

Background

- Hemorrhage is associated with greater than 90% of potentially survivable deaths on the battlefield¹
- Non-compressible Torso Hemorrhage (NCTH) makes up the majority of these deaths.
- Current treatments for NCTH are limited
- Resuscitative Endovascular Balloon Occlusion of the Aorta (REBOA) has shown some success as a hemostatic adjunct²
- Zone 1 (Thoracic) REBOA provides more resuscitative support, but produces more ischemic damage than Zone 3 (infrarenal) REBOA³

Hypothesis

Following arterial injury and hemorrhagic shock, transitioning from Zone 3 REBOA to Zone 1 will prevent cardiovascular collapse in the presence of ongoing venous hemorrhage.

Methods

- Yorkshire swine (70-90kg) were anesthetized, instrumented, and splenectomized
- Uncontrolled hemorrhage was induced via 6 mm arteriotomy in the right femoral artery
- Concurrently, blood was removed from the left femoral vein at a rate of 0.3mL/kg/min to stimulate occult venous bleeding
- After a 45 sec bleed, wound was treated with QuikClot Combat Gauze and the artery ligated
- REBOA balloon was inflated at Zone 3; 500 mL of Hextend administered
- When MAP < 30 mmHg, randomization to Zone 1 or remain in Zone 3
- After 30 minutes, discontinue bleed and deflate REBOA

