

Extracorporeal Potassium and Lactate Removal: Why this will Matter in LSCO?

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AUTONOMOUS REANIMATION AND



EVACUATION RESEARCH PROGRAM

THE GENEVA FOUNDATION

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- Work involving animals was conducted in compliance with the Animal Welfare Act, the implementing Animal Welfare Regulations, and the principles of the Guide for the Care and Use of Laboratory Animals
- In conducting research using animals, the investigator(s) adhere to the laws of the United States and regulations of the Department of Agriculture



[Mil Med.](#) 2017 Nov;182(11):e2046-e2051. doi: 10.7205/MILMED-D-17-00119.

Hyperkalemia in Combat Casualties: Implications for Delayed Evacuation.

[Stewart IJ](#)¹, [Snow BD](#)², [Clemens MS](#)³, [Sosnov JA](#)³, [Ross JD](#)⁴, [Howard JT](#)⁵, [Chung KK](#)⁶.

- Hyperkalemia independently associated with acute kidney injury and mortality

Resuscitative Hyperkalemia in Noncrush Trauma: A Prospective, Observational Study

Robert M. Perkins,^{*,†} Matthew C. Aboudara,^{*} Kevin C. Abbott,^{*,†} and John B. Holcomb[‡]

^{}Department of Internal Medicine, [†]Nephrology Service, Walter Reed Army Medical Center, Washington, DC; and [‡]US Army Institute of Surgical Research, San Antonio, Texas*

- 131 trauma patients; 29% had hyperkalemia at 12 hours after admission

- Prolonged tourniquet use leads to toxic shock syndrome upon release of the tourniquet
 - Also known as ischemic reperfusion injury

Mitigation strategies should be developed to treat hyperkalemia in combat casualties



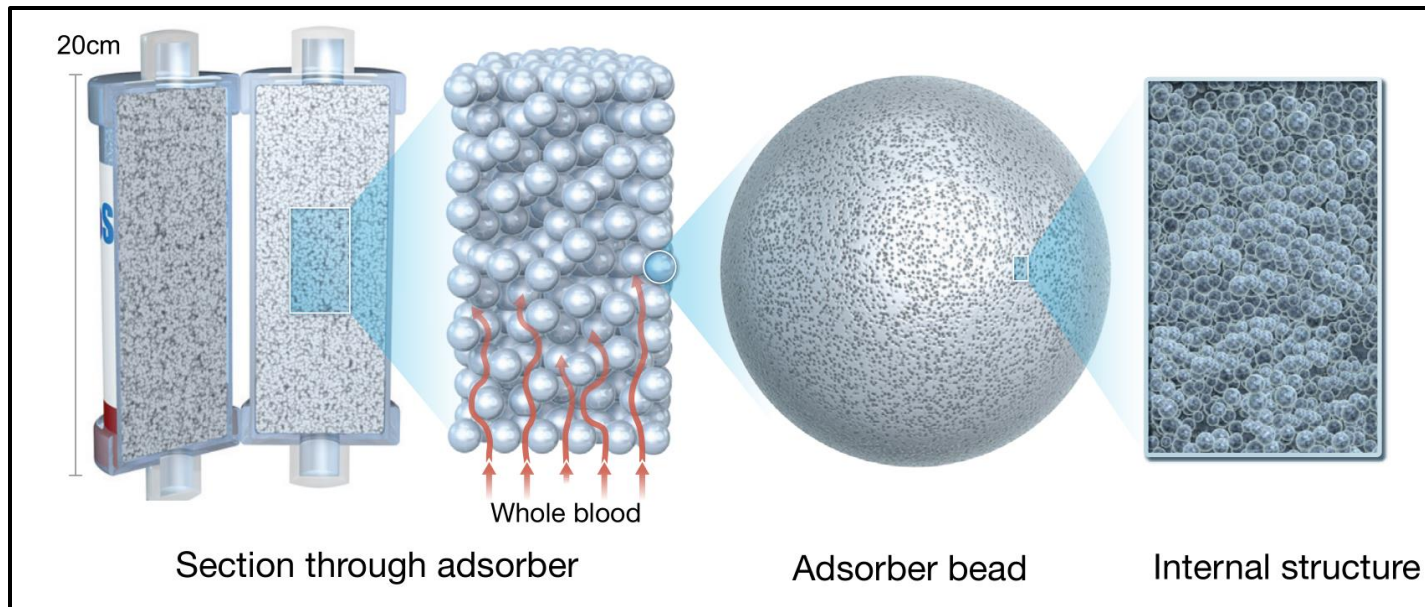
Correlation of serial blood lactate levels to organ failure and mortality after trauma

