

Buying More Time: Innovations in the Early Detection and Treatment of Shock

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What's the Problem?

Hemorrhagic Shock Due to Trauma

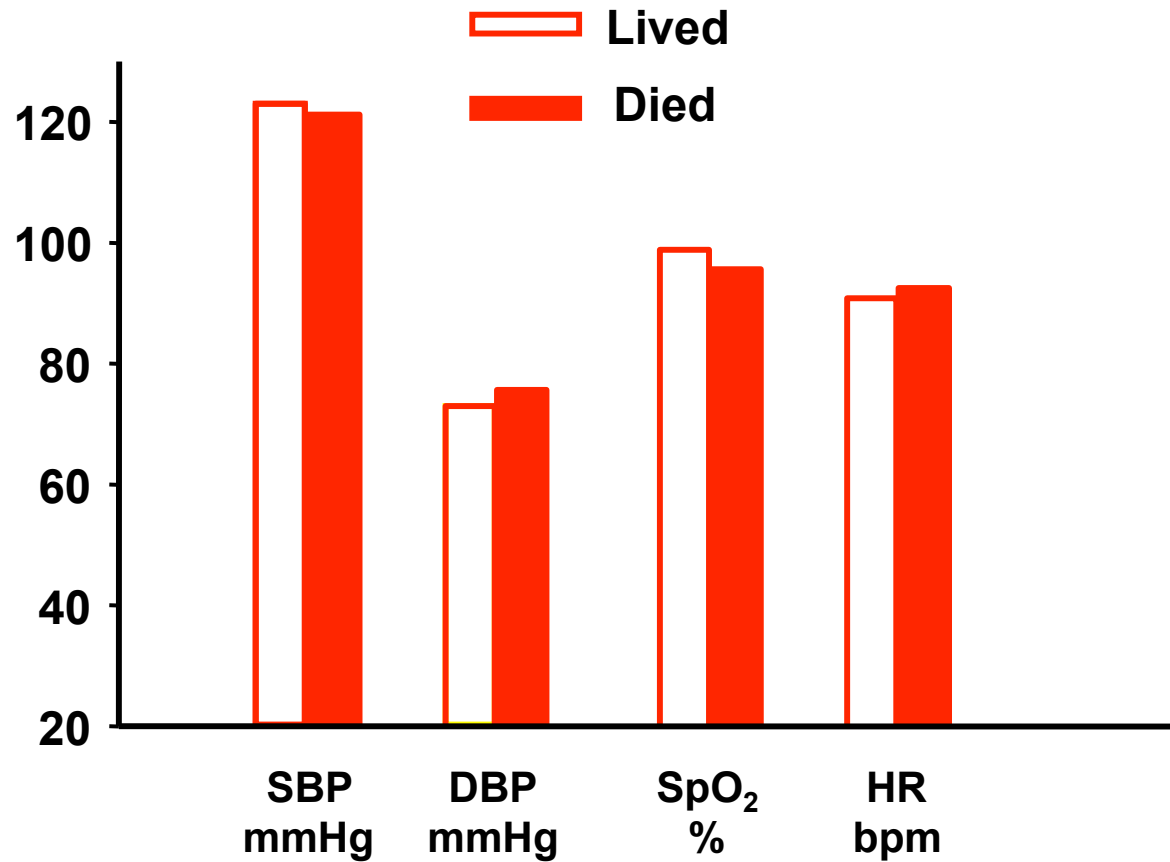
- ~40% of Civilian Deaths
- 5281 Total military KIA in OIF / OEF (2001 to present)
 - >90% are pre-hospital
 - ~25% or 1660 classified as “potentially survivable” deaths on the battlefield
 - >80% or >930 “potentially survivable” of these deaths due to hemorrhage

What clinical parameters do you currently use to identify hemorrhage shock?

What do you think you will use in the future?

How soon will compensatory risk index (CRI) be available to you?

Pre-hospital Study of Severe Hemorrhage



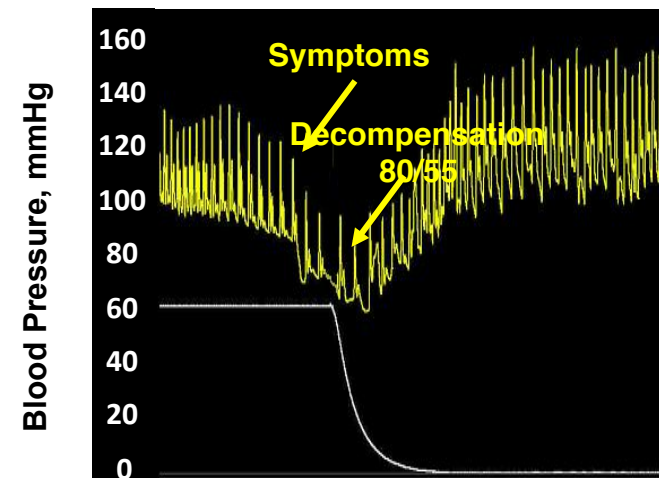
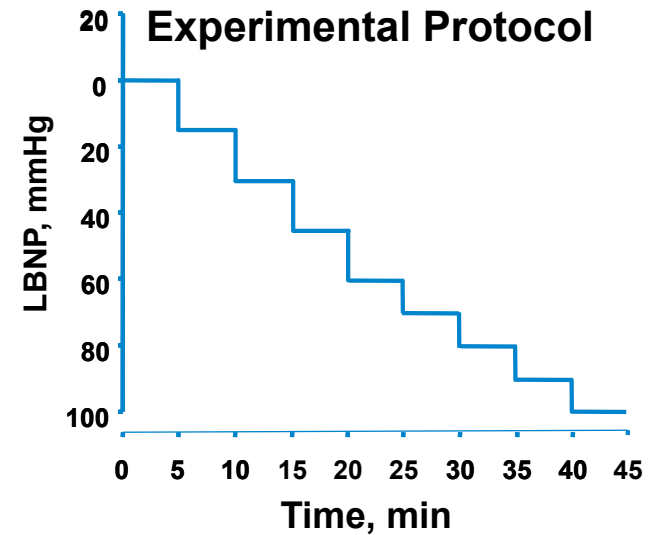
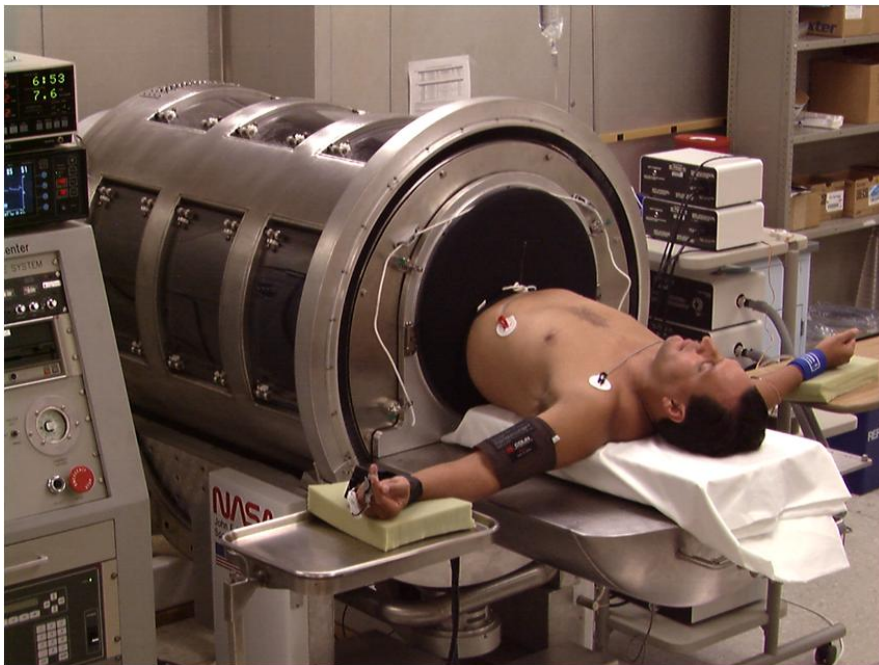
What if . . .

