A Closed Loop Resuscitation System Driven by Non-invasive Parameters Restores Perfusion in a Porcine Hemorrhagic Shock Model

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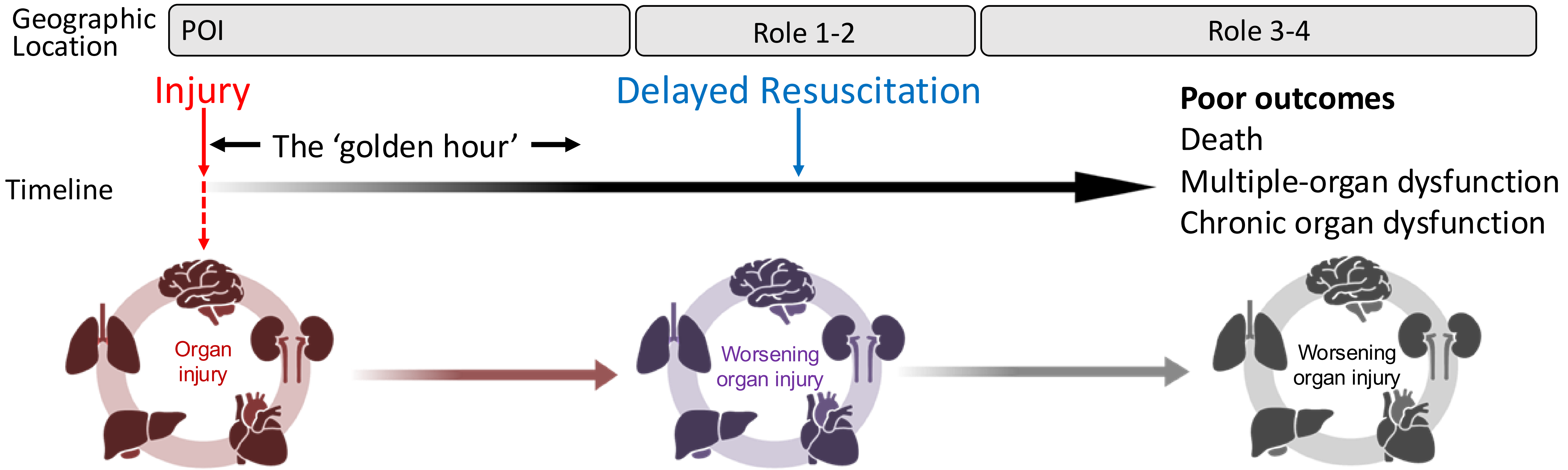
Background

- Of 25% of the combat deaths that are considered preventable, 90% are due to hemorrhage.
- Patients who die from hemorrhage most often do so because resuscitation at the point of injury is impossible and is overall delayed breaching the ‘golden hour’.



Preliminary work

Trauma Care in a Rucksack (TRACIR) - DoW contract W81XWH19C0101

- We developed an autonomous, closed-loop, physiology-based algorithm (**ReFit**: closed Loop **Re**suscitation from shock using **F**unctional hemodynamic mon**it**oring)
- Effective at providing precise resuscitation in a porcine model of severe, compressible and non-compressible hemorrhagic shock, during stationary care and ground and air evacuation using physiologic data from an invasive arterial catheter.

  - Pinsky MR, Gómez H, Wertz A, Leonard J, Dubrawski A, Poropatich R.
    Evaluation of a physiological-driven closed loop resuscitation algorithm.
    CritCareMed. 2024 Dec; 52(12):1-11

  - Pinsky MR, Gomez H, Guyette FX, Weiss L, Dubrawski A, Leonard J, MacLachlan R, Gordon L, Lagattuta T, Salcido D, Poropatich R.
    Autonomous precision resuscitation during ground and air transport of an animal hemorrhagic shock model.
    Intensive Care Med Exp. 2024 May 24;12(1):44