Overview

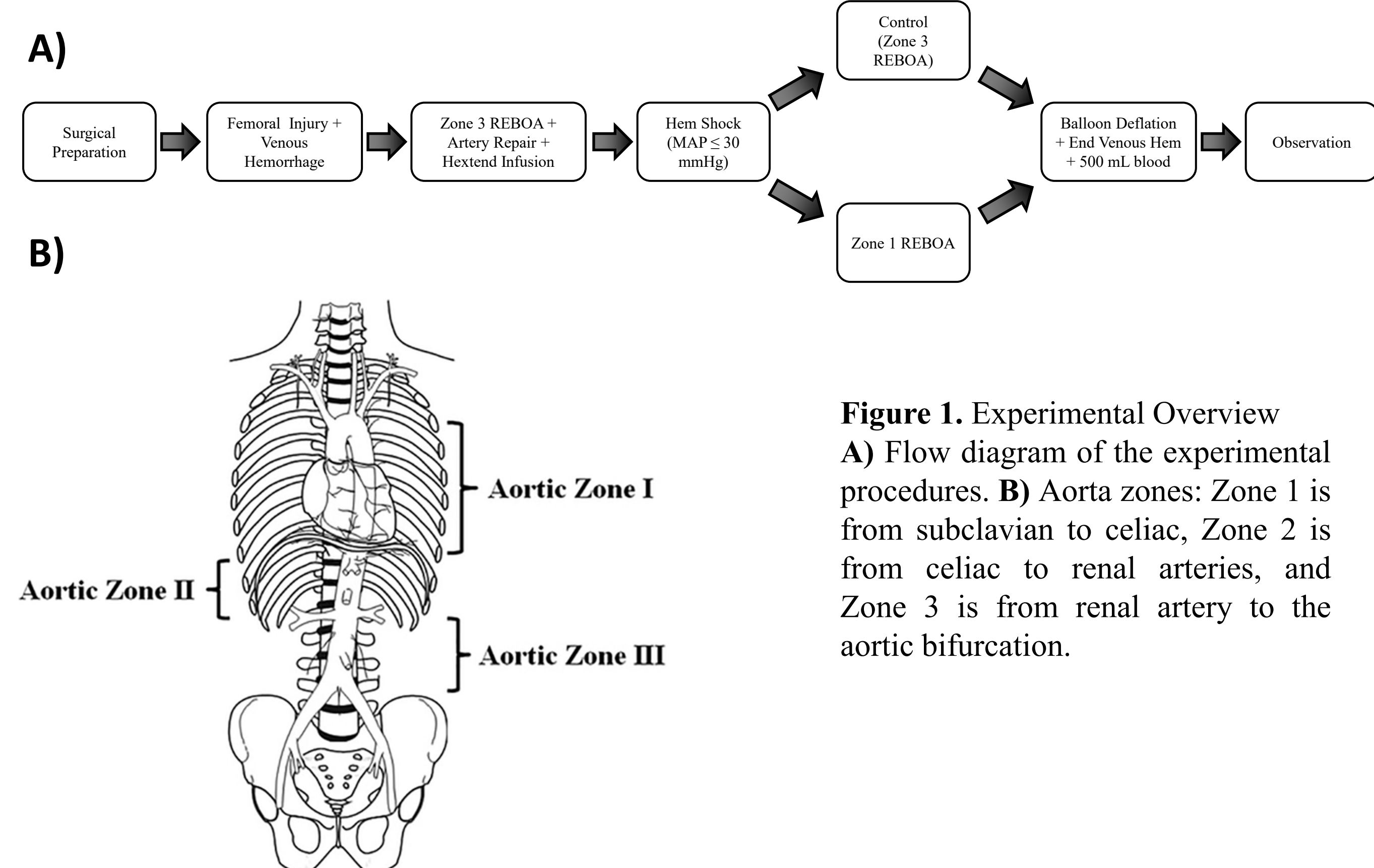


Figure 1. Experimental Overview
A) Flow diagram of the experimental procedures. **B)** Aorta zones: Zone 1 is from subclavian to celiac, Zone 2 is from celiac to renal arteries, and Zone 3 is from renal artery to the aortic bifurcation.

Results

Table 1. Baseline, Injury, and T₀ values

	Zone 3 (n=6)	Zone 1 (n=6)	p-value
Weight (kgs)	74.8 ± 4.8	75.8 ± 4.8	0.726
Length (cm)	158 ± 7	160 ± 8	0.757
MAP (mmHg)	67.2 ± 5.9	65.0 ± 5.0	0.509
EtCO ₂ (mmHg)	42.3 ± 1.9	44 ± 1.9	0.159
Potassium (mmol/L)	3.9 ± 0.4	3.9 ± 0.2	0.919
Lactate (mmol/L)	1.9 ± 0.8	1.7 ± 0.6	0.566
After Arterial Injury			
Blood Loss (% EBV)	28.2 ± 7.2	31.1 ± 8.2	0.532
MAP (mmHg)	38.2 ± 9.5	32.8 ± 10.4	0.376
EtCO ₂ (mmHg)	36.0 ± 1.3	37.2 ± 5.9	0.647
Potassium (mmol/L)	3.7 ± 0.3	3.8 ± 0.2	0.489
Lactate (mmol/L)	2.2 ± 0.6	2.1 ± 1.0	0.868
At T₀, MAP = 30 mmHg			
Venous Blood Loss (% EBV)	48 ± 15	41 ± 4.6	0.299
Time After Artery Injury (min)	90 ± 29	81 ± 20	0.554
MAP (mmHg)	28.8 ± 1.3	29.5 ± 1.6	0.458
EtCO ₂ (mmHg)	31.5 ± 3.0	33.5 ± 6.3	0.498
Potassium (mmol/L)	6.2 ± 2.3	6.0 ± 1.1	0.811
Lactate (mmol/L)	5.8 ± 3.6	6.4 ± 4.4	0.795