- What if we had technology that could indicate a patient's progression toward 'shock' well in advance of changes in vital signs?
- What if we had technology that could provide guidance for accurate resuscitation?

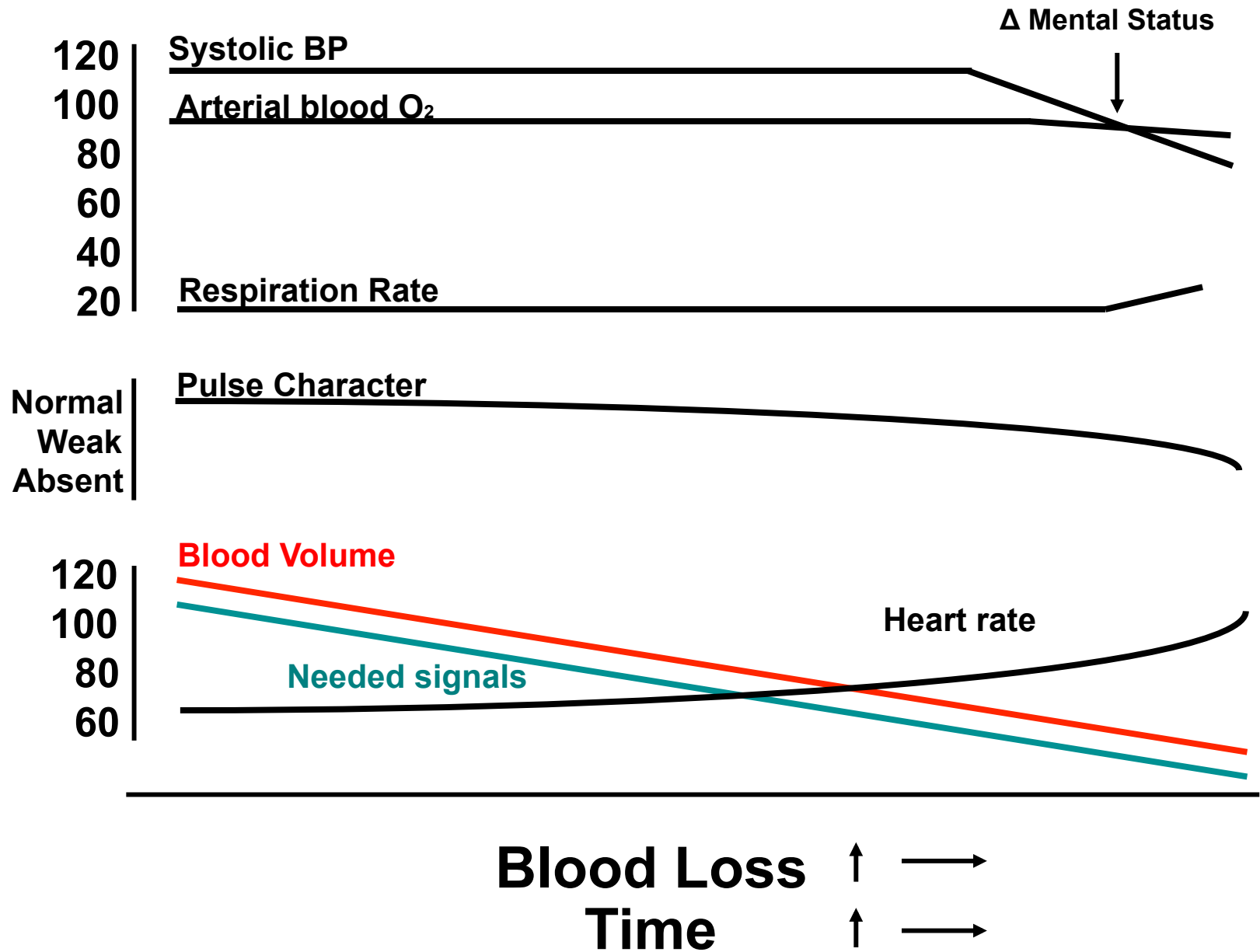
What do we need?

- **Physiological (human) model predictive of shock (hemorrhage, sepsis, etc.)**
- **Reproducible clinical outcome (i.e., hemodynamic compensation)**
- **Identify signals that represent integrated physiology of hemodynamic compensation**
- **Large a data 'library' for algorithm development**
- **Algorithm(s) designed to recognize each INDIVIDUAL patient**

