# Technical innovations that may facilitate real-time telementoring of damage control surgery in austere environments : a proof of concept comparative evaluation of the importance of surgical experience, telepresence, gravity and mentoring in the conduct of damage control laparotomies

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# Technical innovations that may facilitate real-time telementoring of damage control surgery in austere environments: a proof of concept comparative evaluation of the importance of surgical experience, telepresence, gravity and mentoring in the conduct of damage control laparotomies

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**Summary**

Bleeding to death is the most preventable cause of posttraumatic death worldwide. Despite the fact that many of these deaths are anatomically salvageable with relatively basic surgical interventions, they remain lethal in actuality in prehospital environments when no facilities and skills exist to contemplate undertaking basic damage control surgery (DCS). With better attention to prehospital control of extremity hemorrhage, intracavitary bleeding (especially intraperitoneal) remains beyond the scope of prehospital providers. However, recent revolutions in the informatics and techniques of telementoring (TMT), DCS and highly realistic accelerated training of motivated first responders suggests that basic life-saving DCS may have applicability to save bleeding patients in austere environments previously considered unsalvageable. Especially with informatic advances, any provider with Internet connectivity can potentially be supported by highly proficient specialists with content expertise in the index problem. This unprecedented TMT support may allow highly motivated but inexperienced personnel to provide advanced surgical interventions in extreme environments in many austere locations both on and above the planet.

Worldwide, traumatic injury is an ever-increasing cause of potentially preventable loss of life. Operative hemorrhage control is the most critical early intervention that could impact trauma mortality, as bleeding to death has been identified as the leading cause of potentially preventable injury-related mortality. The greatest challenge in changing these outcomes, however, is that the majority of this lethal hemorrhage is intracavitary (chest and either intraperitoneal or retroperitoneal). Such bleeding requires advanced operative therapy to save lives, which implies both the need for surgical and life support equipment compatible with austere environments and for first responders capable of providing truncal hemorrhage control. This dilemma challenges all those providing care in civilian, military, humanitarian and operational settings without prejudice.

A review of combat experiences revealed that traumatic hemorrhage may result in more than 50% of all battlefield deaths, with 90% being from truncal hemorrhage.[1] In the civilian setting, up to 80% of all early trauma deaths result from uncontrolled hemorrhage, with as many as 99% of these hemorrhagic deaths being truncal.[2] This corroborates reviews of Special Forces deaths in which truncal hemorrhage predominated as the most common etiology.[3] Even in the extraterrestrial environment, injury is ranked at the highest level of concern by the National Aeronautics and Space Administration (NASA), comparing the likelihood of occurrence with the impact on mission and health.

 

### Damage control surgery for truncal hemorrhage control in austere and extreme environments

In 1983, a council of trauma surgeons, space physicians and biomedical engineers identified the performance of a laparotomy as the minimum desirable surgical capability to save lives before transfer to Earth for the planned Space Station Freedom.[4] Technically, a laparotomy would facilitate the utilization of damage control surgery (DCS), which could be as simple as placing “packs” around bleeding solid organs and leaving the abdomen “open.” These most basic elements of damage control would result in transforming incompressible truncal hemmorhage into a now compressible scenario. While presumably quite stressful to nonsurgeons, incising the anterior abdominal wall to access the peritoneal cavity is technically simple and is a procedure that might be appropriate for telementoring. Nonphysicians have anecdotally performed this procedure successfully,[5] although there are no data on their performance compared with that of trained operators and/or on their degree of stress. A future adjunct may also be the introduction of expanding foams, which might lessen the size of abdominal opening required in such a prehospital setting.[6]

### Remote telementoring for advanced medical interventions

Informatics advances have rapidly changed our society. The planet is increasingly networked, and satellite-based informatics are potentially accessible anywhere on or above the Earth’s surface. Much of the greatest growth in connectivity has been in developing countries, where mobile phone services are increasingly available at rates out of proportion to the relative development of other basic infrastructure. Philosophically, the United Nations has considered the availability of Internet connectivity as a basic human right. Such technical and practical advances have made remote telementoring for invasive procedures a viable alternative to on-site mentoring in many situations. It has become relatively commonplace to use informatics either to supervise and/or actively guide less experienced operators remotely to perform a variety of surgical procedures regardless of whether the mentor is in the same institution, in another institution or even on another continent.

