



U.S. Army Institute of Surgical Research

Monitoring Trauma Patients in the Prehospital and Hospital Environments: The Need for Better Monitors and Advanced Automation

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Combat Casualty Care



Research for the Soldier

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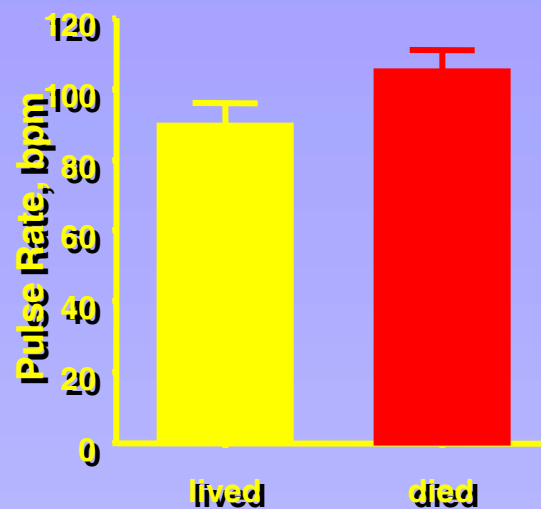
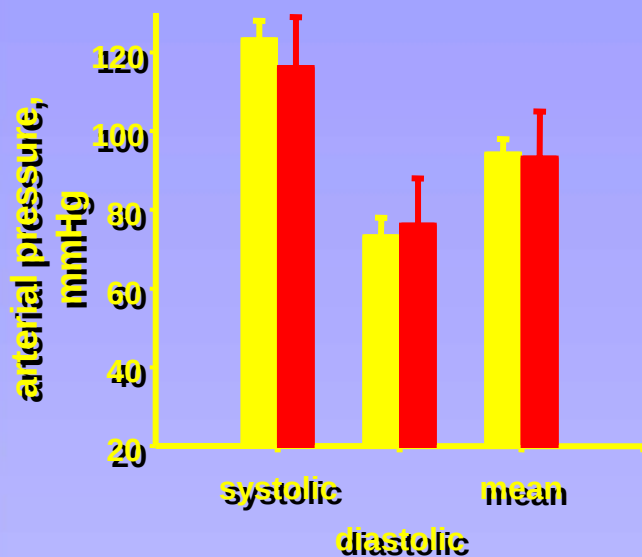
Background



- Diagnosis in the prehospital and/or hospital environments is often inaccurate for trauma patients
- Current prehospital monitors measure vital signs that are not predictive of outcome in many instances
 - Systolic Blood Pressure
 - Heart Rate
 - SpO2



Standard Vital Signs



lived (n = 15)
died (n = 15)

Grouped Vital Signs Do Not Predict Need for Life Saving Interventions

- Considered 3 data sets based on instrument requirements
 - Manual (MG)
 - Semi-Automated (SG)
 - Automated (AG)

Automated Group

- Electronic monitor
 - Automated NIBP (Systolic, Diastolic)
 - Heart Rate
 - EtCO₂
 - Automated Respiration Rate

Semi-Automated Group

GCS Eye
SpO₂

Manual Group

- Demographics (Age, Sex)
- Pulse Character (Radial, Femoral, Carotid)
- GCS Motor, GCS Verbal
- Capillary Refill

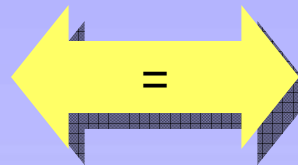
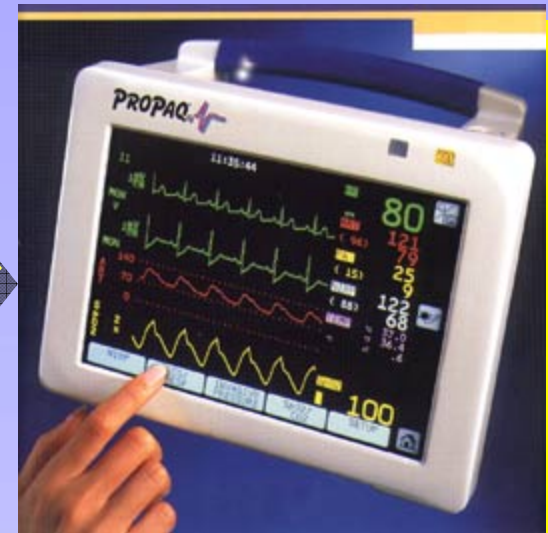
Problem



**Manual Vital Signs
Physical Exam**



Electronic Vital Signs



No difference in prediction of outcome



Triage Problem



- **Civilian:**
 - Consistent overtriage and undertriage problem in the prehospital trauma environment
 - Not unusual to have a 50% overtriage within a large urban area
- **Military:**
 - Inability to effectively predict evacuation requirements balanced with tactical considerations

Cause:

Inability to accurately determine patient status using current methodologies/technologies.