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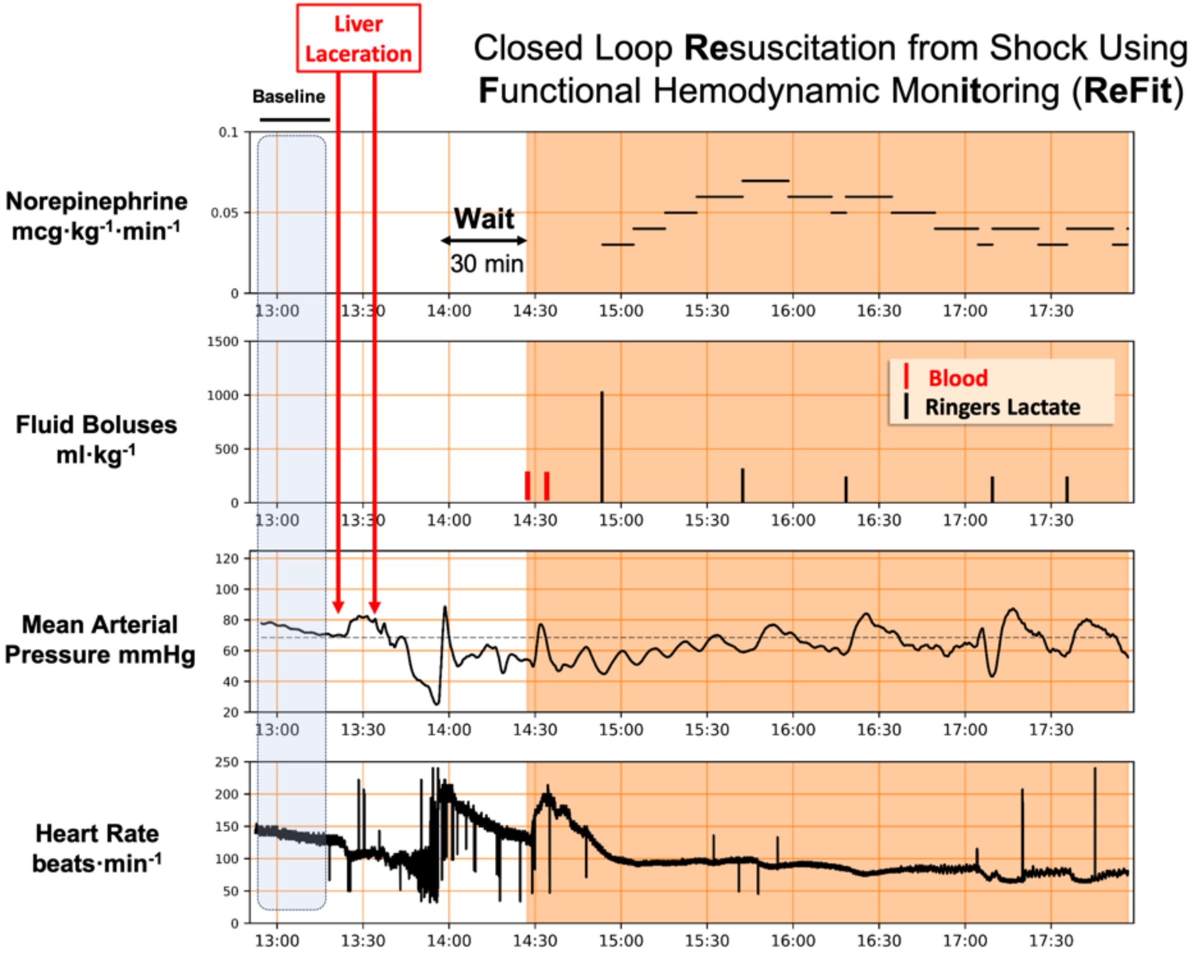
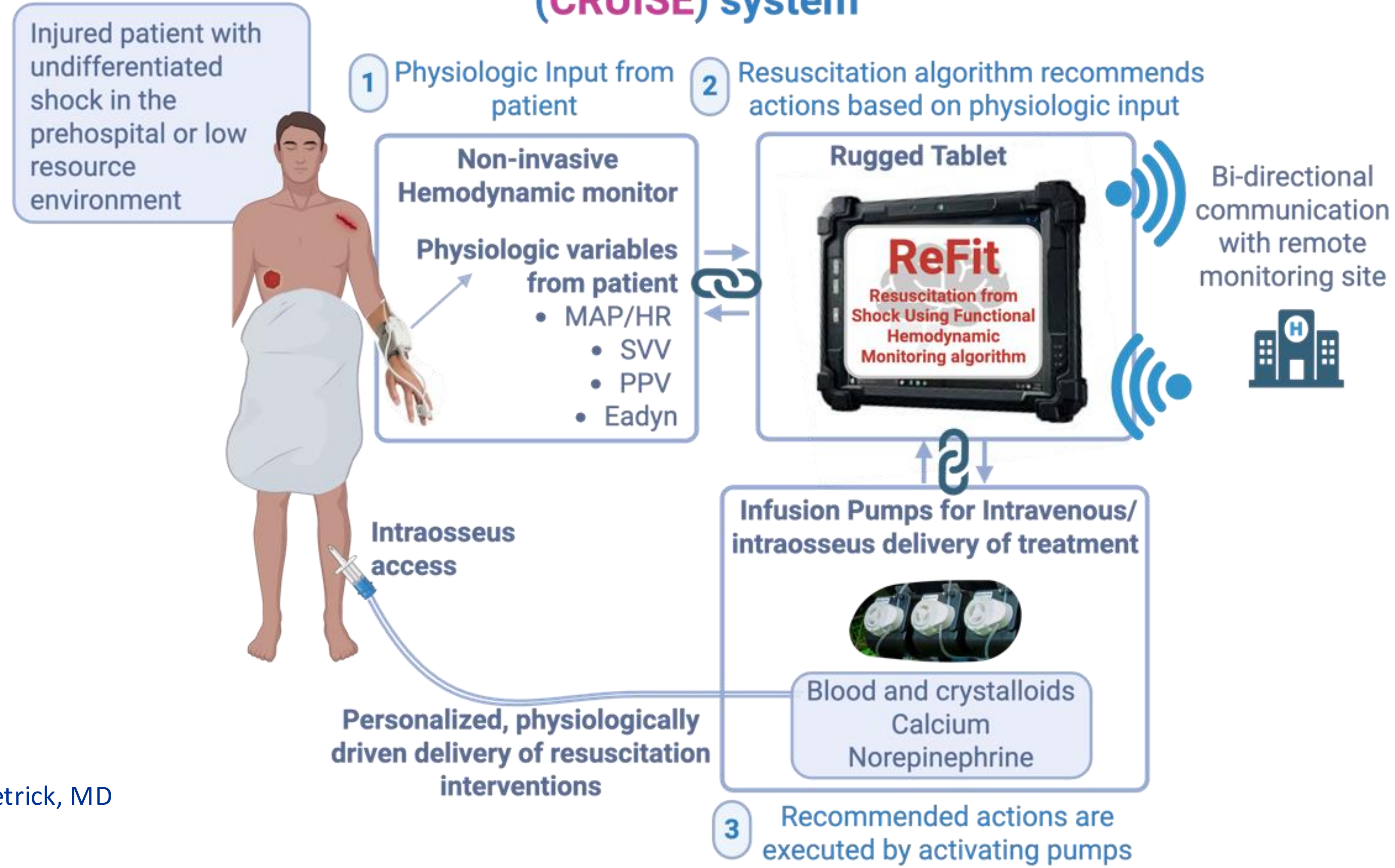
ReFit during air/ground transportation

