

CIMIT Innovation Workshop

Early Innovative Resuscitation and Bleeding Control after Injury

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Workshop Proceedings

CIMIT's goal is to bring together clinicians and engineers and to cultivate a spirit of collaboration in support of its mission to improve patient care by finding, funding and facilitating multidisciplinary collaborations of entrepreneurial-minded scientists. CIMIT is committed to developing products of immediate usefulness. This inaugural CIMIT Innovation Workshop focused on early resuscitation and bleeding control after injury. The workshop is designed to help participants make connections, and the invitees include innovators from medicine, industry, and the military.

Background

Significant improvement has been made in controlling compressible extremity hemorrhage, yet the management of non-compressible hemorrhage continues to be an unsolved and often fatal problem. Trauma is the number one cause of death for children and adults ages 1 to 44. Hemorrhage after a trauma causes 35% of all pre-hospital deaths and over 40% of deaths within the first 24 hours.

Innovation Workshop Topics

- Pre-Hospital Resuscitation: Preventing hemorrhagic shock requires restoration of blood volume and blood pressure. Before any intervention, it is essential to accurately determine the nature of injury and location of the bleeding.
- Non-Compressible External Bleeding Control: Bleeding control and limiting blood loss is crucial. Currently, there is no effective intervention for non-compressible hemorrhage available to military or civilian medics and physicians.
- Internal Bleeding Control: Finding the pool of blood and its source of escape from the circulatory system is an urgent priority of the trauma team. This task is especially difficult because internal bleeding may not become evident until hours after injury.
- Innovative Monitoring: Detecting hemorrhage in the pre-hospital environment and monitoring in hospital settings is often highly inaccurate for trauma cases. Current physiologic monitors are insufficient in aiding diagnosis in trauma-related injury.

Pre-Hospital Resuscitation

David Hoyt, MD, FACS

Executive Director, American College of Surgeons

Pre-hospital resuscitation strategies have evolved over the last century, but there is still no consensus on how best to treat the acutely injured patient. If a patient is bleeding, volume resuscitation is often necessary to ensure adequate oxygen delivery to tissues. Only in the last few decades, because of well-organized systems for caring for trauma victims, has it become possible to conduct clinical studies related to pre-hospital resuscitation.

In World War II, injured soldiers were given plasma, but by the 1960s, the medical community had begun to use isotonic saline for extracellular volume repletion. In the 1980s, researchers studied the effects of supernormal oxygen delivery, but they found that this therapy

produced no benefit and was associated with compartment syndromes. Within the last ten years, scientists have become concerned about the pro-inflammatory effects of normal saline and have investigated the immunological advantages of hypertonic saline. So far, hypertonic saline has been a disappointment because promising initial studies did not translate into improved outcomes. Fresh whole blood has recently received more attention as a potential fluid for resuscitation, as researchers have realized that blood is a complex and poorly understood substance that cannot be replaced piece by piece. At the moment, there is no consensus pre-hospital resuscitation strategy, but it is finally becoming possible to conduct clinical trials in this field.

Non-Compressible External Bleeding Control

Daniel N. Darlington, PhD

Research Physiologist, U.S. Army Institute of Surgical Research, Ft. Sam Houston, TX

In some military settings, eighty-five percent of deaths due to potentially survivable injuries are caused by hemorrhage, mostly in junctional areas such as the groin or armpit. These hemorrhages cannot be controlled with tourniquets. Potential strategies for controlling these hemorrhages involve special bandages and devices for providing compression.

A number of bandages impregnated with anti-hemorrhagic agents have been created. Examples of hemostatic agents include kaolin, which soaks up water and concentrates clotting factors, and deacetylated chitin, which promotes the adherence of wounds. None of these products are

perfect in the field. Celox, for example, is a powder that effectively controls many hemorrhages, but it cannot be used in windy settings because it blows away easily.

Compression devices are alternative method for bleeding control. These mechanical devices are designed to apply pressure in hard-to-compress areas. One device in development, for example, is capable of pushing on the abdominal cavity with enough pressure to cut off blood flow in the abdominal aorta. In the future, combining compression devices with hemostatic bandages could be helpful. From a practical perspective, any new product must be easy to use.

Internal Bleeding Control

Jack Sava, MD

Director, Trauma/Gold Team Surgery, Associate Program Director, General Surgery, Washington Hospital Center

Internal bleeding can be compared to the BP oil spill in the Gulf of Mexico, and certain strategies to control internal bleeding can be compared to those used in attempts to control the spillage of oil from the Deepwater Horizons oil rig. Attempting to stop an oil spill using a “top kill” approach is similar to attempting to control bleeding using counter-pressure. Likewise, drilling a relief well can be compared to phlebotomizing a bleeding vessel.