Environment: Medic Injured Trying to Save Fallen Comrade





Bottom Line



Current monitors present data that is not predictive of eventual physiologic decompensation and are thus inadequate!

Solution



- We need a new type of monitor!
- Requirements
 - Accurate diagnosis of patient status
 - Small/Lightweight
 - Remote/wireless operation
 - Intelligent Decision assist technology
 - Autonomous/closed loop technology for long term care



Accurate Diagnosis of Trauma Patients



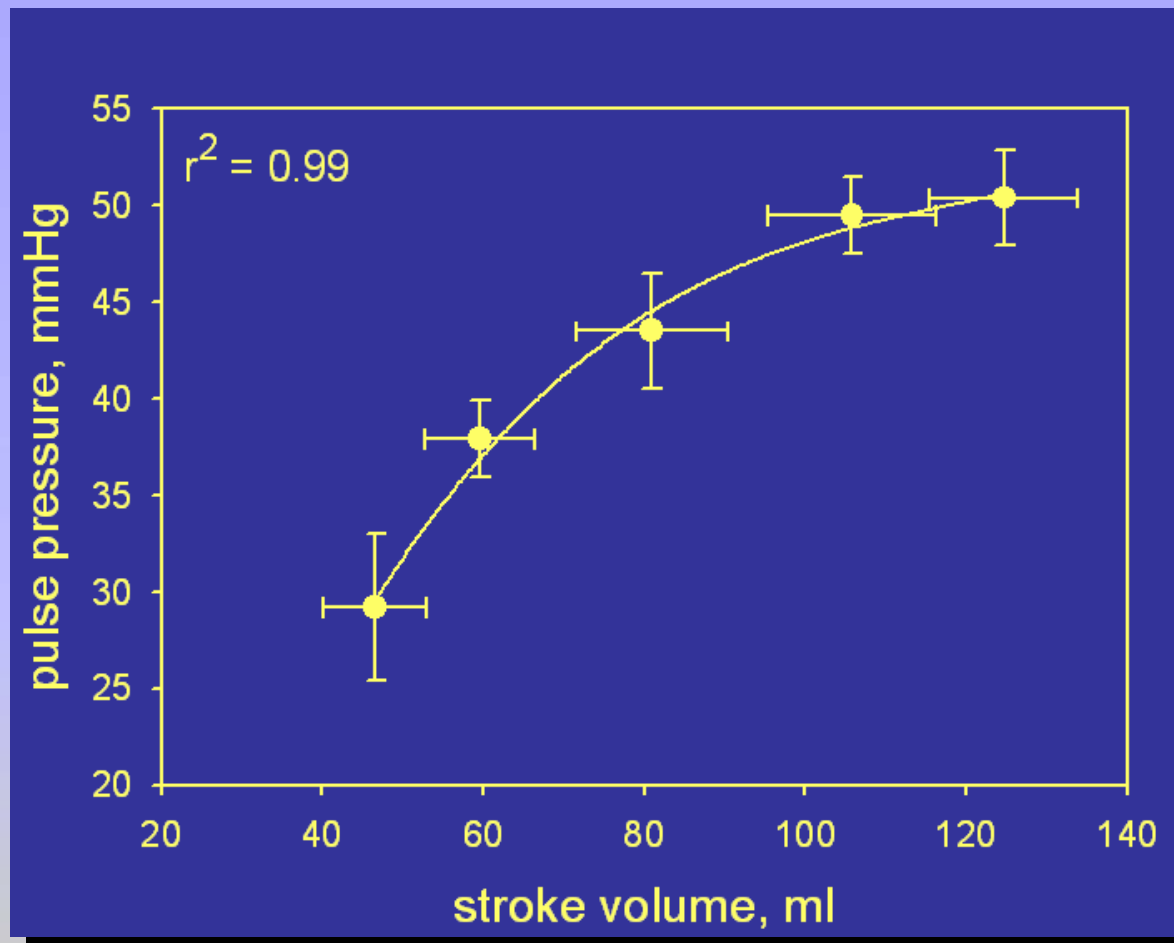
- Need to use new/advanced vital signs
 - Pulse Pressure
 - Shock Index
- Explore combinations of vital signs to enhance probability of correct diagnosis
- Make use of vital sign trends
- Use characteristics of high frequency waveforms
 - Heart Rate Variability
 - Heart Rate Complexity
 - Non Linear ECG Dynamics