Panagiotis Manikis MD, Stanislaw Jankowski (Frcs, Mrcp), Haibo Zhang MD, Robert J Kahn MD, Jean-Louis Vincent MD, PhD 

- High lactate levels and duration of hyperlactemia are correlated with organ failure
 - Average lactate 4.1 mmol/L [0.7–12.7] in subjects with organ failure
- Importance of initial resuscitation to prevent organ failure
- Fluid resuscitation requires lots of time, attention, materials

Current battlefield situation in Ukraine renders resuscitation unfeasible or severely delayed

BACKGROUND: Prototype Description



- CytoSorbents Corporation Damage Control Renal Replacement Therapy
- K+ontrol
- Resin adsorbing material that removes ions from fluid



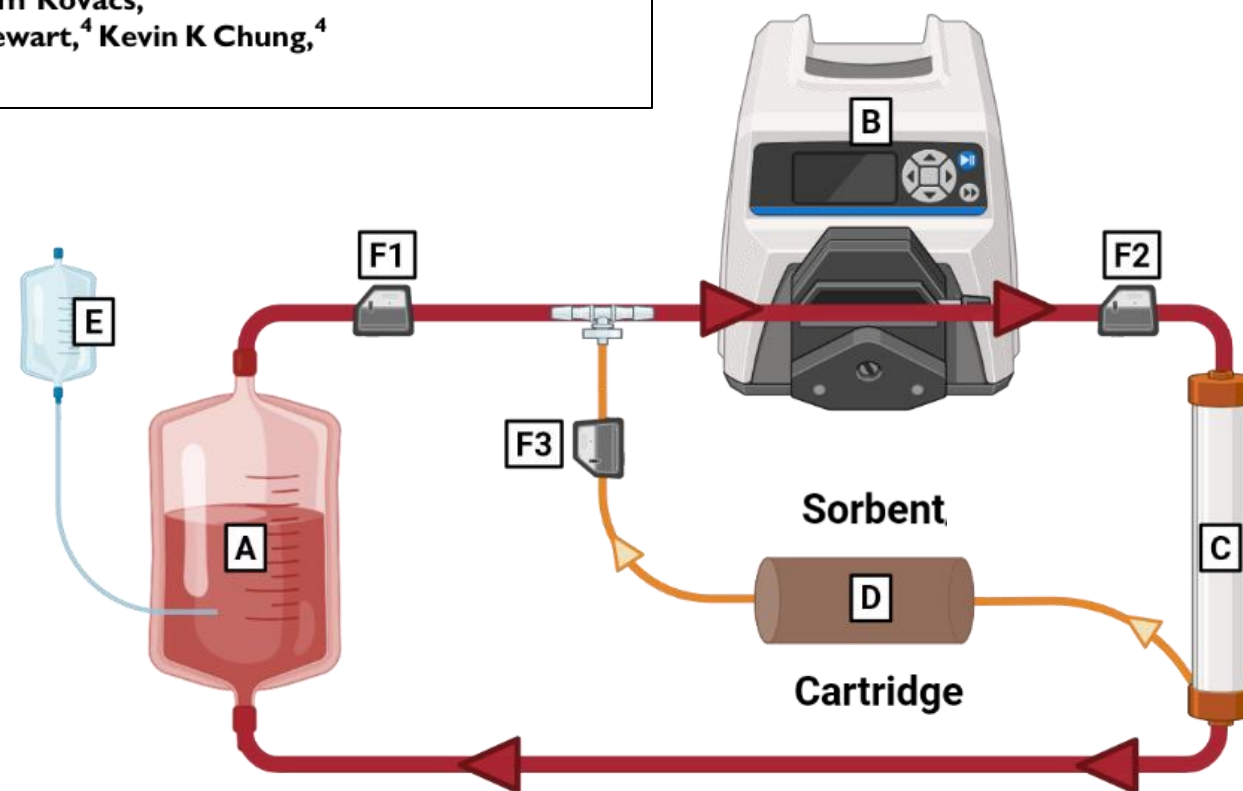


K⁺ontrol rapidly and efficiently reduces potassium in donor blood during ex vivo circulation

George T Harea,¹  Marianne Thrailkill,¹ Isabella Garcia,¹
Brendan M Beely,^{1,2} Daniel S Wendorff,^{1,2} Teryn R Roberts,^{1,2} 
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- **Development of Circulation Platform**
- Circuit consists of:
 - Blood storage container (A)
 - Tubing
 - Peristaltic pump (B) to create a primary blood circulation loop
 - Hemodialysis membrane (C)
 - Flow Meters (F1-F3)