Effective autonomous resuscitation during air/ground transportation



Pinsky et al. Intensive Care Med Exp. 2024 May 24;12(1):44

Cardiovascular Resuscitation Using Informed CloSEd loop (CRUISE) system



Key capabilities:

- Closed loop resuscitation
- Driven by non-invasive hemodynamic signals
- Portable

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University of Pittsburgh Invention Disclosure No. 07438

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Project Review -aims/deliverables of the CRUISE program

1. Design, develop & test the CRUISE system with the purpose of delivering a Generation 2.0 prototype (TRL6) that operates with inputs from non-invasive hemodynamic monitors & as a closed loop decision support system.
2. Execute a blinded observational proof of principle clinical study & deliver the protocol for a future usability study (NOV 2026) with the 59th MDW, San Antonio, TX
3. FDA Breakthrough Device Designation submission - May 2026; pre-IDE FDA submission to follow
4. Completed a Medical Autonomous Care State of the Science meeting: 16-17 Sept. 2025 in Pittsburgh, PA. (220 attendees: 60 DoD, 60 Industry; 100 Academic)

"The rise of medical autonomous care, a paradigmatic turning point for military and civilian delivery of health care"

J Crit Care. 2026 Jul 8:96:155675.doi:10.1016/j.jcrc.2026.155675.

