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Trauma Surgery for Contingency Operations: Test Based Improvements

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Introduction/Overview

This paper describes work undertaken at Wilford Hall Medical Center for testing and quantification of practice changes planned to facilitate the concept of "forward resuscitative surgery." This paper will begin by discussing the rationale for and composition of the Mobile Field Surgical Team (MFST). It will then proceed to discuss the challenges that arose in the formation of the team and it's concepts of operation, with a description of several areas in which we have performed objective testing of the proposed new practices. I will describe our evaluation of the following areas:

- instrument disinfection technique that does not use an autoclave
- live surgery using a pared-down equipment package
- trauma surgery without visible light
- possible application of thermal imaging to commonplace medical care

MFST Concepts

Improving outcomes for our injured soldiers in future conflicts will require the appropriate surgical care to be applied as soon as possible after the injury occurs. This must be accomplished despite several factors that make such a task more challenging:

- Conflict in the future is likely to occur with little warning, and it is likely to take place "over the horizon" from the permanently based medical facilities.
- Because of the rapid rate at which information age combat progresses, a surgical team should be ready to operate soon after reaching the desired location.
- As the field of conflict shifts, it is likely that the surgical team will need to move frequently as well.
- The "line" side of the military will hesitate to give up their airlift capacity for purposes other than transport of "beans and bullets."

Currently available assets (such as the US Air Force Air Transportable Hospital, or ATH) are very capable but are too large and cumbersome to be able to provide the mobility required. For example, an ATH cannot even provide capability for an appendectomy without moving it's full set (52 pallets, 7 C-141 aircraft).

The MFST is designed with significantly less capability than an ATH, but in a package that is small enough move around without overburdening the airlift assets. The <u>early</u> application of surgical care to trauma victims is important, even if the surgical care is not definitive. In other words, the MFST will plan to do resuscitative surgical procedures on patients who would not otherwise survive to reach the next echelon of care. Resuscitative surgery may thus leave the casualty with a requirement for another operation, but their stability for Air Evacuation should be significantly improved.

MFST composition

<u>*Personnel*</u>

- General Surgeon
- Orthopedic Surgeon
- Emergency Medicine Physician
- Anesthesiologist/CRNA
- OR specialist

<u>*Equipment*</u>

- Surgical Equipment - 5 backpacks
- Generator
- 2 folding litters
- Personal gear

Total equipment weight: approx. 600 pounds

Field Disinfection techniques

In search of a way to clean instruments that would not necessitate carrying an autoclave, we chose to study A-33. This is a quaternary ammonium compound with excellent bactericidal activity, though only moderate activity against viruses and spores.

In this experiment, fresh human feces were obtained from healthy volunteers on the day of experiments. The stool was vigorously mixed with 2 liters of sterile saline and dispensed into a container large enough to immerse the 10 surgical instruments to be contaminated. All work was then conducted under a laminar flow hood by personnel wearing gloves and gowns. The ten surgical instruments were placed into the stool mixture for a minimum of 5 minutes and cultured one at a time. After initial culturing, instruments were next placed in a container of A-33 solution prepared according to the manufacturer's instructions using non-sterile potable water. Instruments were then individually scrubbed with a brush from MFST supplies. Particular attention was paid to cleaning teeth and other areas of instruments where fecal material might collect. After scrubbing, instruments were placed back into the same A-33 solution until all the instruments were cleaned. Each instrument was then rinsed individually with 100 ml of non-sterile potable water. After rinsing, instruments were placed in an second identically prepared solution of A-33. After soaking for 15 minutes in the second A-33 solution,

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instruments were removed and wiped dry with sterile 4" x 8" gauze sponges. Instruments were then returned to the stool suspension, and the contamination and disinfection cycle was repeated for a total of 10 cycles to simulate the 10 surgical cases in the MFST concept of operations.

Each instrument was cultured three times during the experiments: after initial stool contamination, after the last(10th) disinfection, and after an 11th recontamination to reassess stool suspension bacterial counts. To neutralize residual disinfectant which might inhibit bacterial growth, Dey/Engel (D/E) broth was prepared prior to the experiments and dispensed in 1.0 ml aliquots into sterile capped tubes. Sterile swabs were moistened with D/E broth and used to sample designated instruments areas felt to be most likely to be difficult to disinfect, such as joints. Swabs were then placed in test tubes and vigorously agitated to dislodge microorganisms. Samples of the D/E broth were then removed in a sterile manner and cultured as follows: for aerobic cultures, 0.1 ml was spread on a blood agar plate; for anaerobic cultures, 0.1 ml was spread on an anaerobic blood agar plate. Plates were incubated at 35 ° +/-2° C and examined for evidence of growth at 48 hours and again after 5 days. Colonies on plates were counted and gram stained. Swab cultures of the second A-33 solution were also obtained after the last disinfection.