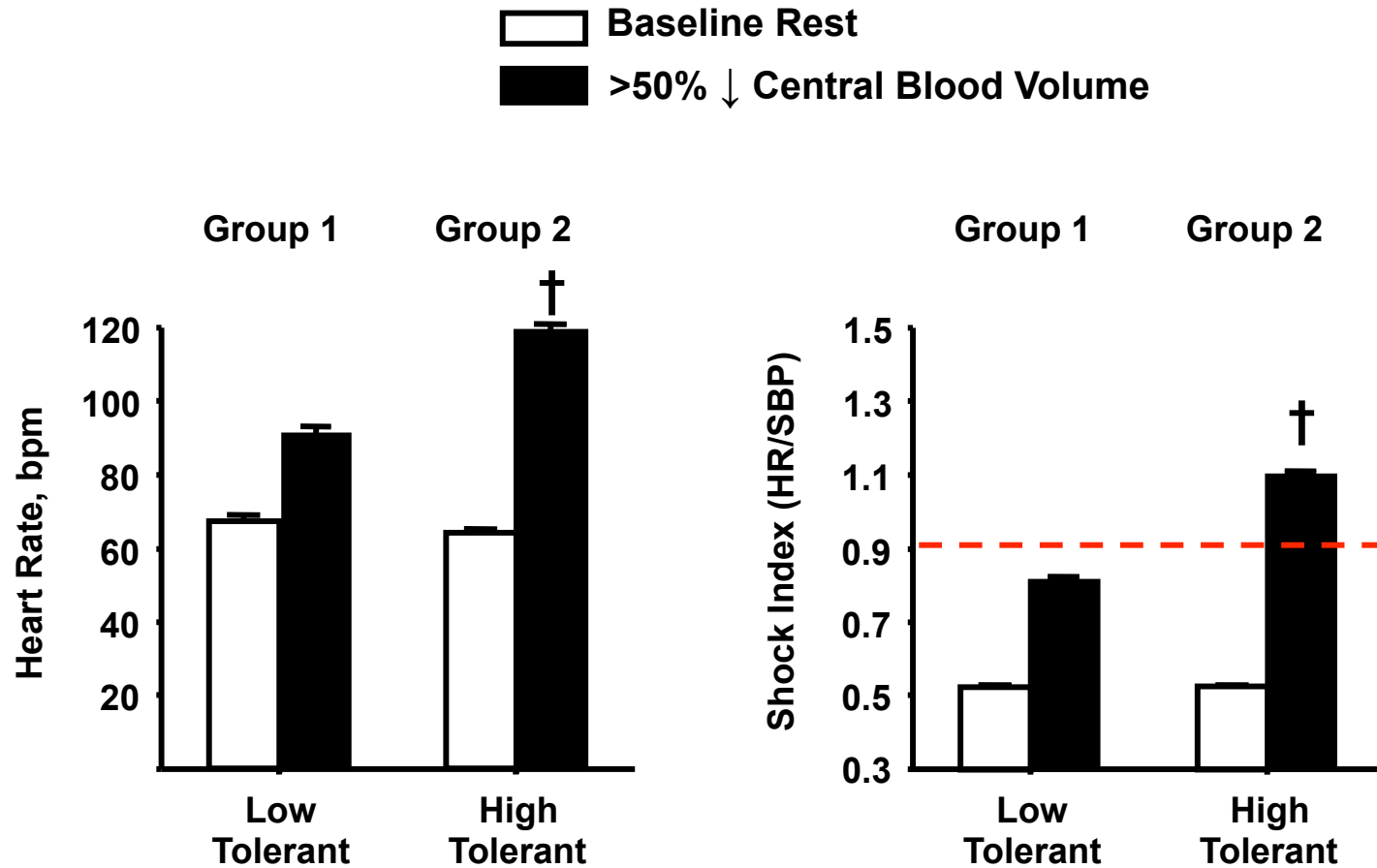
Human Model of Hemorrhage Lower Body Negative Pressure (LBNP)



Need for Early Signals of Hypovolemia



Heart Rate and Shock Index Responses are Associated with Tolerance to Reduced Blood Volume



Tolerance to Reduced Central Blood Volume is Associated with Blood Pressure Oscillations

Low Tolerant (max LBNP = -30 mmHg = ~450 ml)

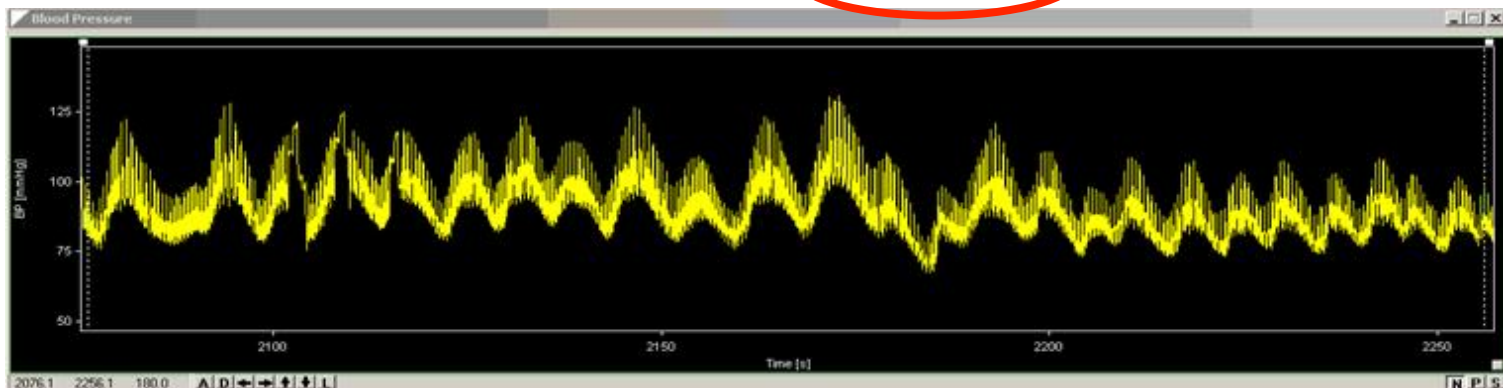
Average SBP = 116 mmHg

Decompensation

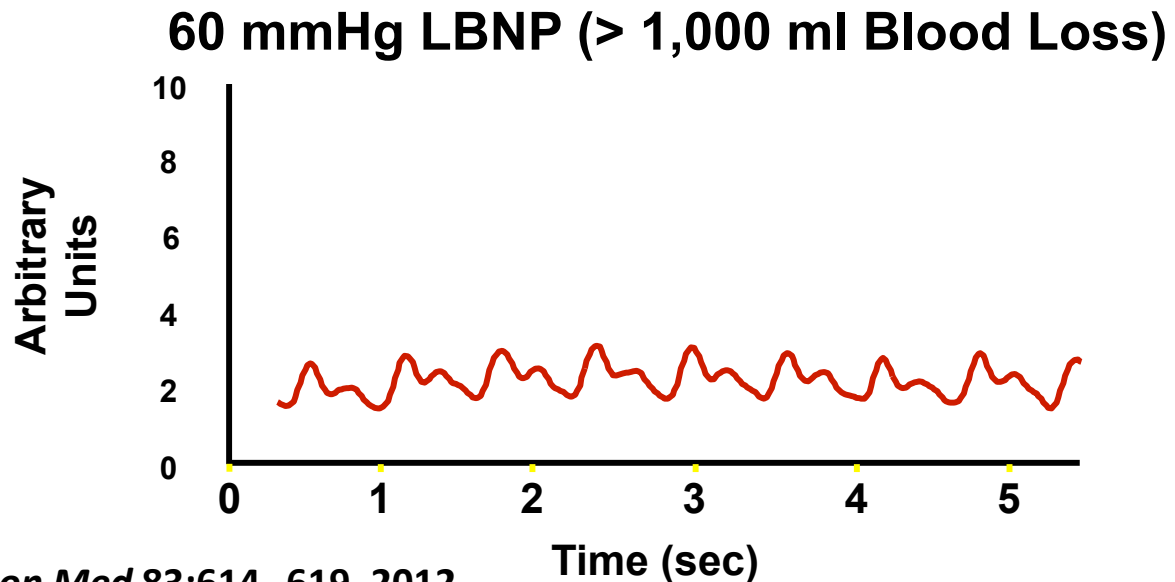
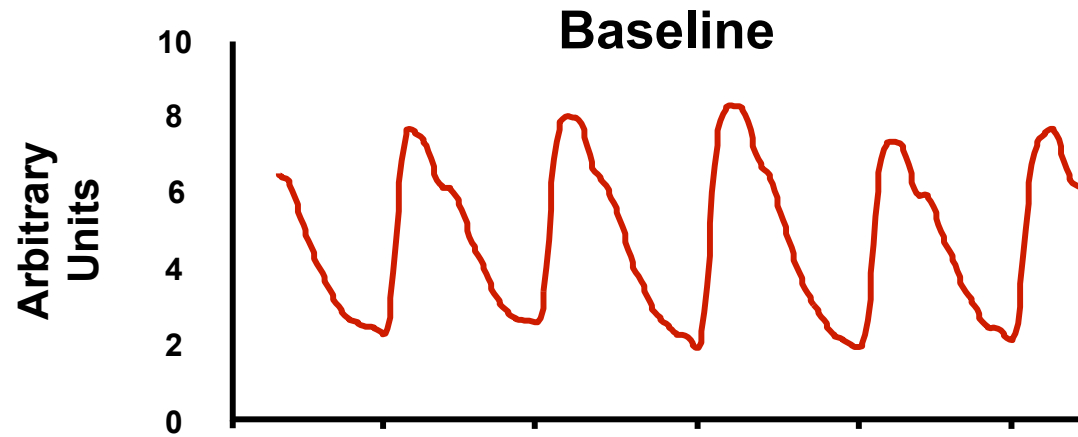