MAP, Mean Arterial Pressure; EBV, Estimated Blood Volume; EtCO₂, End-Tidal CO₂

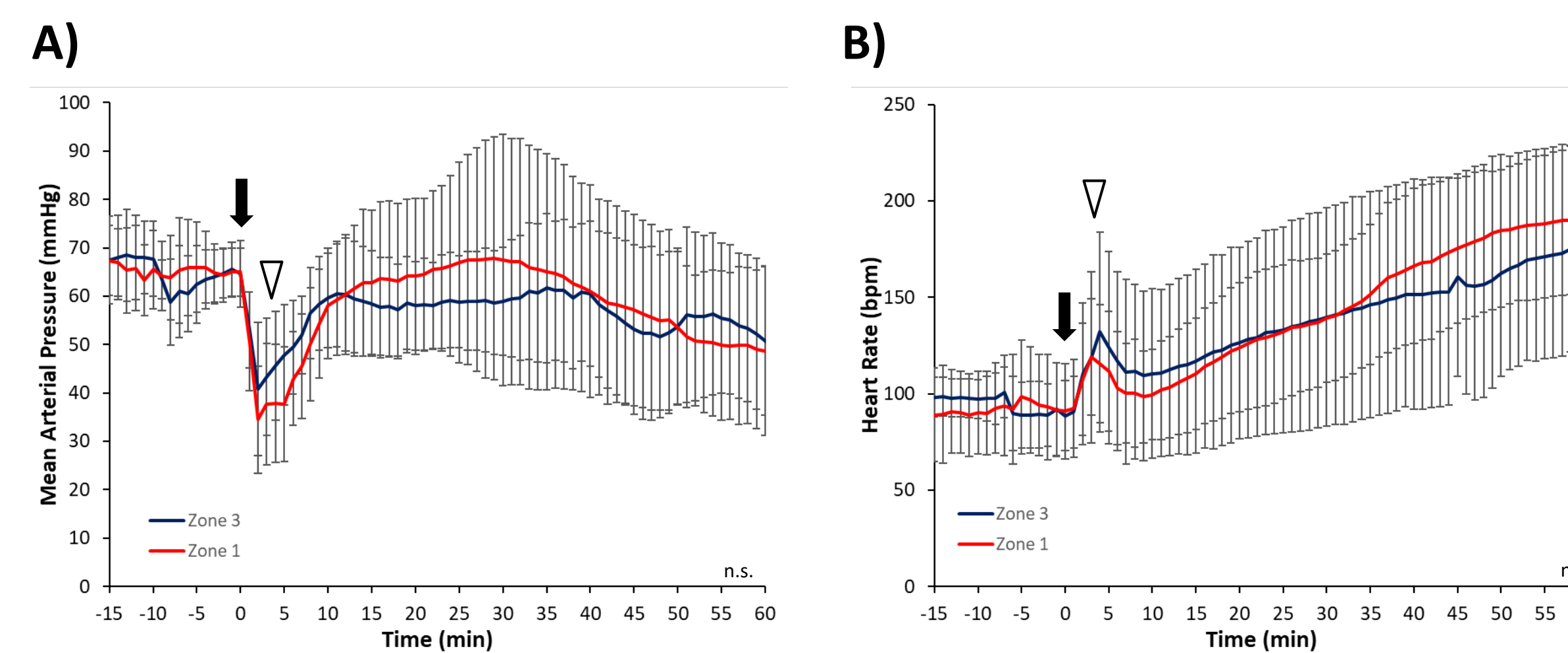


Figure 4. Arterial Injury Hemodynamics. **A)** Mean arterial pressure measured at carotid. **B)** Heart Rate. Arrow indicates femoral artery injury. Arrowhead shows Zone 3 REBOA inflation and start of Hextend Infusion (500 mL)

