEMCL
- Prioritize procedures and skills based on urgency priority of the condition
- Determine level of experience necessary for each condition
  1. Recognize and describe symptoms
  2. Make initial diagnosis
  3. Implement initial treatment intervention
  4. Treat to stabilization
- Determine how to optimize training for each procedure or skill given its priority
Dental training

- ExMC gap 4.11: Limited dental care capabilities
- Dental working group held Mar 2012
  - Participants were JSC/Wyle personnel, private dental practitioners, and an Army special forces dentist
  - Addressed the following:
    - Specific dental skills identified and prioritized
    - Terrestrial training standards reviewed with emphasis on analogous environments (e.g., special forces medics)
    - Areas for improvement in current crew training identified (e.g., hands-on experience in a high volume setting)
- Serves as a model for other SME panels

Telemedicine Workshop hosted by ExMC in 2011

- Participants were internal personnel, external experts in telemedicine, and users of telemedicine
- Goal: Create a medical operational concept for a near-Earth asteroid mission

Just-in-time (JIT) training

- Current use of “just-in-time training”
  - CMOs trained by computer-based tutorials with real-time telemedicine guidance at point of care
  - Used for ultrasonographic investigations on ISS with good results
- Need to develop a database of resources usable without real-time ground support
- Design optimized training programs for instruction in and practice with how to use resources

Training in hardware use

- Current CMO training includes instruction on ISS medical hardware
- Need to engineer new hardware and software to address unique needs of exploration missions
- Need to design optimized training programs for new technology
Behavioral health training

- Behavioral health of crew critical to mission success
- Crew medical officer must be able to diagnose and treat
- Best way to train yet to be elucidated
  - Analysis of training for personnel in analogous remote and high-stress environments
Prevention of knowledge and skill decay over time

- Extensive studies in literature pertaining to ACLS
  - Rarity of events and infrequent or inadequate training are contributing factors
  - Initial overtraining is a potential countermeasure
- Will need to be individualized
- Will need to be adapted to the timeline and the time constraints of the mission

Key lessons learned

- There are no gold standards for training
- Must balance validity and reliability with feasibility and practicality
- Medical training optimization is an ongoing area of current research in analogous environments
- Any training procedures will require flexibility and constant adaptation to rapidly changing science of medicine
Areas for future investigation

- Prioritize skills by the criticality and urgency of the associated condition
- Define to what experience level each skill must be taught
Questions?
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