Pulse Pressure



- **Statistically significant for tracking stroke volume**

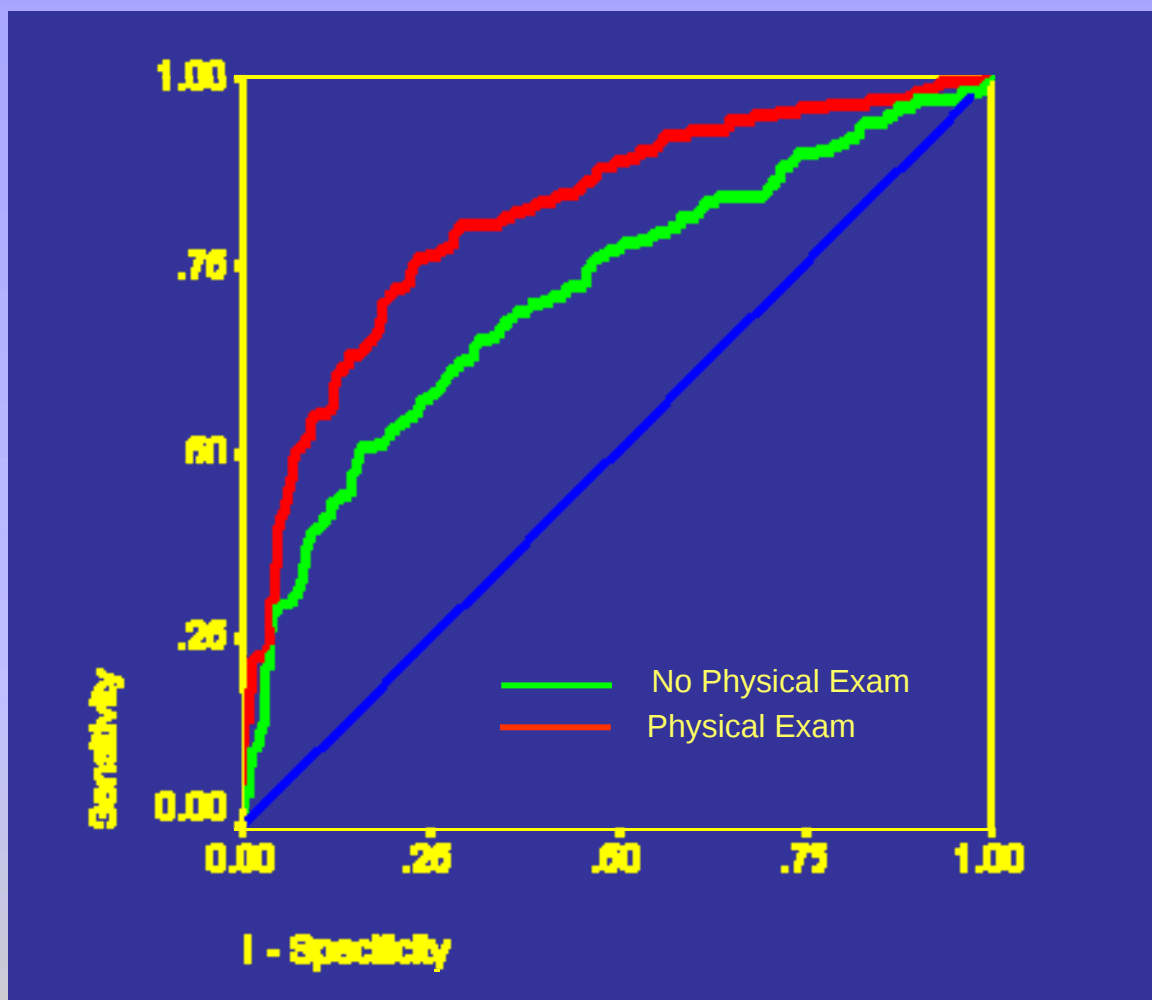




Combination Vital Signs



Combination of Shock Index, Shock Index Trend,
