“TRAuma Care In a Rucksack (TRACIR)”
Closed-loop Autonomous Care
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Mission:
- Support medical research interests of the Departments of Defense and Veterans Affairs
- Organize collaboration among investigators at the University of Pittsburgh to promote forward planning of research initiatives in advance of award announcements to enhance readiness of the University to compete for federal funding
- Develop new research themes in collaboration with DoD investigators

Problem to Solve
How can we initially treat and stabilize a casualty at point of injury using autonomous and robotic systems and clear the battlespace via unmanned evacuation?

Case example for the U.S. Department of Defense with civilian application
Korean War
1st use of MEDEVAC

In the first month of the war, the US Army evacuated over 500 injured soldiers. Over 5040 injured soldiers were evacuated by helicopter by the end of 1951.

Current approach - MEDEVAC

CASEVAC platform?
V-22 Osprey
capacity: 24 PAX or 6 litter/10 PAX

V-22 Osprey
CASEVAC with 2 litters and medic attendant

DARPA Aerial Reconfigurable Embedded System
(ARES)
New challenges for future healthcare delivery
Future approach
UAV, autonomous care, with robotic critical care
closed loop intervention

DP-14 Field Hawk
Fast, Agile Aerial Resupply, 430 Lbs Payload
VTOL: No Runway Required

Problem to solve

• How do you provide initial trauma resuscitation at a remote site with all medical resources (drugs/monitoring) contained in a “rucksack” delivered by an unmanned vehicle for a 15-30 minute casualty evacuation?

• Features include:
  • Monitoring
  • autonomous/semi-autonomous
  • Re-engineered monitoring systems
  • Medical intervention (drugs/needle insertion)
  • Telemedicine (when OPSEC allows)
  • Systems/Software integration

“Trauma Care in a Rucksack – TRACIR”

• Research collaboration: University of Pittsburgh School of Medicine and the Carnegie Mellon University: Engineering, Computer Science, Robotics Institute

• Concept: quickly installed on any ground or air vehicle (manned or unmanned), to provide tele-mentored, semi-autonomous, or autonomous enroute care during short or medium range patient transport.

• Project focus: next generation trauma patient management solutions using machine learning & novel biosensors that integrates with miniaturized advanced intelligent decision support tools, with advanced robotics intervention technologies and an ability to:
  1) set up by one person in a few minutes on any casualty for any “vehicle of opportunity” designated for casualty evacuation.
  2) telemedicine capable when communication networks are available

Critical Access Hospitals

Potential Civilian Market

As of July 27, 2018, there are 1,348 CAHs located throughout the United States.
Machine Learning

**Definition:** A type of artificial intelligence (AI) that provides computers with the ability to learn without being explicitly programmed.

Machine learning focuses on the development of computer programs that can change when exposed to new data. The process of machine learning is similar to that of data mining.

![Machine Learning Diagram]

**TRAuma Care In a Rucksack (TRACIR) Elements**

- **Research**
  - Big Data/Analytics
  - Machine Learning/AI
  - Novel biosensors
  - Validated animal models
  - Validated human models
  - Robotic expertise

- **Technology**
  - Vendor agnostic

- **Clinical Experience**
  - Mil-CIV

- **Need**
  - Autonomous
  - Robot controlled UAV/UGV
  - Cardiopulmonary resuscitation
  - Clear the battlefield

**Foundation:** Dedicated research team that is mission focused
FDA Approved Non-invasive Biosensors to be Assessed In TRACIR

<table>
<thead>
<tr>
<th>Sensor Name</th>
<th>Primary variables measured</th>
<th>Manufacturer</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rainbow pulse oximetry</td>
<td>SpO2, hemoglobin, heart rate, plethysmographic variability index</td>
<td>Masimo, Inc</td>
</tr>
<tr>
<td>Cyto-Cam-IDF imaging</td>
<td>microcirculatory flow</td>
<td>Braedius Medical B.V.</td>
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<tr>
<td>Maxv/Perio-Capnograph</td>
<td>bustral mucosal FiO2</td>
<td>Exostat Inc</td>
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<td>InfSight</td>
<td>tissue O2 saturation</td>
<td>Hutchinson Industries, Inc</td>
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<td>ClearSight</td>
<td>vascular tone, heart rate, SpO2</td>
<td>INTERMED, Inc</td>
</tr>
<tr>
<td>LiDCO and CNAP</td>
<td>finger plethysmographic blood pressure and cardiac output (CDS)</td>
<td>Edwards LifeSciences, Inc</td>
</tr>
<tr>
<td>NICOM</td>
<td>CO, thoracic fluid content</td>
<td>Cheetah Medical</td>
</tr>
<tr>
<td>Accuryn TraumaCath</td>
<td>urine output, intra-abdominal pressure, heart rate, respiratory rate</td>
<td>Petren Medical, Inc.</td>
</tr>
<tr>
<td>Electrical Inductance Tomography</td>
<td>total volume, pneumothorax, and respiratory rate</td>
<td>Swisstom</td>
</tr>
</tbody>
</table>