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Methods

Design

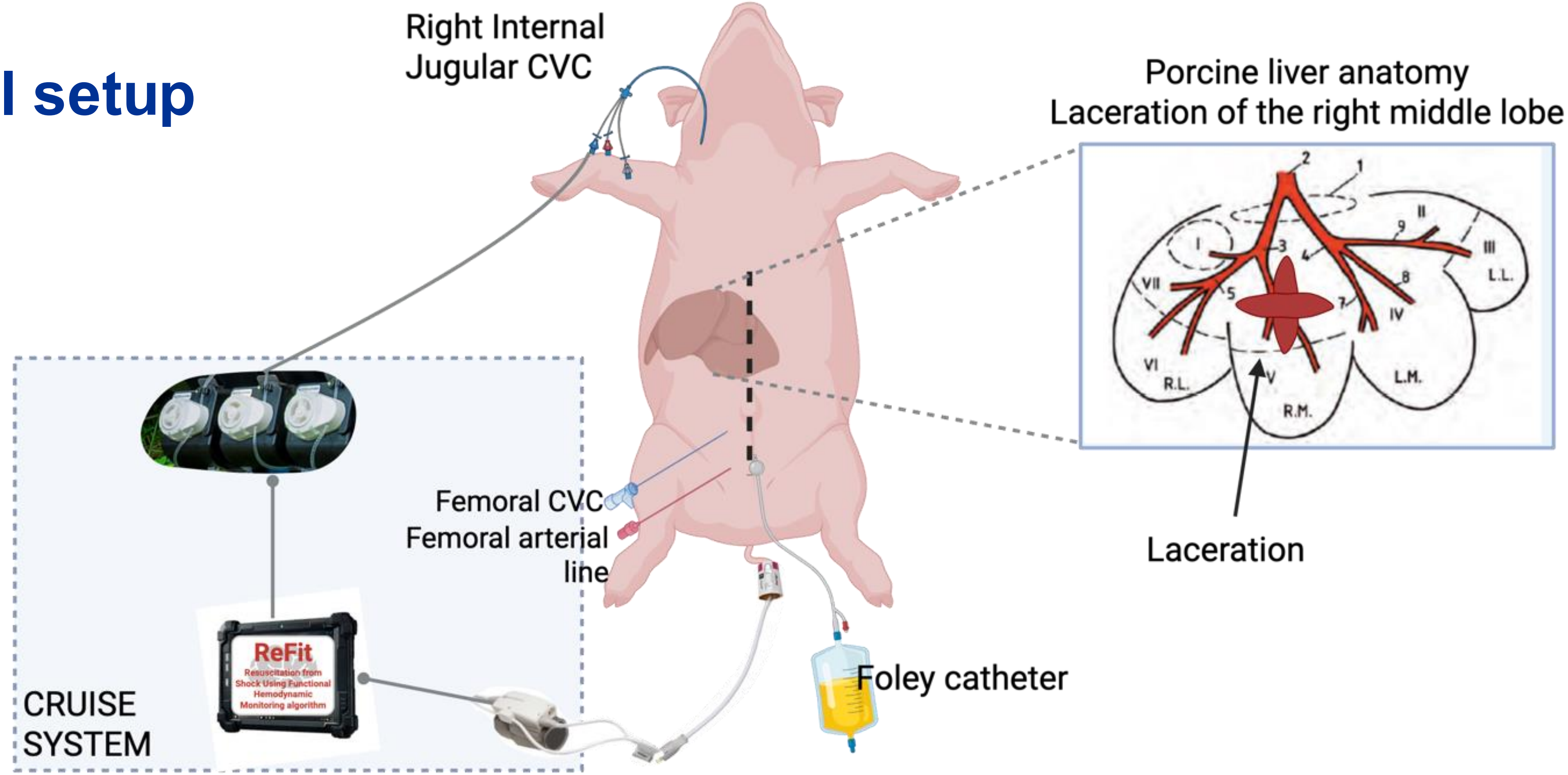
- Prospective, experimental, porcine, non-compressible hemorrhagic shock model.