With the paucity of experienced medical personnel in space, NASA has led efforts to marry information technology advances with “just-in-time” mentoring techniques to guide advanced ultrasound diagnoses on the International Space Station performed by mentored nonphysicians. Recent innovations by our own research group have involved efforts to follow up on these techniques and greatly simplify the infrastructure and technical requirements for telementoring technical procedures, such as point-of-care ultrasonography, to facilitate terrestrial care. We have found it very feasible to guide novice caregivers to perform just-in-time ultrasound examinations using handheld smartphones in the hands of the remote mentor.[7] We perceive that almost any potential care provider with Internet access anywhere on the planet could be guided through advanced diagnostics and/or medical procedures.[8]

### Surgery in weightlessness and space as an example of the ultimate extreme environment

Although surgical diseases have been suspected and have influenced decision-making, to date no human operations have ever been performed in space. However, complex surgical procedures have been performed on animals in space.[9] A wide array of operations and invasive interventions have also been performed during the weightless conditions provided by parabolic flight, including minor procedures on living humans. The cumulative conclusions of these various investigations has emphasized that complex surgical procedures should be technically feasible in weightless environments if cardinal principles are respected.[10] These studies, however, have all been conducted with experienced surgeons; to our knowledge, no experience mentoring nonsurgeons in complex tasks in weightlessness has been completed to date. The nearest analogue is the successful remote guidance that the group from Henry Ford Hospital in Detroit, Mich., provided to a simulated Mars environment in the Canadian Arctic.[11] This group was able to provide clinical control from a terrestrial base using telementoring techniques to enable the remote diagnosis and removal of an anatomical appendectomy model using laparoscopic stapling technology by a nonsurgeon.[11]

### “Hyperrealistic training” and the Human Worn Partial Task Surgical Simulator (Cut Suit)

In addition to remotely guiding less experienced responders to perform complex tasks, these responders can also be trained beforehand using highly realistic scenarios that involve advanced realism and detailed/functional anatomic/physiologically real training models. Besides improving skills, such approaches also enable learners to better manage stress and increase confidence in situations that have been termed “hyperrealistic.”[12,13] The Human Worn Partial Task Surgical Simulator (Cut Suit) is a realistic surgical training tool that allows for the simulated performance of actual surgical procedures.[12] In addition to perfused extremities, the Cut Suit also has perfused internal organs that may be accessed through the abdominal wall and can be incised to bleed and repaired or excised to control hemorrhage. The Cut Suit is regularly being upgraded and in the near future will be equipped with specific in-line flow sensors that will permit an accurate calculation of simulated blood loss during different procedures and situations and with different surgeons.

### Real-time telementoring of damage control surgery in austere environments

With this rationale and technology in place, our Canadian Forces–supported Tele-Mentored Damage Control Surgery in Austere Environments research group will be undertaking a progressively more complex series of studies to evaluate the feasibility of mentoring first responders to undertake hemostatic laparotomies with intraperitoneal packing in increasingly complex environments. The progressively more complex phases of the study will build upon each other and will consist of controlled comparisons aiming to discern objective performance differences in the conduct of damage control laparotomies related to

- surgical experience (trained surgeons v. nonphysician medics),
- telementoring (telementored nonphysicians v. unsupported nonphysicians), and
- gravity (damage control laparotomy in weightlessness [0*g*] v. terrestrial [1*g*] gravity).

There will also be 2 additional related and complementary arms evaluating the performance benefits of remote telementoring in relation to performing damage control laparotomies in the austere environment of a far-forward operating base and on board a maritime vessel as well as the benefits of telementoring to assist in the performance of extremity hemorrhage control, emergency chest drainage, medication preparation and advanced surgical airway management. The primary outcome of all interventions will vary as appropriate to provide the most meaningful clinical parameter for assessment but will include the volume of reservoir simulated bloodshed before hemorrhage control is obtained. Nested throughout all these studies will be comparative evaluations of the relative ratios of salivary stress hormones (e.g., cortisol), which indicate the relative degree of physiologic and psychological distress that an operator is experiencing during any particular task. The hypothesis will be that the virtual presence of the remote mentor will reduce the stress felt by the responder while completing their tasks.

Through this series of increasingly more complex studies that build upon the prior iteration, the investigators hope to demonstrate that technical adequacy and safety can be provided with modern informatics to allow first responders to safely perform damage control laparotomies in a variety of austere settings when no other clinical alternatives exist.

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**Contributors:** All authors contributed substantially to the conception, writing and revision of this commentary and approved the final version for publication.

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