TRACIR Construct
DoD, Industry & Academia Collaborations

- Cloud Computing
- Bandwidth/compression
- Cyber-Security
- HIPAA
- UAV/UGV
- Robotics
- EHR Integration
- Telehealth
- Autonomous/Semi-autonomous Machine Learning
- StatMedEvac Database
- ECMO Catheters
- UPRM Medical Devices

UPMC StatMedEvac

- **UPMC STAT Medevac** provides aeromedical & critical care transport for ~12,000 patients per year with 17 helicopters in Pennsylvania, Ohio, West Virginia and Maryland
- Largest & busiest non-profit air transport system in the US
  - previous & ongoing DoD funded pre-hospital clinical research done collaboratively (Emergency Medicine and Trauma) at UPMC/University of Pittsburgh
UPMC StatMedEvac Database

- StatMedevac Database includes records for nearly 200,000 helicopter EMS calls (61,600 with trauma) spanning almost 20 years
- Database includes over 700 variables, including dispatch timing & location, patient demographics, time-stamped procedure and vitals records, assessments, and outcomes
- Continuous signal records downloaded from ZOLL clinical patient monitors & include biosignals such as EKG, NIBP/IBP, SpO2, ETCO2, temperature, and associated derived measures
- Workflow links the EMR record stored in our database to each signal record through a unified MATLAB signal database platform
- Data density 250 Hz; 1473 variables; 6.5M individual data rows

“TRAuma Care In a Rucksack” Pitt Support System

- Cardiopulmonary Research Laboratory
  - Director: Michael R. Pinsky, MD for last 38 years
  - 20x35’ Large animal surgical facility
  - Equipment necessary for any cardiovascular and general surgical procedures
  - Primary test animal: PIG
  - Multiple physiological monitoring devices
  - All stored data use a common LabView format
  - MatLab-based data collection

“TRAuma Care In a Rucksack”

- Cardiopulmonary Research Laboratory
  - Able to supply anesthetized porcine preparations, as per TRACIR proposal with physician surgical support to maintain animal viability during autonomous device insertion studies
  - Presently scheduled for 40 pig studies over 4 years
“TRAuma Care In a Rucksack”

• Cardiopulmonary Research Laboratory
  – Create a closed-loop controller to run the existing open-loop control program presently used in the laboratory to resuscitate pigs from hemorrhagic or septic shock
  – Trial closed-loop system in silico using existing +60 pig physiologic experimental and monitoring data first, then with only non-invasive and surrogates of non-invasive monitoring systems
  – Trial closed-loop system in real hemorrhage and chest trauma conditions
  – Trial closed-loop ventilatory system in chest trauma condition
  – Goal: 72 hours closed-loop support post-resuscitation

“TRAuma Care In a Rucksack”

• STAT MedEvac Data to identify similar biologic signatures to those seen in our porcine model

• In silico study of closed-loop control using STAT MedEvac data simulations of real flights when cardiorespiratory insufficiency developed to
  – Identify the minimal dataset needed to drive resuscitation
  – Variance in monitoring and treatment induced by specific types of trauma

“TRAuma Care In a Rucksack”

• Hershey Medical Center Lower Body Negative Pressure Chamber (LBNP)
  • Center Director - Larry Sinoway, MD
  • LBNP simulates progressive hemorrhage (hypovolemia) in healthy volunteers
  • Trial our ensemble of non-invasive monitoring devices to see if they can identify hypovolemia and its level of severity
  • Study 6 volunteers each on three separate occasions as monitoring ensembles evolve
TRACIR Event Detection Approach

By fusing data captured from multiple sensors and applying supervised machine learning, we are developing more predictive cardio-pulmonary resuscitation events than currently exist.