Respiratory Rate

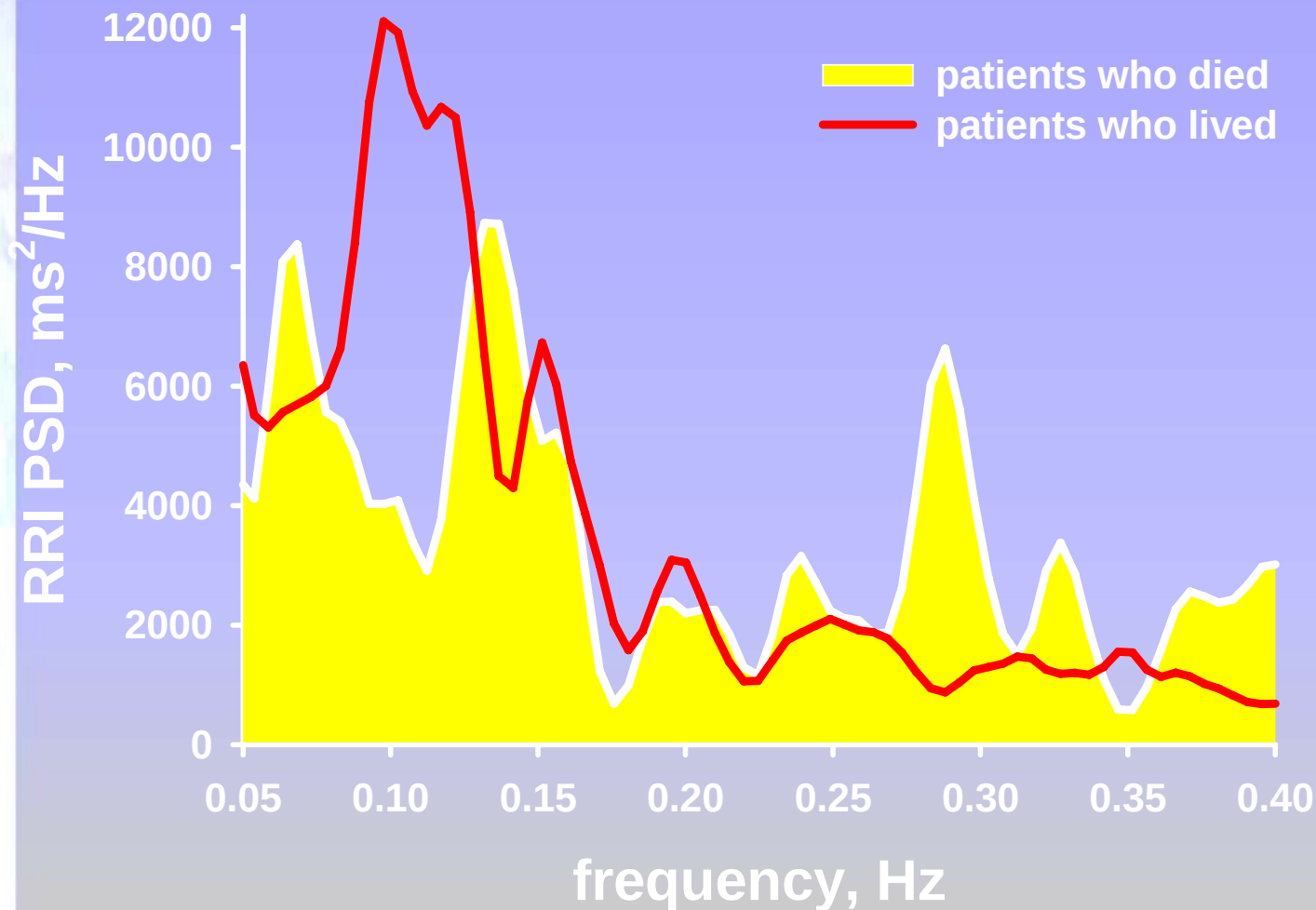




Waveform HR variability



Measures Sympathetic/Parasympathetic activity based on the frequency distribution of the RRI values.