High Tolerant (max LBNP = -80 mmHg = ~1,200 ml)

Average SBP = 104 mmHg



Arterial Waveform Features as a Marker of Compensatory Reserve

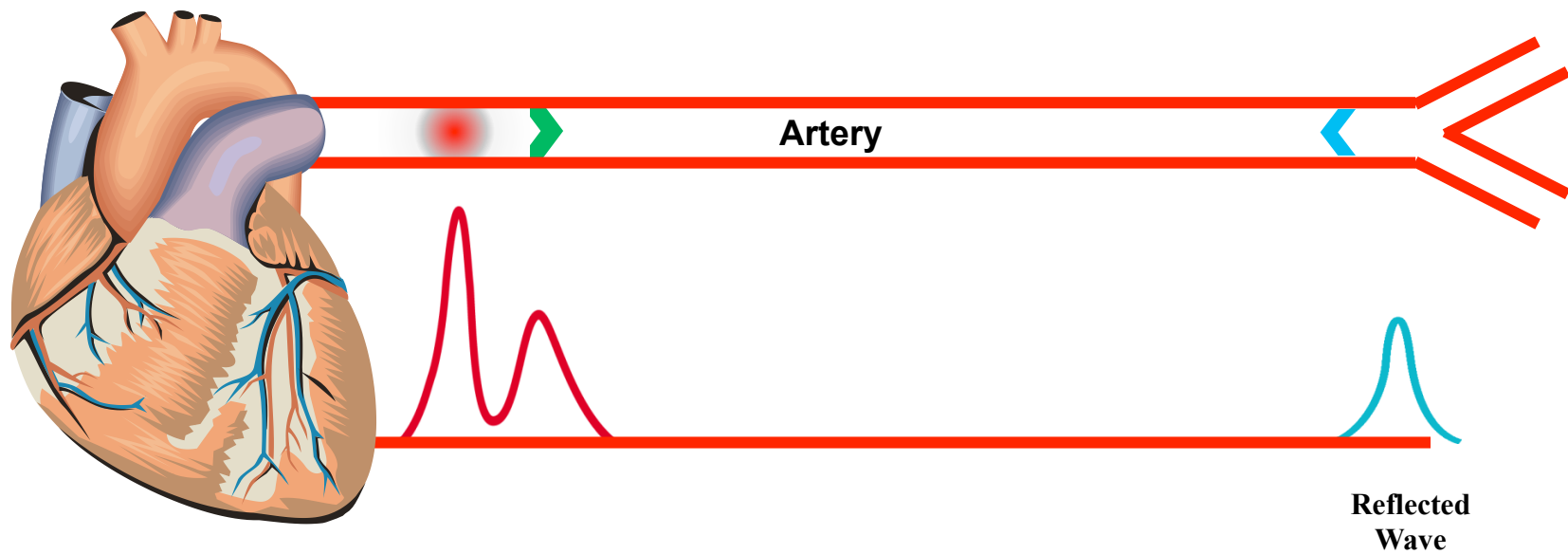


Requirement for Improved Diagnosis of Hypovolemic Shock

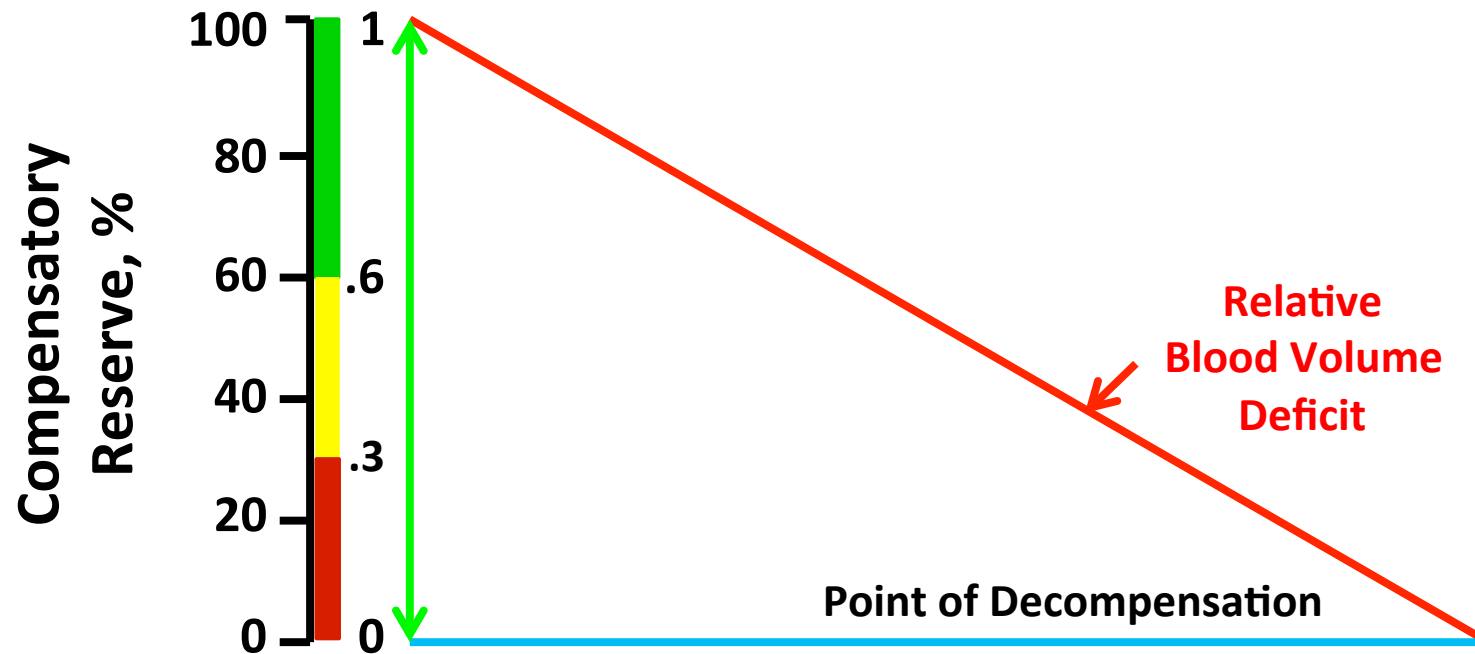
What should we measure?

