The History of Surgical Care in Space Symposiums

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Over the last 40 yr, NASA has sponsored a series of symposiums dealing with the issues of surgical care during spaceflight (**Table I**). This article briefly summarizes those workshops and highlights the changing thought processes of the participants. It is interesting to note that the issues and questions to be resolved are essentially the same from symposium to symposium, but both the questions and the conclusions have become more sophisticated over the years.

Conceptualization and Planning Symposium for the Management of Trauma and Emergency Surgery in Space—July 20–21, 1983, Houston, TX[16]

The design reference mission was a space station with a small definitive medical care time (14–21 d predicated on the Shuttle flying every 2–3 wk) that would be self-sufficient regarding medical and surgical care. Many issues were discussed by the 20 academic surgeons who attended, including chest trauma, vascular trauma, abdominal trauma, orthopedic injuries, neurosurgical trauma, burns, postoperative care, monitoring, anesthesia, diagnostic radiological imaging, medical computer data management, and surgical training for a future space surgeon.

Full surgical capabilities were advocated. Less than that was considered "foolhardy and unacceptable." A fully trained general surgeon actively practicing clinical surgery was advocated as the crew medical officer (CMO). The main technical problems identified were restraint and the control of bleeding in weightlessness. Animal surgery in parabolic flight was advocated to gain experience with surgical techniques in space. It was advocated that a consultant's network be established and used on a regular and continuing basis. Telemedicine experience needed to be developed.

In retrospect, the conclusions seem naive. However, this is more understandable given the extreme optimism at this time regarding future spaceflight, as the Shuttle would be flying every 2–3 wk and we would soon be building a large space station.

Space Station Freedom Health Maintenance Facility Consultants Conference (Surgical Care Issues Working Group)—August 27–29, 1990, Houston, TX[2]

The purpose of this multispecialty medical conference was to discuss the evolving capabilities of the proposed Space Station Freedom health maintenance facility (HMF), especially in light of recent mandated changes in downsizing the facility. The Space Station Freedom project was active from 1984–1993 and was different from the International Space Station (ISS) in that there was not a medical evacuation option [no Soyuz or assured crew return vehicle (ACRV)]. Therefore, it had a definitive medical care time of 45 d (time required for Shuttle rescue). The medical care system needed to be very surgically capable, and this was provided by the HMF. The CMO would probably be an M.D., and some were still advocating a surgeon. The HMF was 1200 lb and 2400 ft^2.[1,3] It consisted of a surgical workstation (waist-level operating room table), digital X-rays, surgical task lighting, surgical cautery, ventilator, defibrillator, intravenous pump, a waste management system (including surgical suction), a medical computer, capability for telemedicine, and anesthesia.[15] Surgical procedures being proposed were complex wound closures, chest tube insertion, tendon repair, appendectomy, limb amputation, orthopedic procedures, and open abdominal, thoracic, and vascular procedures.

The following changes had recently been mandated for the HMF just prior to the conference:

- An ACRV would probably be present, providing a medical evacuation option;
- The digital X-ray capability would be eliminated;
- Surgical cautery had a radio frequency interference problem and would be eliminated;
- The waist-level workstation (operating room table) was in doubt due to too much weight and volume;
- The CMO would probably not be an M.D.; and
- There was an overall need to greatly decrease weight, volume, and power.

The capability to perform open abdominal procedures, vascular procedures, thoracic procedures, and the treatment for all except minor burns needed to be dropped. The need to perform advanced trauma life support (ATLS) was still critical—cervical collar and pelvic binder use and chest tube insertion were emphasized. The capability to perform open orthopedic procedures needed to be dropped. Most fractures could be treated with splinting or relatively simple external fixation. There was a critical need for X-ray

This feature is coordinated and edited by Mark Campbell, M.D. It is not peer-reviewed. The AsMA History and Archives Committee sponsors the Focus as a forum to introduce and discuss a variety of topics involving all aspects of aerospace medicine history. Please send your submissions and comments via email to: mcamp@1starnet.com.

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DOI: https://doi.org/10.3357/AMHP.6360.2023

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Table I. Surgical Care in Space Symposiums.

DATE	TITLE
1983	Management of Trauma and Emergency Surgery in Space
1991	Space Station Freedom HMF Consultants Conference (Surgical Care Issues Working Group)
1996	Life Sciences Long-Duration Spaceflight Conference
1997	Clinical Capabilities Development Project—Surgical Care Issues Working Group
2002	Long-Duration Mission Surgical Planning Working Group (Dr. Norm McSwain)
2005	Surgical Science in Support of Human Space Exploration
2015	National Space Biomedical Research Institute Surgical Capabilities for Exploration
2018	Minimally Invasive Expeditionary Surgical Care Using Human-Inspired Robots

capability, as there was no realistic ability to accurately diagnose a pneumothorax. However, many in the group felt that a pneumothorax could be diagnosed and treated based upon clinical findings. Orthopedic injuries could be adequately diagnosed and treated without X-ray capability. Ultrasound had a future potential that was very promising for a wide range of imaging situations.

There was a concern about delayed wound-healing during spaceflight. The wound-healing ability during spaceflight was unknown. There was a concern about bleeding, restraint, and surgical performance in weightlessness. It was unknown if these issues were problems, as no experience existed. Parabolic flight research could answer some of these questions. There was a concern about contamination of cabin atmosphere with biological fluids. Containment surgical hardware might be needed. Most agreed that efforts should continue to have the CMO be an M.D. The statement was made, "Don't put hardware onboard unless you have the CMO capability to use it. Limitations will be based upon the CMO capabilities and not the hardware."