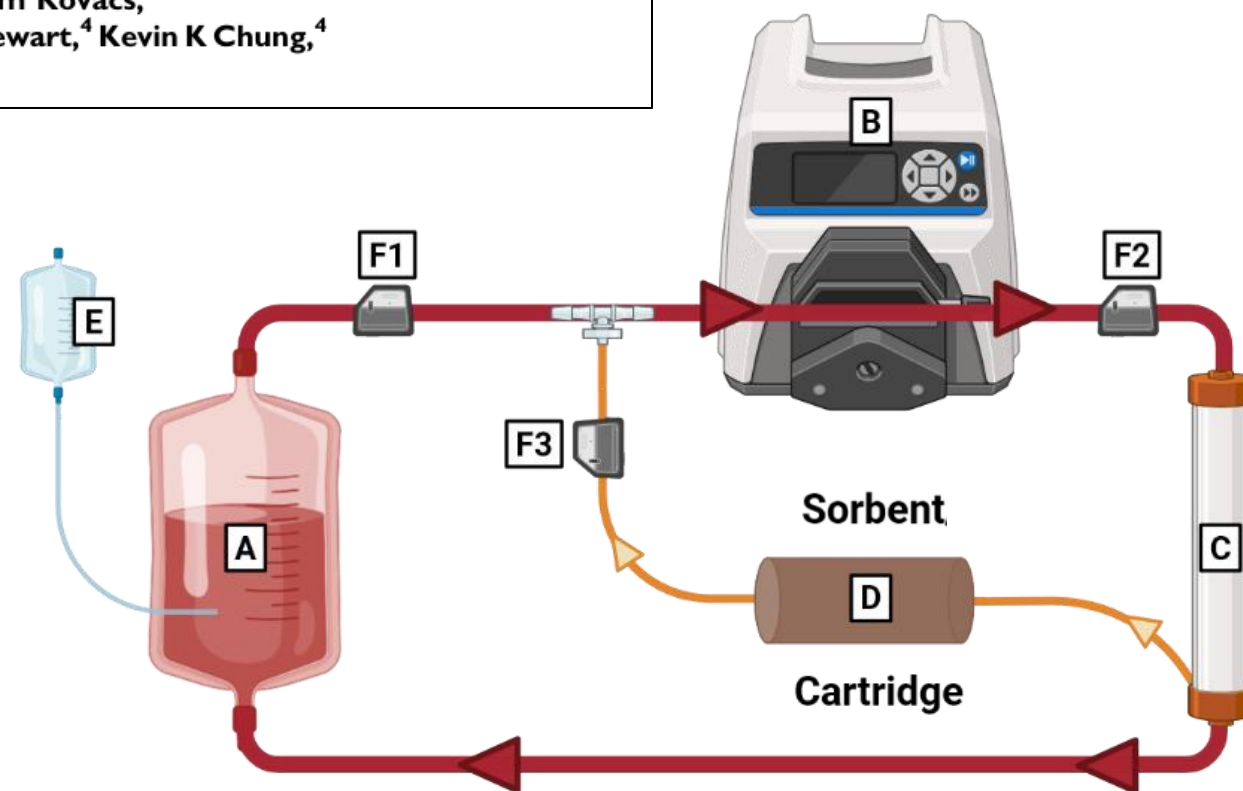


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