- continuous feature changes in the arterial waveform**
- arterial waveform oscillations**

Arterial Pulse Waveform

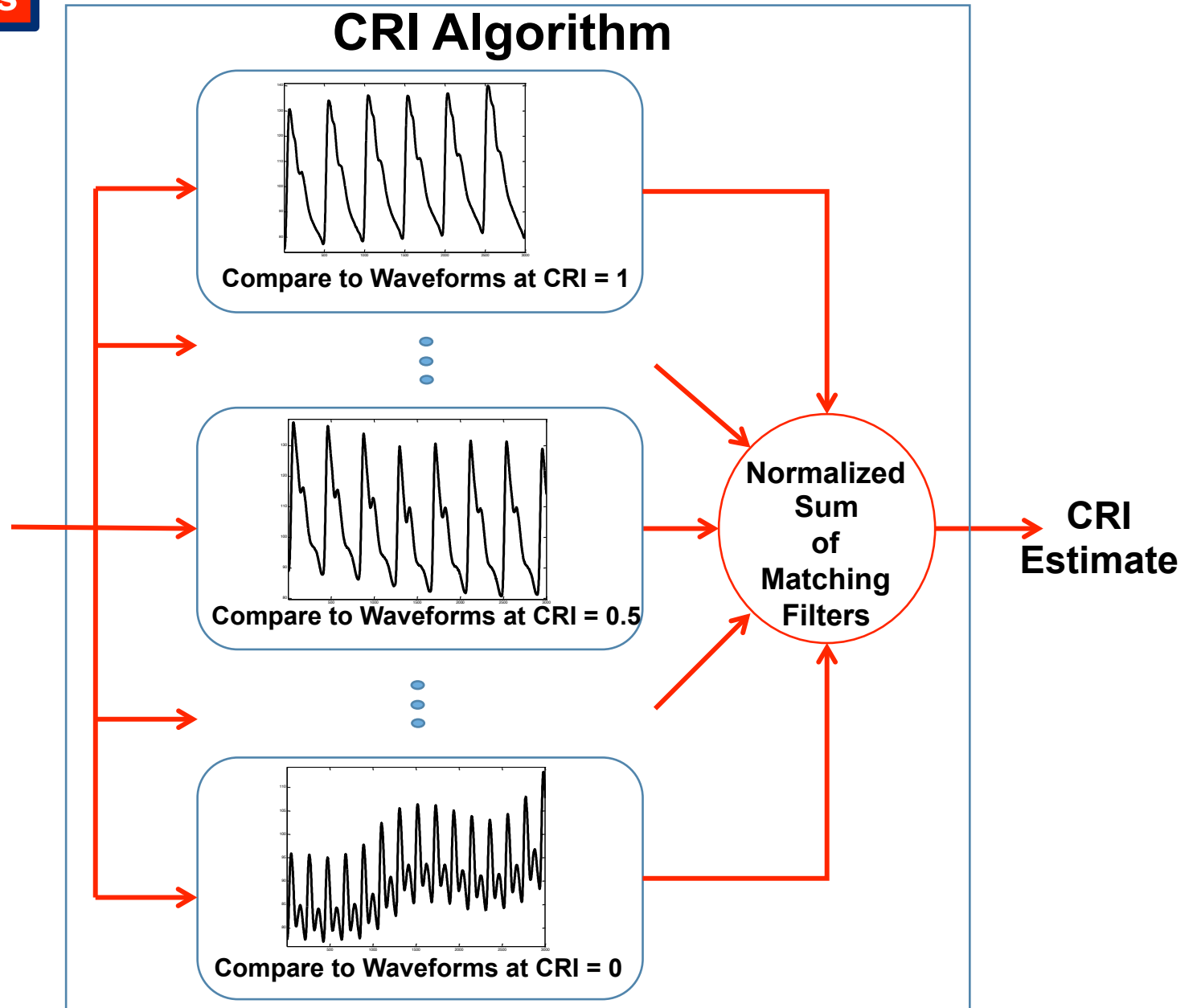
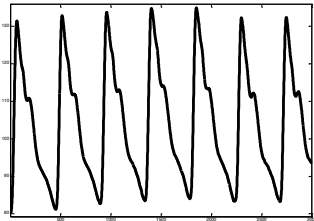


Compensatory Reserve



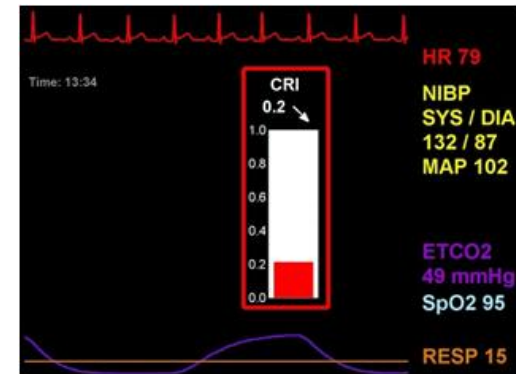
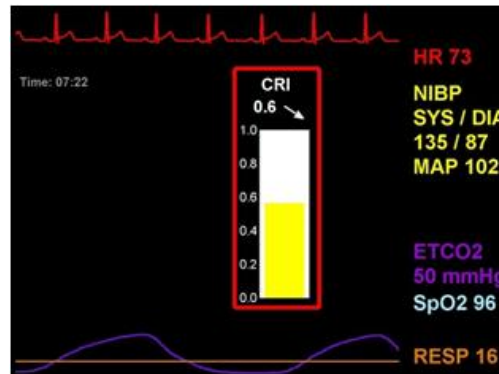
How CRI Works