In summary, with the need to downsize the HMF and the presence of an ACRV for medical evacuation that would decrease the definitive medical care time to 24 h, the surgical capabilities required were greatly reduced. There was a more realistic connection between what capabilities were absolutely needed and the severe operational constraints defined by the minimal hardware provided and the limited training of the CMO. Areas where we had a lack of knowledge or experience on how to actually perform a surgical procedure in weightlessness were better defined. In the next several years following this symposium, a series of parabolic flights were performed that helped to answer procedural questions regarding surgery in weightlessness, such as how to provide restraint,[9] how to control bleeding,[7] the difficulties in performing a complex surgical procedure,[6] and the feasibility of performing ATLS procedures.[8]

Clinical Capabilities Development Project—Surgical Care Issues Working Group—April 8, 1997, Houston, TX

This multispecialty medical conference mostly focused on the ISS, but issues concerning future long-duration spaceflight were also discussed. There were several important changes to the space station project. The Space Station Freedom was now the ISS and the HMF (1200 lb) was now the health maintenance system (200 lb). The waist-level workstation was now a floor-level crew medical restraint system. There would be a medical evacuation option (either Soyuz or X-38/ACRV). The CMO would not be an M.D. and would have minimal training (less than 200 h). The health maintenance system was capable of advanced cardiovascular life support and ATLS except for no chest tube insertion hardware or training. It had a ventilator, monitor, and defibrillator. The focus was on stabilization, monitoring, and transport. There was no integrated surgical kit and there was no ability to organize and restrain surgical instruments. Surgical instruments were provided in individual sterile packaging only.

The most important life science issues for future long-duration spaceflight were felt to be: psychological support; radiation effects; cardiac, bone, and strength deconditioning; and providing for remote medical/surgical care. The surgical issues that were discussed included laparoscopy,[5,11] future robotic surgery, CMO capabilities (hopefully an M.D.), prophylactic appendectomy,[10] extremely long communication delay with telemedicine, delayed wound-healing, and future blood substitutes. It was stated, "There is not any operation performed laparoscopically that cannot be performed easier and with less hardware as an open procedure."

Long-Duration Mission Surgical Planning Working Group—October 2002, Houston, TX

This was chaired by Dr. Norm McSwain and, unfortunately, there are no published results. The group consisted of 20 academic leaders in surgery and critical care medicine who were generally not familiar with space medicine. The group was given a Mars expedition as a design reference mission and discussed what surgical events would need to be treated and what should be the expedition medical officer's (EMO) credentials and training. The goal was to develop a detailed training curriculum.

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The surgical capabilities need to be selected based upon:

- High incidence of occurrence;
- High impact to mission or crewmember;
- High ability that treatment will result in a curative result;
- Minimal hardware logistics; and
- High ability to be able to train an EMO.

It was concluded that there was a need to have enough surgical capability to perform major open procedures (exploratory laparotomy and appendectomy) and external fixation for orthopedic fractures. Some surgical diseases cannot be treated (vascular surgery is not trainable). Laparoscopy will probably not be available due to hardware constraints and inability to train. Many procedures can be performed with imaging and percutaneous techniques. There was a need to have the capability (hardware, supplies, EMO training) to perform a large number of surgical procedures on future long-duration spaceflights, including, but not exclusively, an appendectomy. An EMO would need training in other fields than surgery, but an M.D. could perform a large number of selected operations at the level of a second-year surgical resident if given 6 mo of focused surgical training.[4]

Surgical Science in Support of Human Space Exploration—December 2005, Houston, TX

This conference was held with 20 mostly academic surgeons familiar with space medicine issues. Discussed topics included robotic surgery, laparoscopy, urological ureteral stenting for stone disease, ultrasound-directed percutaneous drainage,[18] and diagnostic ultrasound to detect pneumothorax and intra-abdominal trauma.[14,17]

Surgical Capabilities for Exploration and Colonization Space Flight—December 2015, Houston, TX—National Space Biomedical Research Institute[13]

This was a multispecialty conference with mostly attendees from surgical fields. All were familiar with space medicine issues.

The issues discussed were:

- Selection of the healthcare provider (CMO);
- CMO training requirements;
- Establishing a controlled healthcare procedure zone in the spacecraft;
- Wound-healing and hemostasis;
- Developing onboard fabrication capabilities (three-dimensional printing of surgical instruments);
- Multitasking of onboard equipment;
- Identifying new healthcare equipment, devices, and supplies; and
- The need for increased resources for research to develop space healthcare devices and supplies.

Minimally Invasive Expeditionary Surgical Care Using Human-Inspired Robots—October 2–3, 2018, Pensacola, FL[19]

This was a narrowly focused discussion group of 25 participants with expertise in robotic design, space medicine, or robotic surgery. It was to familiarize the group with what research potential existed for future robotic surgery in spaceflight.[12]

Conclusion

These conferences and symposia over 40 yr have continually discussed what surgical capabilities would be required for a future long-duration spaceflight and, based upon that determination, what surgical hardware would have to be provided and what level of training would be needed for the CMO. Experience has shown that whatever surgical hardware and CMO capabilities are requested and planned for are drastically diminished by the reality of severe hardware and training constraints.

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