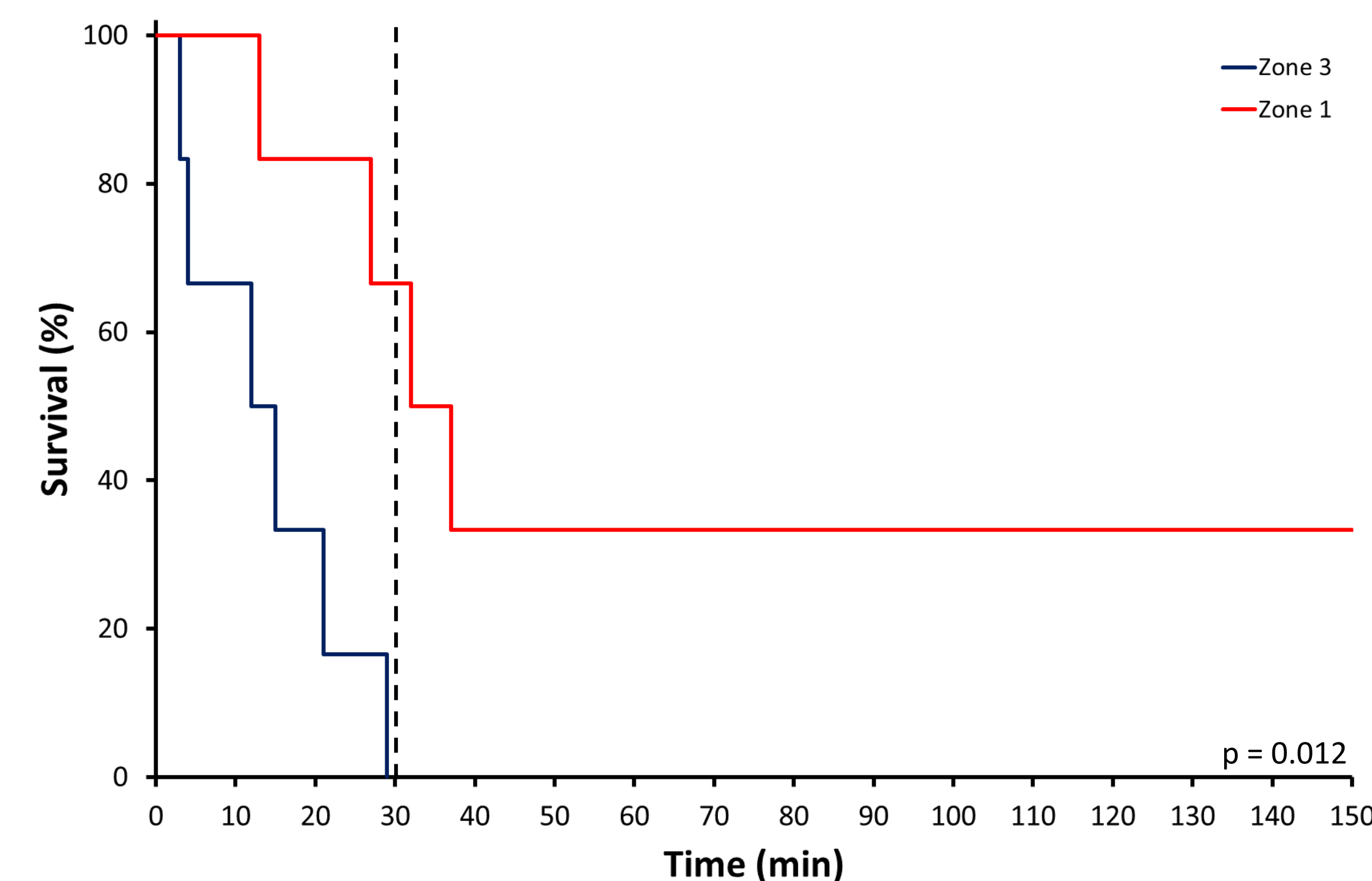


Figure 3. Kaplan – Meier Survival Curve. T₀ is when MAP reaches 30 mmHg. Dotted line (T₃₀) represents end of controlled hemorrhage and balloon deflation. Groups compared using log-ranks analysis.