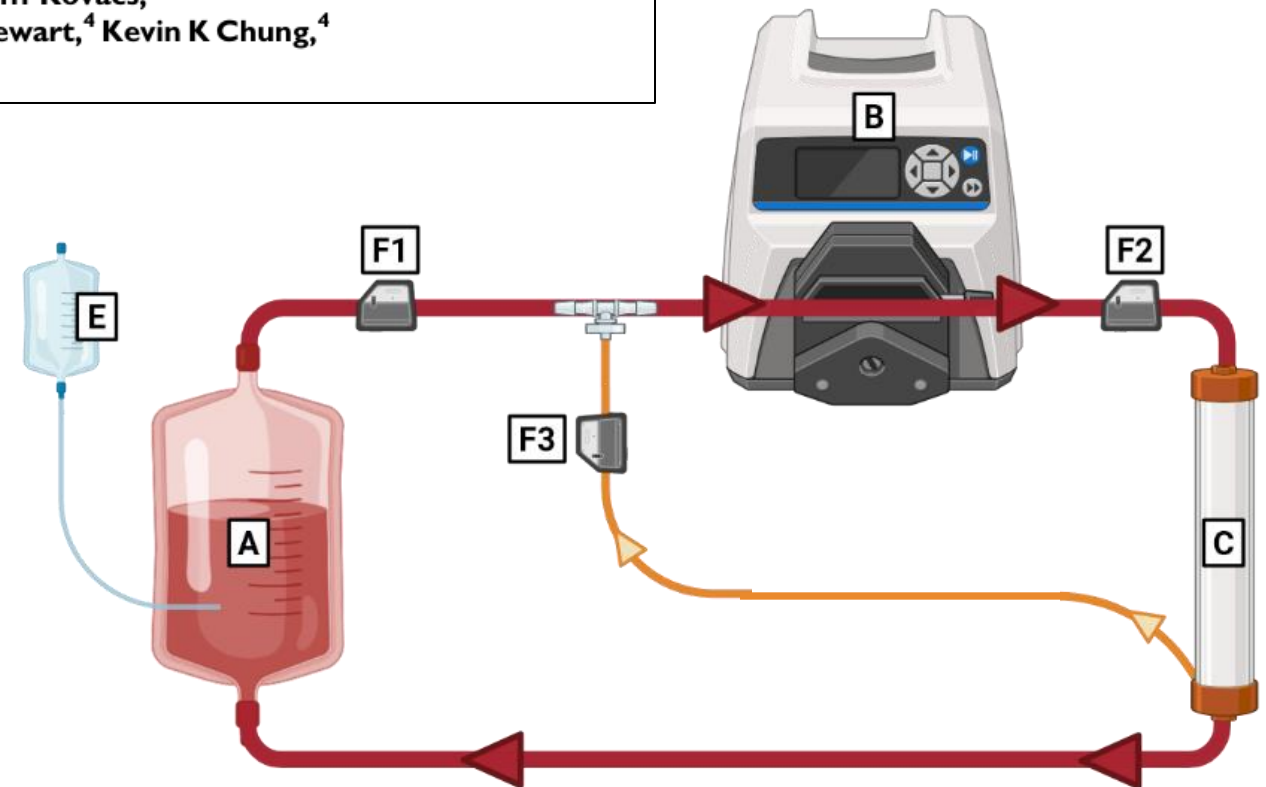