Input 30
Heartbeats
of
Patient's
Arterial
Waveform



New Decision-Support Monitor Display

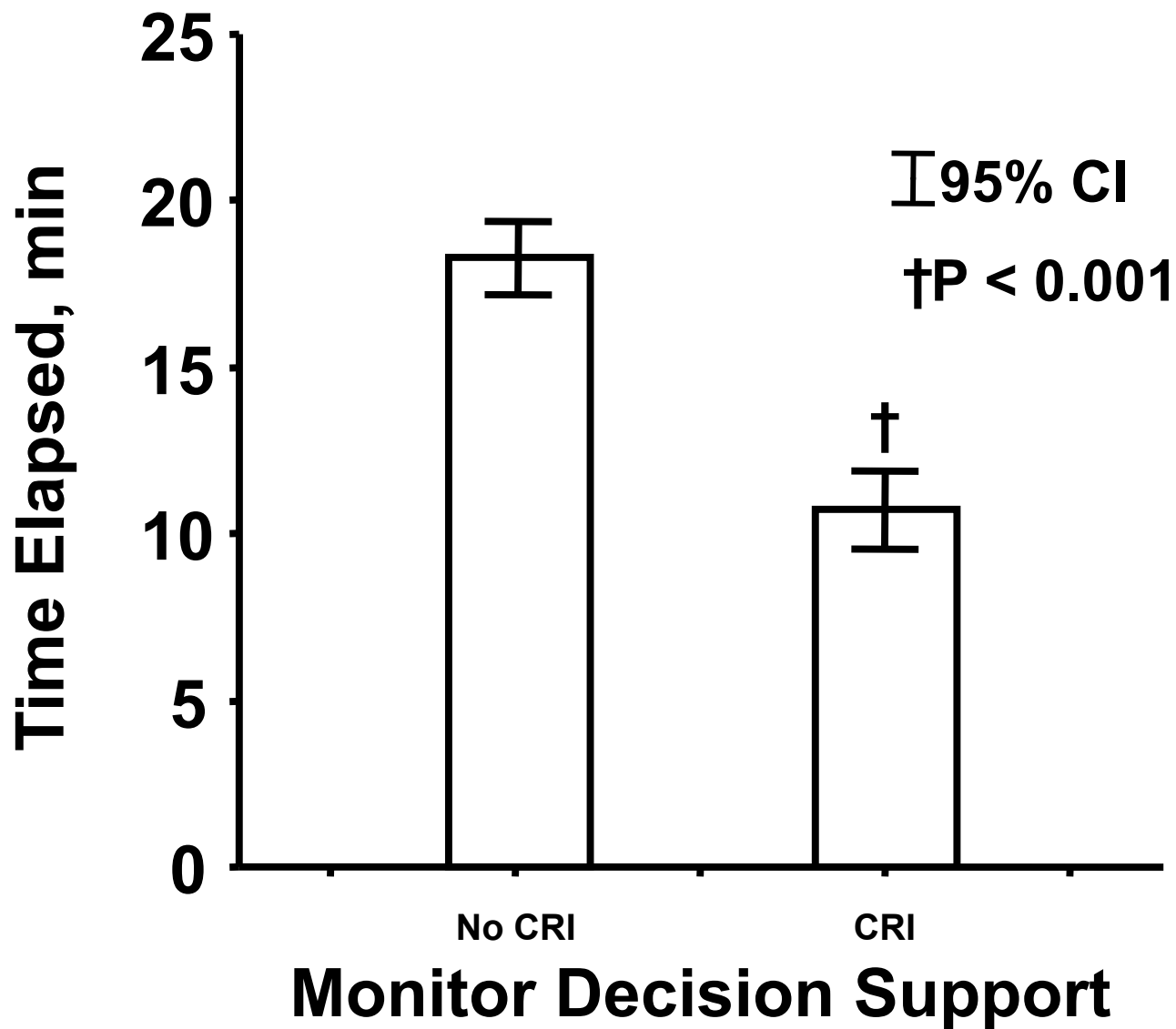
Compensatory Reserve Index (CRI) or 'Fuel Tank' Concept



Video of 'Tracking' CRI

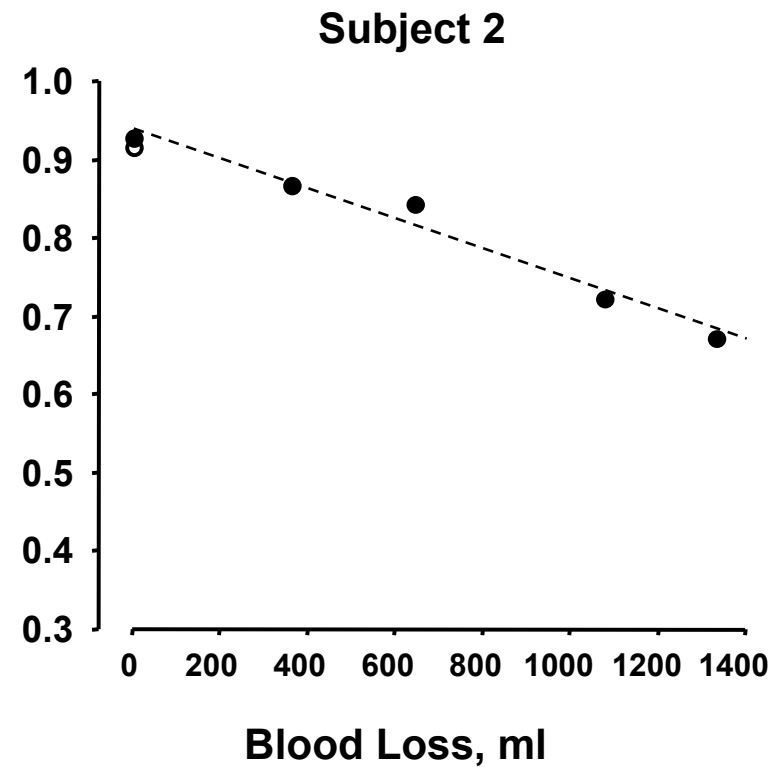
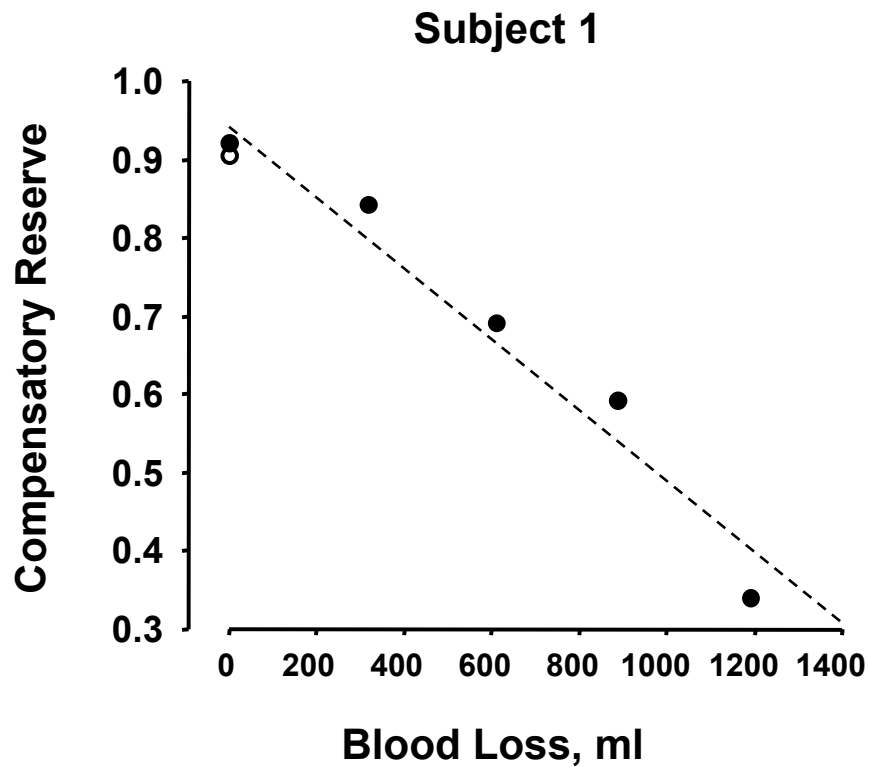