Objective

- To test whether the CRUISE system can be successfully driven by non-invasively derived physiologic inputs and provide clinically relevant hemodynamic resuscitation.

Methods

Experimental setup



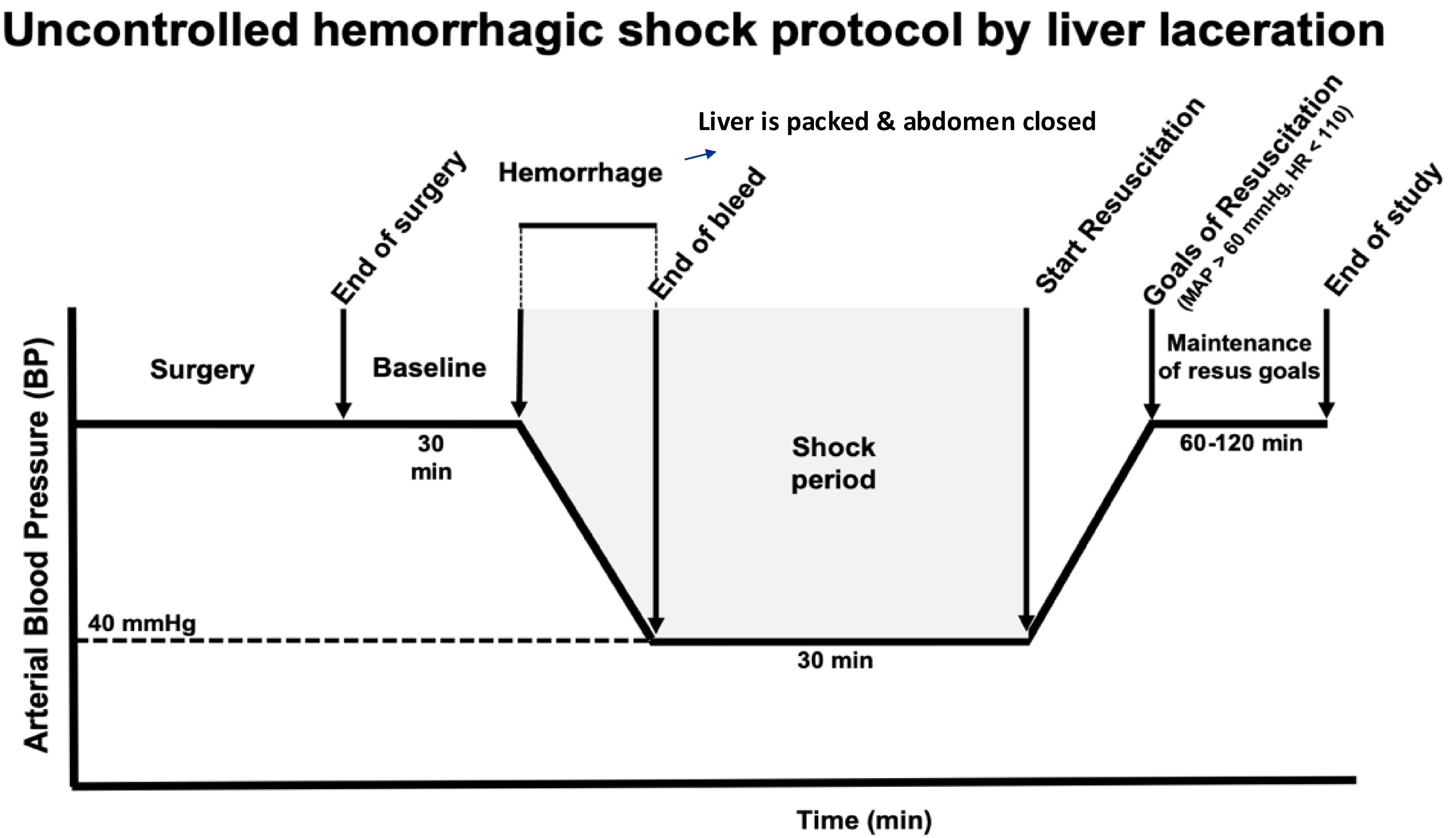
Methods

The CRUISE system operates by iteratively asking and answering the following questions:

1. Is the patient insufficient?
   - MAP < 65%
   - HR > 110 bpm
2. Is the patient volume responsive (SVV or PPV)?
3. Is the arterial load high or low (Eadyn)?