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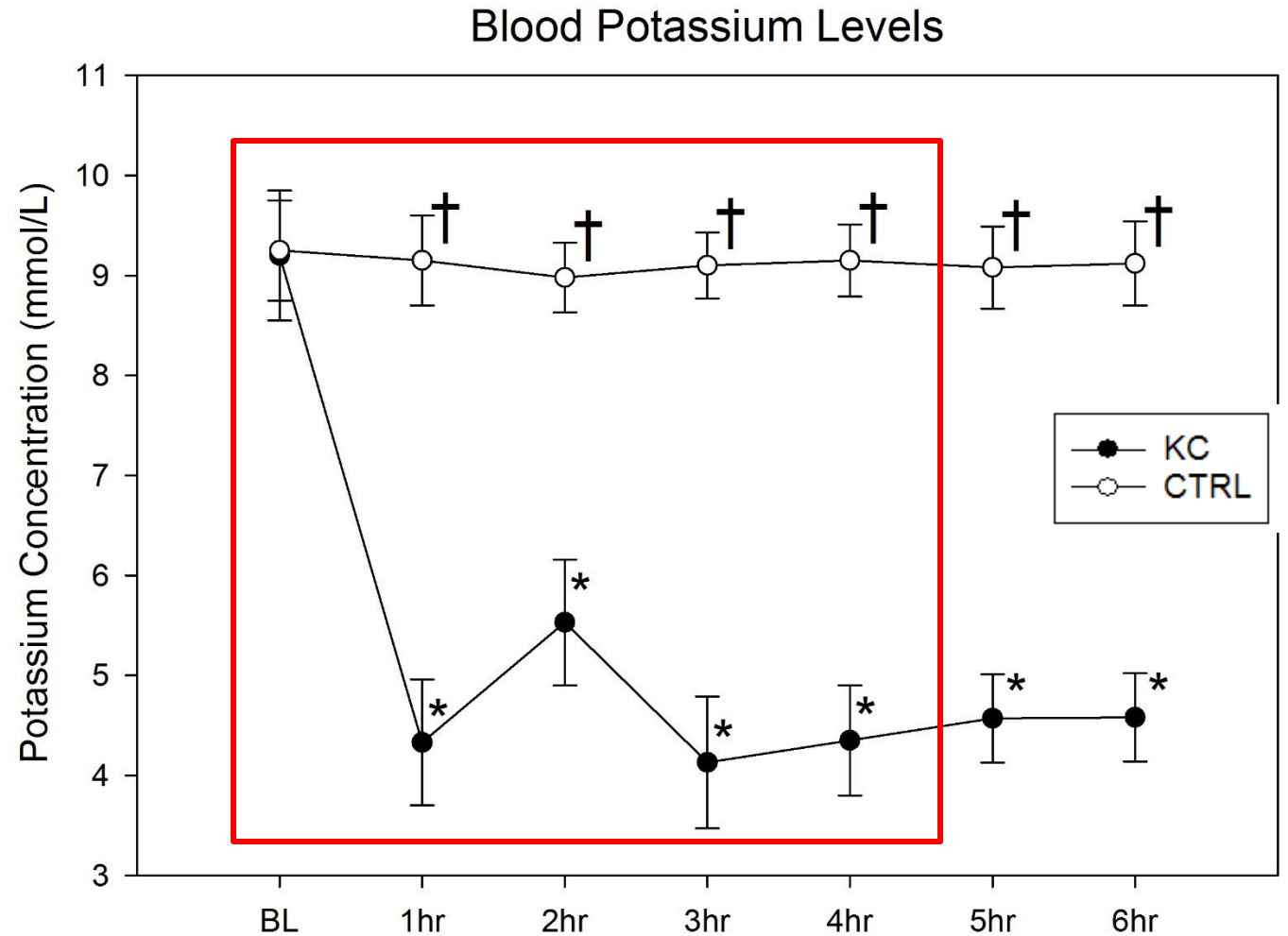
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- Control Group: K⁺ remained constant (~9 mmol/L)
- Treat group, observed K⁺ decrease to 4 mmol/L at 1 hour
- 50% decrease in K⁺ concentration