Time to Recognize Unstable Patient

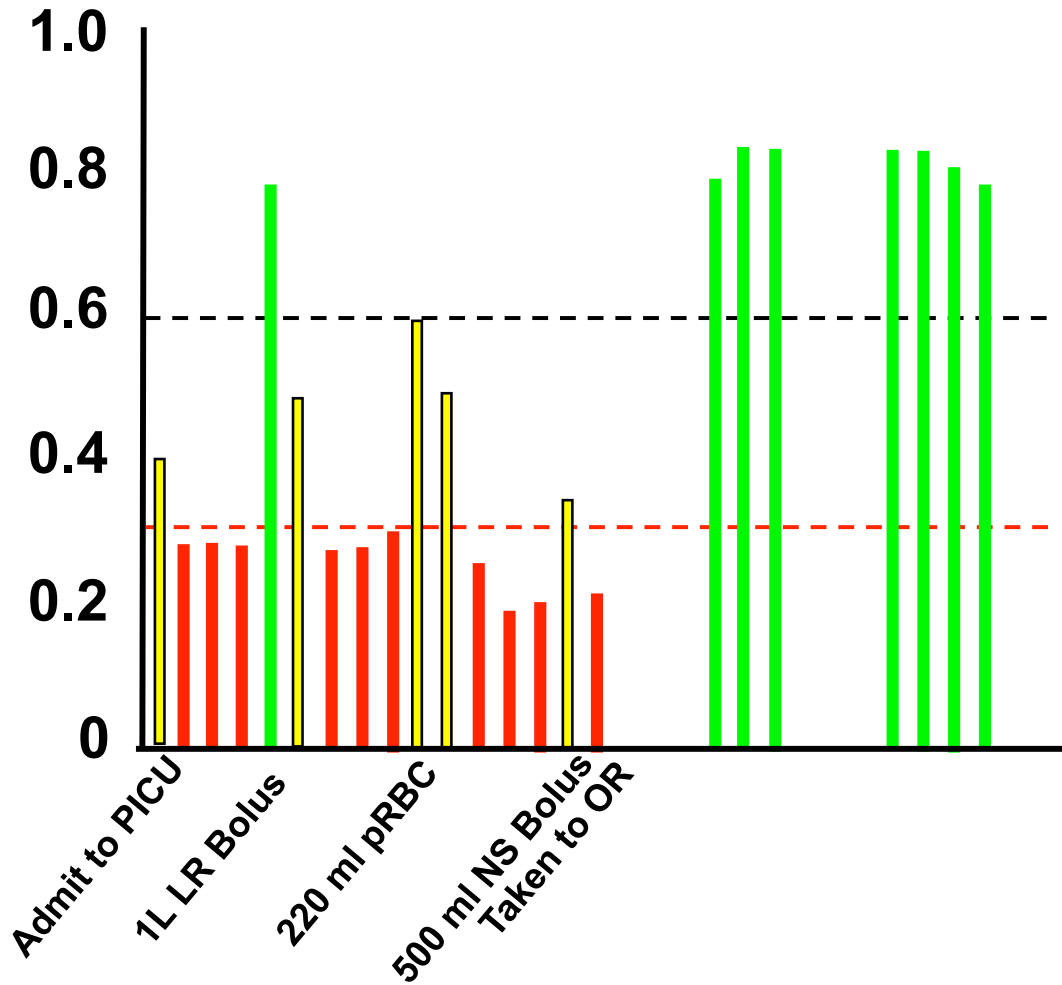


Algorithm Specificity

Blood Withdrawal Model of Hemorrhage



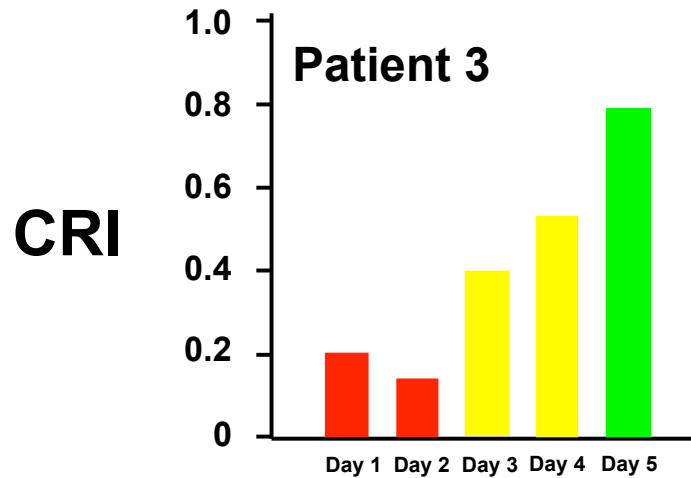
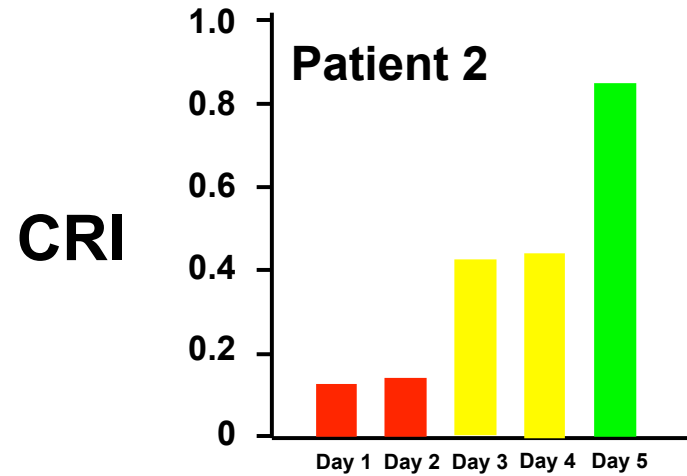
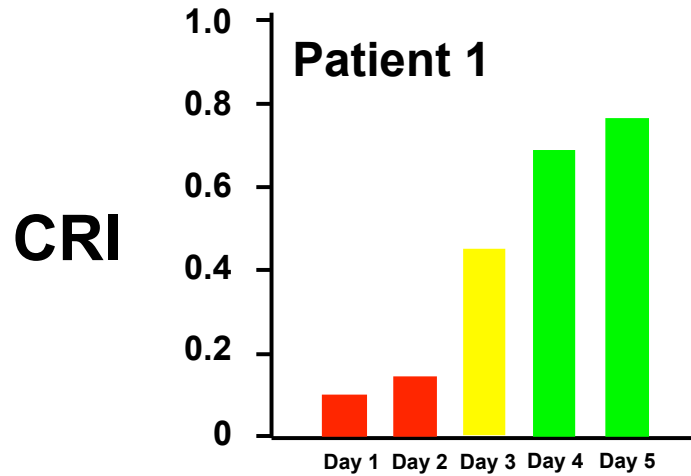
Tracking Patient Status during ICU Care