Blood vessels in the body can be thought of as pressurized tubes within a cavity. The flow through each tube is determined by the fluid pressure and the resistance. Increasing blood pressure can contribute to blood loss, suggesting that delayed fluid resuscitation could have therapeutic potential. Applying external counter-pressure to a bleeding vessel could also reduce

blood loss, both by lowering the pressure gradient and by shrinking the opening in the blood vessel.

Strategies to control internal bleeding tend to involve either pressure or coagulation. Pneumatic suits have been tested to apply counter-pressure to internal bleeds, but these caused significant soft tissue damage. Insufflation is a technique that involves the injection of carbon dioxide into the peritoneum in order to raise pressure within the peritoneum. Systemic procoagulants have been tested, but these tend to be weak because stronger procoagulants would clog the entire vascular system. A more effective strategy could involve a systemic procoagulant activated by a secondary stimulus such as heat or light. Many of these strategies are still in development and could potentially cause serious side effects, but almost any side effect is better than bleeding to death.

Innovative Monitoring: The Collection of Dense Physiologic Data Across the Academic Enterprise

John A. Morris, Jr., MD

Professor of Surgery & Biomedical Informatics; Chief, Division of Trauma & Surgical Critical Care, Vanderbilt University

The goal of patient monitoring is to predict a patient’s trajectory before critical decompensation occurs. Vitals signs such as heart rate have long been used to monitor patients, but new vital signs, such as heart rate variability and morphology, are now being studied as well. Capturing this additional information requires a lot of information storage capacity, but it has the potential to improve patient outcomes. Researchers have found that low heart rate variability is correlated with mortality and appears to be affected by adrenal insufficiency.

As new technology allows healthcare providers to collect an ever increasing amount of information, analyzing this information has become a major

challenge. More information is currently collected than could ever be used to make clinical decisions. Presenting this information in a distilled yet useful format is vital, but there is no consensus as to what this format should be. Vital signs in the field are used differently than in the intensive care unit, so the format of information should be dependent on the setting. In the future, new combinations of vital signs will hopefully be presented in formats designed to help care providers make better decisions.

**Advanced Technology Innovations:
Neurologic Diagnosis and Rehabilitation**

Professor Neville Hogan

Newman Laboratory for Biomechanics and Human Rehabilitation, MIT

Each year in the United States, eight hundred thousand people have a stroke, and there are approximately six million stroke survivors living in the country. Stroke rehabilitation often involves physical and occupational therapy, and the cost of stroke treatment is approximately \$74 billion per year. Researchers working with Neville Hogan of MIT are creating safe and gentle robots to improve

An innovative feature of the robot is that the operator does not control force or motion but instead controls impedance. The robots work with one limb or joint at a time and help people accomplish motions that they would otherwise have difficulty initiating or completing. The technique takes advantage of neuroplasticity, or the ability of the brain to rewire itself in response

to new stimuli. Passive movement is not sufficient to help patients improve their motor function, and therapy cannot be too intensive without reducing the ability of the brain to consolidate what it has learned.

Hogan and his team are investigating whether or not their robots can be used to help patients with other neurological problems, such as cerebral palsy and traumatic brain injury. Their goal is to create therapies that patients can use at home, which would be easier for patients and would reduce healthcare costs. Ongoing challenges involves determining exactly what exercises patients should do with the robots and what type of supervision, if any, is needed by patients working with the robots.

**Advanced Technology Innovations:
The Promise of Biomimetics**

Jeff Karp, B.ENG., PhD

Co-director of Regenerative Therapeutics, Department of Medicine, BWH; Principal Investigator, Harvard Stem Cell Institute, Harvard-MIT Division of Health Sciences and Technology

Biomimetics refers to the use of designs found in nature to solve human problems. A good example of a biomimetic product is a gecko-inspired medical adhesive. The adhesive derives its stickiness from closely packed microscopic filaments, similar to filaments found on the feet of geckos. The filaments create an enormous amount of surface area, which promotes adhesion to other surfaces predominantly because of van der Waals

forces. The gecko-inspired adhesive is long-lasting and, with some modifications, can be used within the moist environment of the body. When designing the adhesive, scientists wanted an adhesive with high elasticity, minimal chemical reactivity, and excellent biocompatibility. The adhesive they created can be used to augment sutures or to deliver drugs.