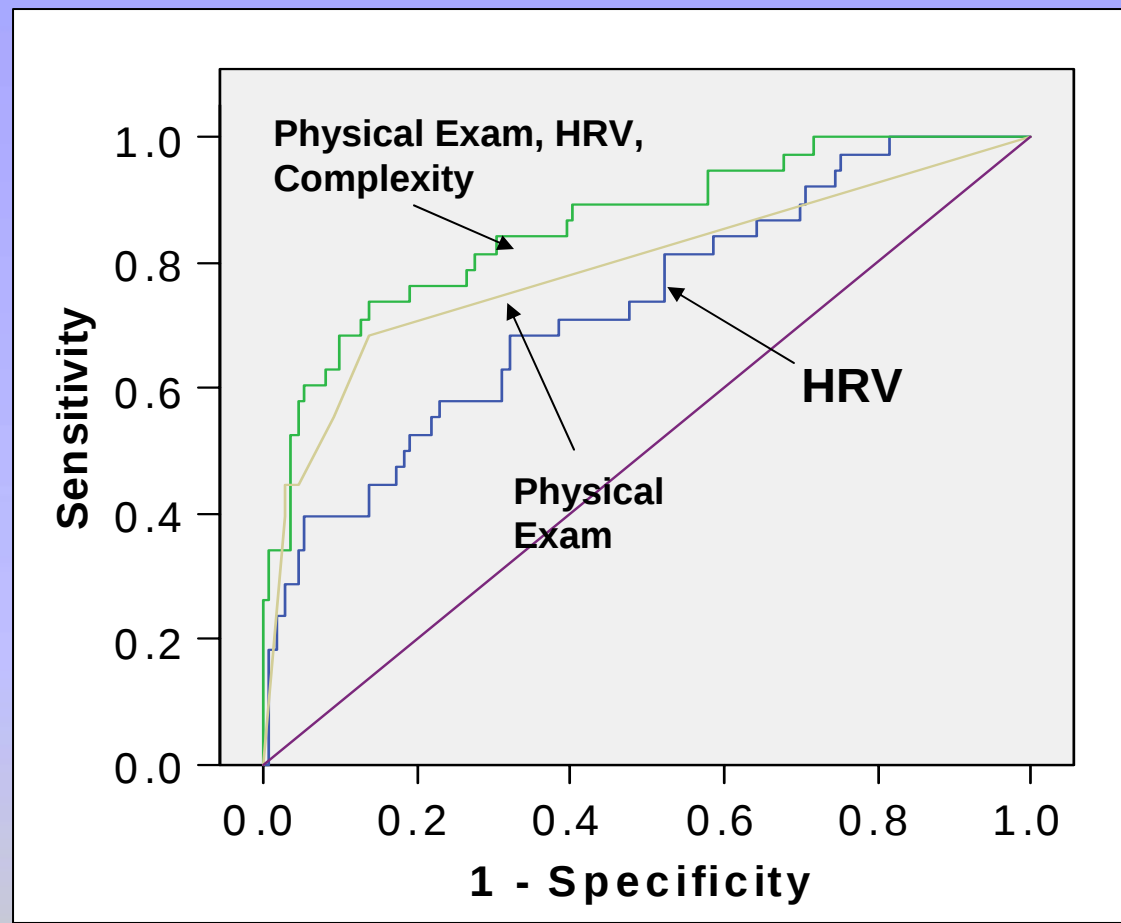


Waveform Complexity



Quantifies the regularity of the HR signal through entropy calculations with in the RRI values.

Prediction of LSI





Addition of more parameters



- | <u>Parameter</u> | <u>Survival ROC</u> |
|--|---------------------|
| • Single Vital Signs | 0.75 |
| • Physiology and Trends | 0.80 |
| • Physiological Variability | 0.85 |
| • Physiology, Coagulation,
and Immunology | 0.96 |
- *The more **significant** data we get, the more predictive we can be!*

Problem



- Monitoring can be enhanced to further improve patient care...However:

“We keep monitoring patients to death”
-- Anonymous

Now What?



- Use enhanced prediction algorithms and inputs into intelligent medical systems to better assist medical providers
 - Decision Support Systems
 - Advanced Triage Systems
- Move validated medical systems into full automation for closed loop care of patients



Decision Assist (support) Technology



- Decision support systems are a class of computer-based information systems that support decision making activities
 - Type of intervention
 - What intervention to use based on the expertise of the user
 - When do we apply intervention?
 - Where should a patient be taken based on readings?
 - Where should a patient be transported to?

Benefits



- Helps to remind experts on proper patient care during critical procedures and/or mass casualty situations
- “Pushes” the expertise built into the software to non-expert providers
 - i.e. burn standard of care procedures for field use
- Maintains the open loop concept – Not a replacement for good clinical judgment



Types of DSS



- **Model Driven**
 - Used for statistical data manipulation
 - Example: Expected response of a company's stock to a selloff
- **Communication Driven**
 - Used for coordination of tasks between users
- **Data Driven**
 - Used for manipulation of time series data
- **Document Driven**
 - Manipulation of unstructured information from documents
- ***Knowledge Driven***
 - *Most appropriate for medical systems*
 - *Emphasizes problem solving skills*



USAISR DSS Examples



- **ICU DSS Framework**
 - Decision support framework for management of burn patients admitted to the USAISR Burn Center ICU
 - Resuscitation – Implemented
 - Tight glucose control - Implemented
 - Hypotension management – Working
 - Albumin use - Working
 - Abdominal compartment syndrome diagnosis and management - Working
- **Mobile Burn Resuscitation**
 - Decision support for burn resuscitation in a mobile/handheld system for field resuscitation