- Admitted after significant blunt trauma, but CT abdomen negative
- Bowel injury detected ~24 hours after admission, required resection

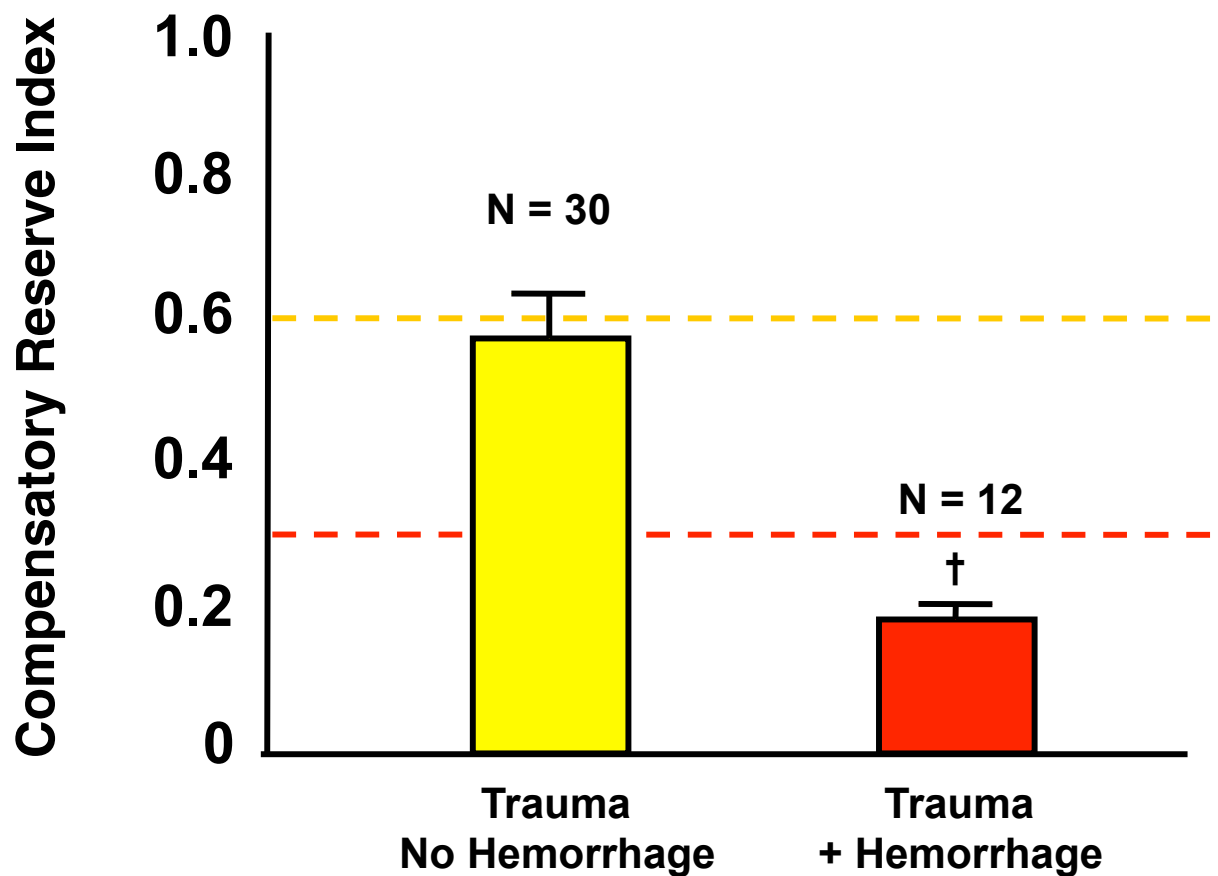
Algorithm Specificity

Dengue Fever Model of Hemorrhage

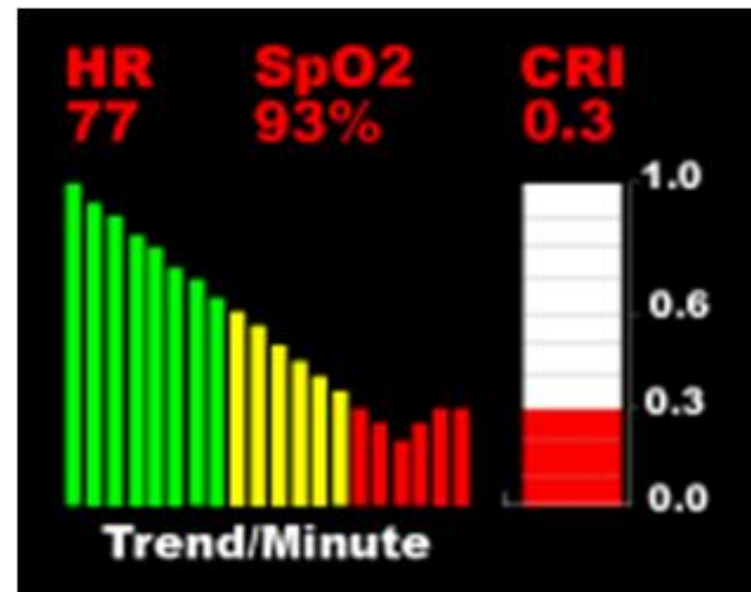


Algorithm Specificity

Tracking Trauma Patient Status



New CRI Monitor Screen



Summary diagnostic new tool benefits

- **Early marker of patient status**
- **Provides time to act**
- **Not just point in time; continuous**
- **Based upon complex physiological relationships (i.e., reserve)**
- **Specific to the individual patient**

**Hemorrhagic Shock =
'Zero' Compensatory Reserve**

Effective Resuscitation =

**Restoration of the
Compensatory Reserve**

Tracking Blood Loss & Resuscitation