Results

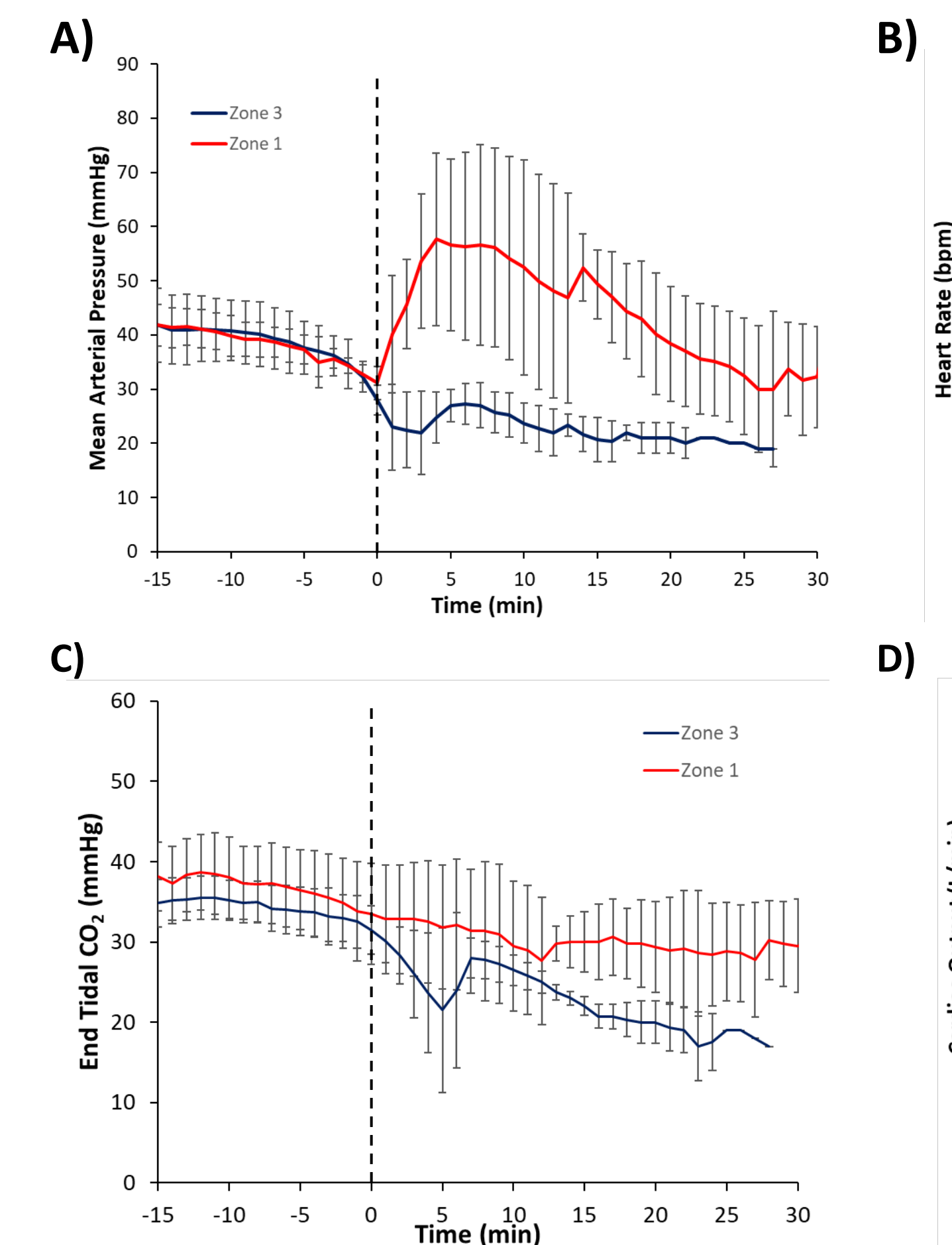


Figure 4. Hemodynamics. **A)** Mean arterial pressure measured at carotid. **B)** Heart Rate. **C)** End Tidal CO₂. **D)** Cardiac Output measured by a pulmonary artery catheter. Arrow indicates femoral artery injury. Arrowhead shows Zone 3 REBOA inflation and start of Hextend Infusion (500 mL) to Zone 1 if selected (T₀)

Conclusion

- Transition to Zone 1 conferred a survival advantage over Zone 3 in this model of hemorrhagic shock
- Hemodynamic results show resuscitative support during Zone 3 REBOA and Zone 1 REBOA could not be performed
- A comparison of post-deflation physiology between Zone 3 REBOA and Zone 1 REBOA could not be performed
- Future studies should reflect different

References

1. Eastridge BJ, Mabry RL, Seguin P, et al. Death on the battlefield—improving casualty care. *J Trauma Acute Care Surg.* 2012;73:s431-s437.
2. Granieri S, Frassini S, Cimbanassi S, et al. Impact of resuscitative endovascular balloon occlusion of the aorta in traumatic abdominal and pelvic exsanguination: a systematic review. *J Trauma Acute Care Surg.* 2022. Mar 20
3. Stannard A, Eliason JL, Rasmussen TE. Resuscitative Endovascular Balloon Occlusion of the Aorta for Hemorrhagic Shock. *J Trauma* 2011; 71(6): 1869-72

Acknowledgments

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Disclaimer

The views expressed here are those of the authors and do not necessarily represent those of the Department of the Defense or its components. The experiments reported here were conducted in accordance with the principles set forth in the National Institute of Health Publication 11-14849 Rev. 08-2011 and the Animal Welfare Act of 1966, as amended.