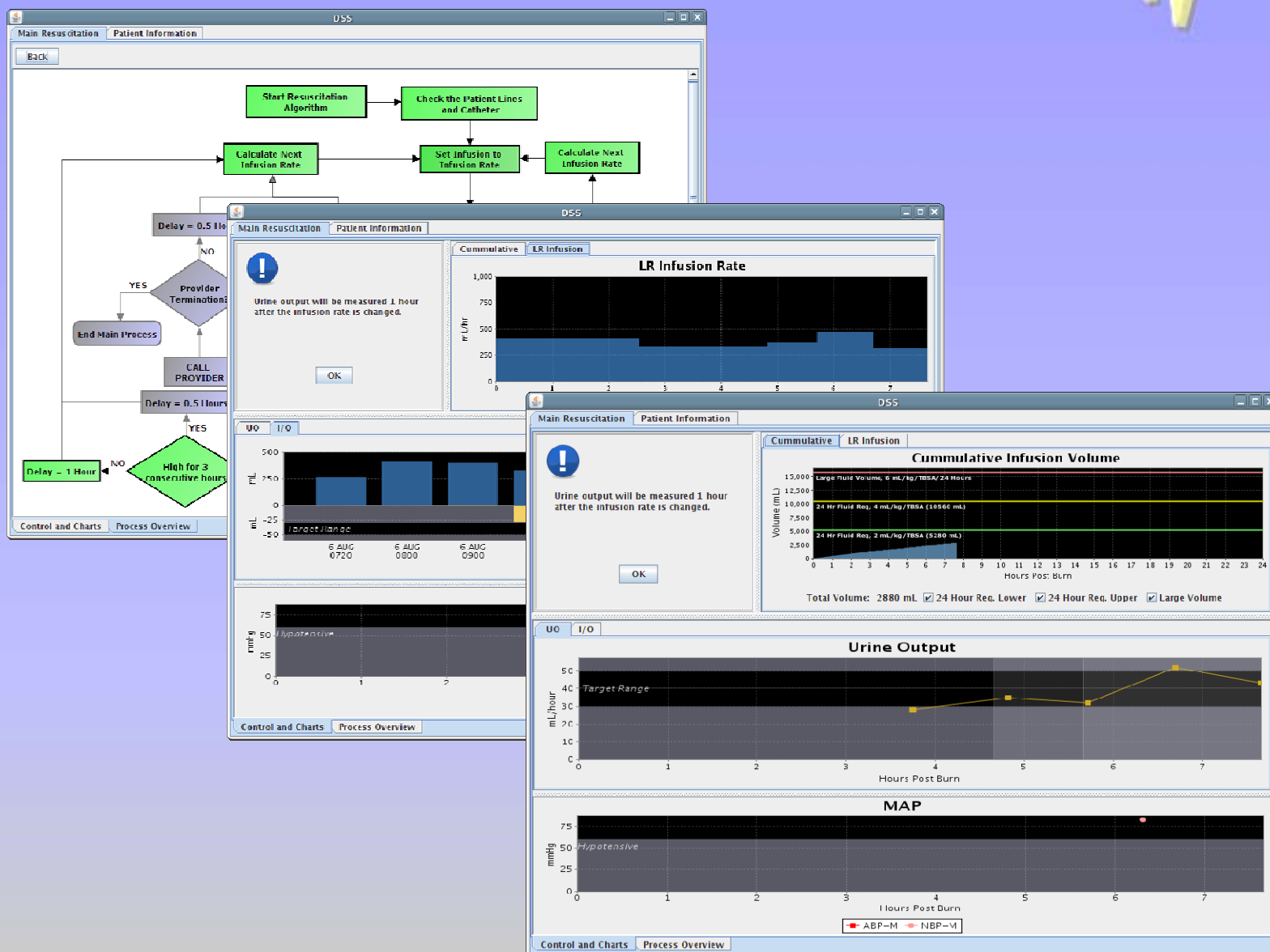
Automation and Closed Loop



- Use accurate inputs to control therapy for patient care
 - Examples:
 - Resuscitation
 - Ventilation
 - Pain Control
 - Hemorrhage
- Feedback system allows for more accurate delivery of therapy