MULTIPLE SENSING MODALITIES
FUNCTIONAL HEMODYNAMIC MONITORING
MACHINE LEARNING INFORMATIVE FEATURES & PATTERNS PERSONALIZED RESUSCITATION PROTOCOLS

TACTICAL DATA REPOSITORY
UPitt StatMedEvac Dataset of 61,000 trauma patients
(pre-hospital --> OR --> ICU --> Ward)

TRACIR Team/Partners

Industry Partners
Numerous

Clinical Protocol Design
- Human and porcine clinical studies
- Biomarker/sensor selection
- MedEvac system testing
- Clinical support of machine learning
- User interface design support
UPitt Trauma Surgery, Critical Care Med, CT Surgery and Emergency Medicine, UPMC

Clinical and Artificial Intelligence
- Clinical data machine learning
- Intelligent processing of sensor data
- Clinical control algorithms
- Software system specifications, design, development, verification, and validation
- Software user interface, data registry
CMU Auton Lab, Robotics Institute

Robotic
- Robotic assessment and intervention
- Sensor/articulator system design
- Autonomy through soft, modular, and highly articulated robotics
- Hardware systems design, development, integration and testing
CMU National Robotics Engineering Center, Birobotics Lab, Robotics Institute

DoD Partners
USAAMC, NTRC, USAARL, AMEDD C&S, NAMRU-2, USMC, DNI

Project Management
- DoD liaison
- Clinical and robotic systems requirements
- Coordination of efforts
Center for Military Medicine Research, Univ of Pittsburgh

The “System”
Data Origins in Our System

- Recorded by Medics in EMR
- Environment
- Patient Status
- Evolving Pathology
- Biosignals
- Continuous Recorded by Monitor

Continuous Signal Data*

- ECG
- Pulse Oximetry
- IBP / NIBP
- CO₂
- Impedance
- Temperature

> 24,000 Hours of Signal Time

*Capabilities of the ZOLL monitor

DoD funded Research Approach

- Developed under previous NIH R21 / R01 projects at Pitt in collaboration with the Resuscitation Outcomes Consortium
- Signal data & EMR combined into a single MATLAB platform
- Supports flexible individual or batch analyses using EMR time-stamps as parsing guide points
- DoD Grant: StatMedEvac dataset refined with series of experiments in traumatized porcine models, followed by human studies with simulated hemorrhage and ICU validation
- Separate and complementary DoD grant at CMU for robotics portion of TRACIR
TRACIR provides a next generation intelligent cardiopulmonary resuscitation management tool at its core. Advanced robotics are used to aid in providing autonomous assessment and interventions.

Concept: Specially Configured Rucksack

- Abdomen compression straps unfold from structure
- Pull out rail from rear of backpack structure for transporting soldier and used as attachment point for robotic equipment and UAV pod

Concept #1: Rucksack Frame -> Mini-Stretcher

Rear of backpack unfolds into mini-stretcher
Material within backpack unfolds into a full body stretcher

- Air pressure is used in key areas to inflate support structures
- Handles included to transport soldier
- Abdomen compression straps can be unfolded to apply pressure

**Concept #2: Full Body Stretcher**

Deployed version of stretcher mat with torso compression strap active

- Plugs (marked in green) around device allow for connection to air gun to fill support components
- Head/neck support bladder becomes stiff after filled with air

**Modular Attachment Point for Robotics Implements**

Head support bladder also acts as a connection point for robotic equipment
“TRAuma Care In a Rucksack”
Deliverables

- A proof of principle that a totally autonomous system can identify, treat and sustain stability in a porcine model of hemorrhagic shock, pneumothorax and lung injury
- Early spin offs will be algorithms for semi-closed loop diagnosis and treatment in the field
- Deliverables can be modified by CMU robotic progress

Questions?

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“TRAuma Care In a Rucksack”

- STAT MedEvac Data Base
  - Emergency Department-owned Waveform physiologic data on all air transport patients
  - Presently 5,500 trauma patients complete data sets collected and linked to in-flight EMR
  - All patient data de-identified
  - Goal 8,000 trauma patient database by 2021
  - Present goals
    - Link to hospital EMR
    - Format data structure to allow supervised ML of impending cardiorespiratory insufficiency