The initial counts of bacteria after contamination ranged from 6.4×10^5 bacterial to 1.3×10^7 bacterial/ml. Seven out of 10 instruments had no bacterial growth after 10 cycles of stool contamination and disinfection with A-33 alone. Three instruments grew low numbers of bacteria (3, 17, 3 bacteria/ml for instruments labeled C, E, and H respectively) after final disinfection. The final bacterial counts after the instruments were recontaminated in the stool suspension ranged from 2.0×10^6 to 2.1×10^7 bacteria/ml.

Salvage Surgery Skills Lab

Ten Yorkshire swine, each weighing 70 to 90 kg were pre-anesthetized. Anesthesia was induced with 2.5% isoflurane using the flow over vaporizer (Ohmeda Universal PAC, Madison, WI) and maintained with spontaneous breathing of room air. The animals were transported to tents at a field site after initial intubation at the Clinical Investigations facility. After aseptic preparation with Betadine, sterile drapes were applied. Evaluating surgeons then surgically induced multiple injuries to which the operating surgeon was blinded. Ten multisystem trauma cases were specifically designed to evaluate MFST equipment and concepts in the surgical care of thoracic, abdominal, vascular and head trauma, as well as major fractures. The ten animals underwent sequential damage control procedures using only equipment and supplies contained in MFST backpacks. During the 16 hours of the surgical lab, the outside temperature ranged from 42 to 54 degrees Fahrenheit, with 4 of the procedures being performed at night. Animals were supported for 30 to 60 minutes postoperatively in the field setting, and then euthanized. Equipment and damage control procedures were evaluated by the participating team members. In all, the team members were pleased with the functionality of the backpacks.

Damage control procedures were performed on the ten animals in 15 hours and 45 minutes. The first animal died near the end of the first case secondary to hypothermia. Twenty-two operative procedures were performed during the 10 cases. The intravenous fluid supply was adequate.

Salvage Surgery in a Light-Limited Environment

The evaluation of night vision equipment and surgeons' performance in a light-limited environment was accomplished following initial training in the use of night vision goggles (NVG's), and consisted of salvage surgery with NVG's utilizing the porcine model. Two generations of NVG's were used in the evaluation; AN/AVS 6 and AN/AVS 9 (ITT, Roanoke, VA). The AN/ALS 6 and AN/AVS 9 goggles provide Snellen visual acuities of 20/40 to 20/70, and 20/20 to 20/40, respectively. The experiment tested the ability to operate with very limited light and NVG's alone and then the use of the two goggle types with infrared (IR) illumination. The injuries were similar to those treated in the salvage surgery skills lab. Operative times and the gross ability to complete required procedures in the light-limited environment were recorded, and were compared with results of the initial salvage surgery skills lab.

Thermal Imaging and the Detection of Bowel Ischemia

Four pigs were pre-anesthetized. Laparotomy was performed on each animal and a 25 cm segment of mid-jejunum was isolated and tagged with silk sutures. Arcade and collateral vessels were ligated at the marking sutures to allow perfusion of the segment through a single mesenteric vessel pair. The two mesenteric arteries to the isolated segment were then ligated. A Generation 2 thermal imaging system (Army Night Vision Labs, Ft. Belvoir, VA) was used to detect a marked temperature change between the marking sutures 10-25 seconds after vessel ligation. Five minutes after ligation the extent of bowel ischemia was estimated using the following six methods; unaided visual inspection in normal light, visual inspection with NVG's and IR illumination, palpation of mesenteric arterial pulse, doppler ultrasound of antimesenteric surface of jejunum, fluorescein injection with Wood's lamp examination and evaluation using a thermal imaging device with and without cool fluid contrast (room temperature). Measurements of the junction of viable and non-viable tissue were made from the marking sutures with each technique. After two hours of warm ischemia under general anesthesia, a generous section of mid jejunum was harvested. The jejunum was pinned to maintain length and sent for permanent section in a glutaraldehyde solution. The jejunum was longitudinally sectioned and measurements were made between the reference ties and the microscopic demarcation line of necrosis.

Light was judged inadequate to perform major salvage surgery without IR illumination.

Conclusions

Optimization of outcomes for casualties in 21st century conflict will require surgical capability that is more mobile than before. Development of such mobile surgical capability include the application of testing and simulation wherever possible.