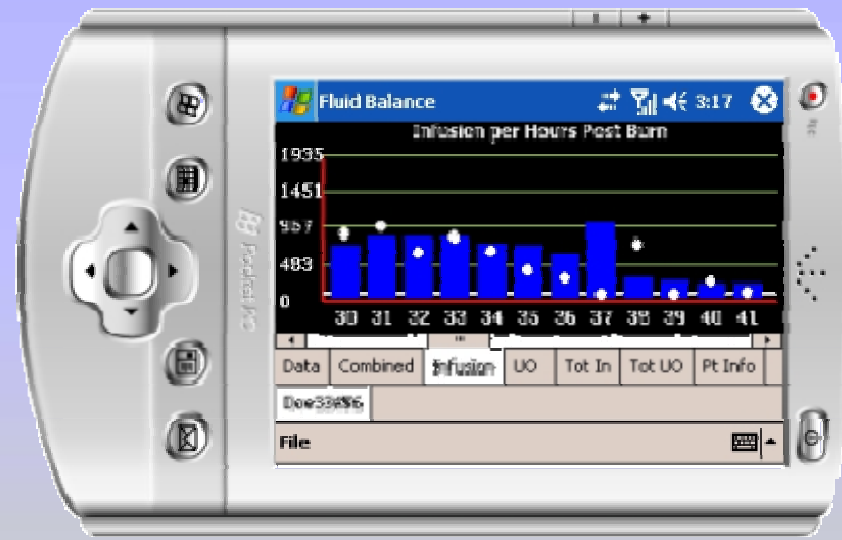
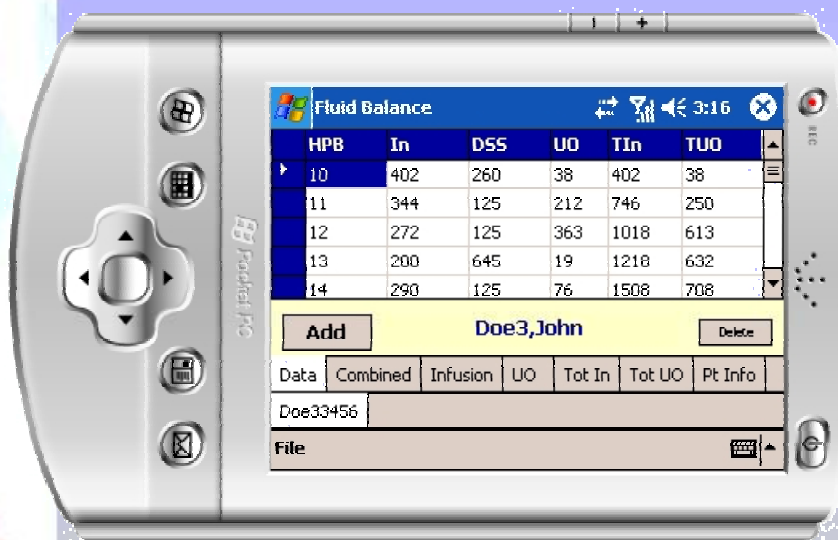
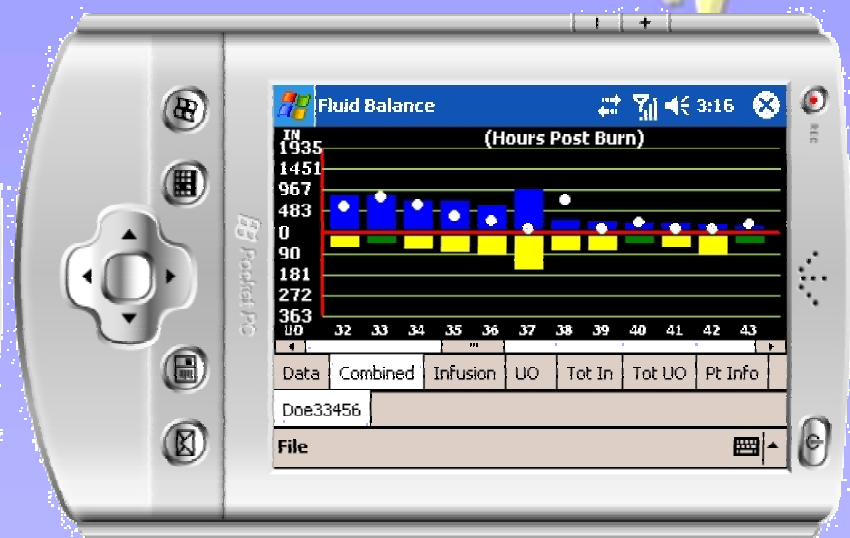
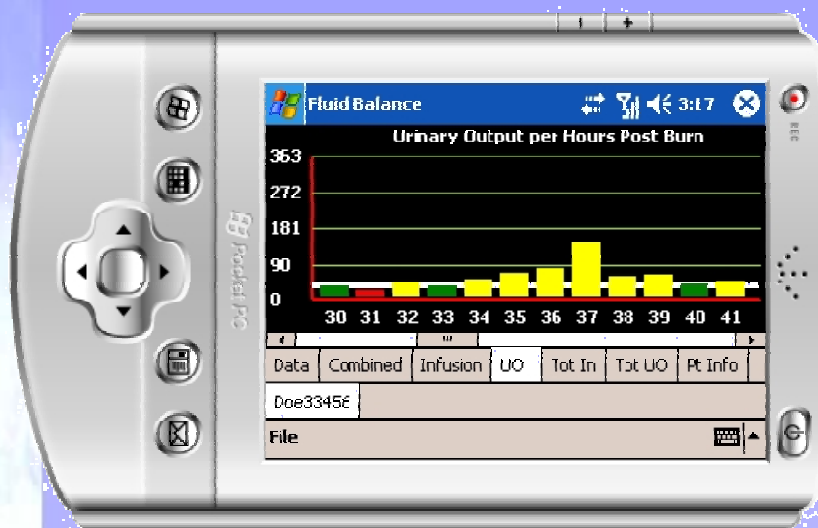


Action Shots of DSS (ICU Version)





Action shots of DSS (Mobile)



The Future



- Full Automation
 - Closed loop
 - Computer control of sensors and actuators
 - Automated patient management