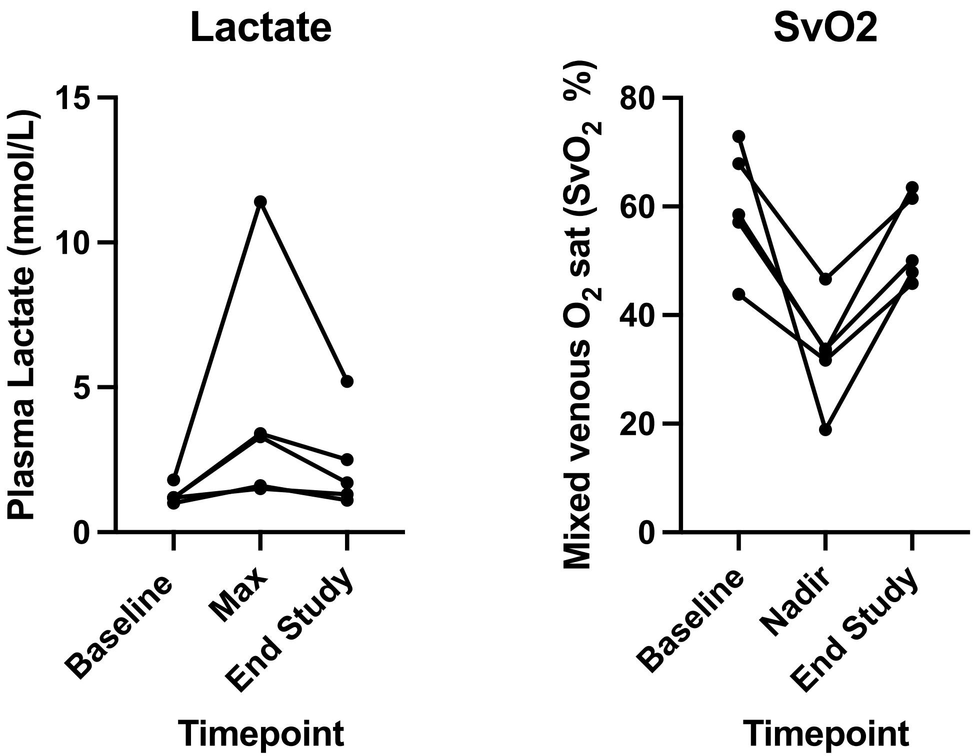
Backup Algorithm
When no signal is detected from the non-invasive hemodynamic monitor (e.g., during severe hypotension), the Backup algorithm is triggered which provides fluids and vasopressors until signals return. Once signals return, the system defaults back to CRUSIE.

Experimental setup



Results

- All animals were successfully resuscitated
- Hemodynamic goals were achieved in times comparable to previous invasive studies (46.5 ± 20.3 min vs. invasive 52 ± 12 min from prior publication).
- Tissue perfusion improved:
  - Decreased lactate (Max lactate 4.2 ± 4.1 vs. end of study lactate 2.3 ± 1.6 mmol/L)
  - Increased mixed venous oxygen saturation (min SvO2 32.9 ± 9.8% vs. end of study SvO2 53.7 ± 8.1).



Results

- The backup algorithm triggered in all animals (8.6 ± 6.2 minutes post-laceration).
- The backup algorithm maintained resuscitation and increased perfusion until signals returned.
- MAP and SVV non-invasive signals were present 94 ± 3% and 93 ± 3% of all resuscitation time, respectively.
- Resource utilization was similar to invasive models: fluid (1349 ± 304 mL), blood (329 ± 119 mL) and norepinephrine (115 ± 119 mcg).

Conclusion

- CRUISE effectively diagnoses and treats severe hemorrhagic shock using non-invasive signals.
- The backup algorithm ensures continuous resuscitation during signal gaps, which is critical for use in austere environments where invasive monitoring is unavailable.

Questions?

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