Lightweight Trauma Module (LTM), Impact Instrumentations



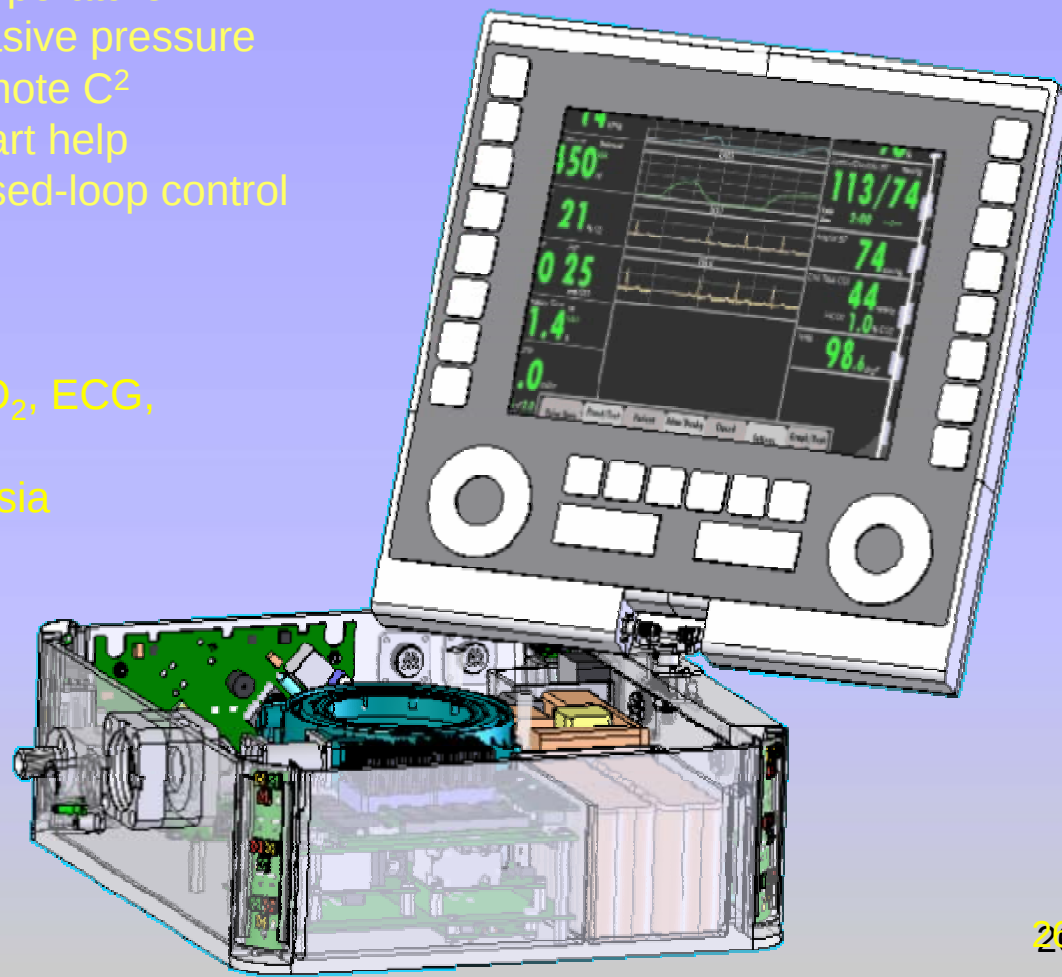
Integral

- Ventilator
- 12-lead ECG
- Pulse-Ox
- NIBP
- Data I/O
- Electronic med. record
- CO₂
- AED
- Temperature
- Invasive pressure
- Remote C²
- Smart help
- Closed-loop control

- Respiratory mechanics
- **Pulse Pressure, Shock Index, HRV**

Modules

- Aspirator
- I.V. pumps
- Multipatient monitor (SpO₂, ECG, NIBP)
- Patient controlled analgesia
- Spirometer
- O₂ concentrator
- Patient warming
- Stress test
- Anesthesia Module
- Ultrasound imaging
- Visualization
 - Oto/ophthalmoscope
 - macrolens camera



Wireless Vital Signs Monitor (WVSM), Athena GTX



*An Automated Wireless, Battery
Powered Medical Tool to Assist the
Medical Personnel in the Field and
Hospitals in Tracking and Monitoring
Patients' Vital Signs
Continuously....in a small and
affordable package using WLAN and
MS Windows O/S*



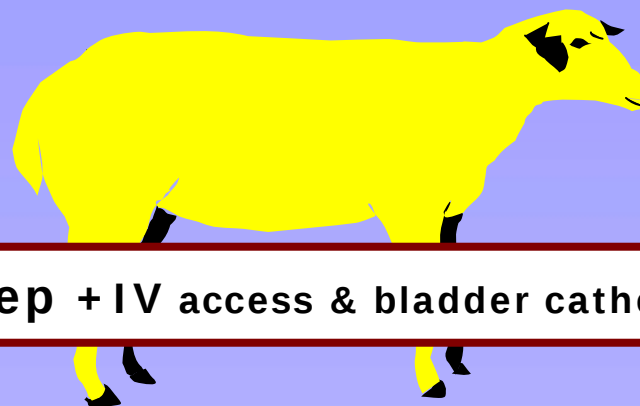
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Closed-Loop Resuscitation of Burn Injury

IV Pump



Sheep + IV access & bladder catheter



Bard® Urine Monitor



PC-Visual Basic controller



* G Kramer, University of Texas Medical Branch



Hourly Urinary Outputs:

on-target, under-target and over-target



Group	on-target	under-target	over-target
Tech Control 11 sheep, 508 measurements	198 40%	122 25%	175 35%
CLR controlled 10 sheep, 475 measurements	214 47% p = 0.23 1.31 (CI 0.85, 2.0)	73 16% p = 0.02 0.58 (CI 0.38, 0.89)	173 38% p = 0.65 1.10 (CI 0.74, 1.65)

target range defined as 1.0 – 2.0 mL/hr target

Conclusion



- Need better monitoring technologies
 - New vital signs
 - Combinations of standard, new, and trended vital signs
 - Advanced complexity vital signs
- Need to develop decision support systems
 - Additional tools to expert users
 - Better care for non-expert care providers
 - Open loop concept
- Future: Closed loop and automation
 - Computer control of sensors and actuators



QUESTIONS?