* denotes a statistical difference between BL and the hourly timepoint for the Control group,
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- Heparin administered to prevent clotting
- ACT maintained at 999 seconds

	Group	BL	1hr	2hr	3hr	4hr	5hr	6hr
Activated Clotting Time (secs)	Treat	968.3 ± 30.7	999 ± 0	940.8 ± 58.2	911 ± 80.8	999 ± 0	999 ± 0	904.5 ± 94.5
	Ctrl	999 ± 0	999 ± 0	999 ± 0	999 ± 0	973.8 ± 25.2	999 ± 0	999 ± 0
pH	Treat	7.31 ± 0.09	7.17 ± 0.07 *	7.11 ± 0.07 *	7.09 ± 0.08 *	7.06 ± 0.07 *	7.05 ± 0.07 *	7.02 ± 0.07 *
	Ctrl	7.31 ± 0.09	7.27 ± 0.08 **	7.24 ± 0.07 **	7.2 ± 0.07 **	7.17 ± 0.06 **	7.15 ± 0.06 **	7.13 ± 0.06 **
pCO₂ (mmHg)	Treat	44 ± 18.4	45.2 ± 17	48.5 ± 17.4 *	49.3 ± 17.1	50.8 ± 16.8 *	52.3 ± 16.5 *	55 ± 16.3 *
	Ctrl	28.7 ± 4.8	30.9 ± 5.3	33.2 ± 5.7	36.2 ± 6.7	37.8 ± 6.4	40.5 ± 7.3	42.2 ± 7.7
pO₂ (mmHg)	Treat	132.5 ± 27.8	105.8 ± 19.9 *	90.2 ± 15.4 *	76.7 ± 11.6 *	67.8 ± 8.5 *	61 ± 6.5 *	57.7 ± 6.3 *
	Ctrl	114.7 ± 29.8	92.8 ± 22 **	77.2 ± 16.2 **	67.7 ± 13.3 **	61.8 ± 11.4 **	56.5 ± 10.5 **	53.5 ± 9.9 **
Potassium (mmol/L)	Treat	9.2 ± 0.7	4.3 ± 0.6 *	5.5 ± 0.6 *	4.1 ± 0.7 *	4.4 ± 0.6 *	4.6 ± 0.4 *	4.6 ± 0.4 *
	Ctrl	9.3 ± 0.5	9.2 ± 0.5 †	9 ± 0.4 †	9.1 ± 0.3 †	9.2 ± 0.4 †	9.1 ± 0.4 †	9.1 ± 0.4 †
Plasma Free Hemoglobin (mg/dL)	Treat	80 ± 20.7	74 ± 21.8	73.3 ± 17.8	90 ± 15.1	95 ± 12.3 **	100 ± 12.1 **	110 ± 11.8 **
	Ctrl	90 ± 40.2	74 ± 14	92.5 ± 29.5	110 ± 33.9 *	127.5 ± 37.7 *	145 ± 49.1 *	157.5 ± 57.9 *

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- pH decreased in both groups starting at hour 1

No gas exchange =

Increase in pCO₂ =

Increased acidity

	Group	BL	1hr	2hr	3hr	4hr	5hr	6hr
Activated Clotting Time (secs)	Treat	968.3 ± 30.7	999 ± 0	940.8 ± 58.2	911 ± 80.8	999 ± 0	999 ± 0	904.5 ± 94.5
	Ctrl	999 ± 0	999 ± 0	999 ± 0	999 ± 0	973.8 ± 25.2	999 ± 0	999 ± 0
pH	Treat	7.31 ± 0.09	7.17 ± 0.07 *	7.11 ± 0.07 *	7.09 ± 0.08 *	7.06 ± 0.07 *	7.05 ± 0.07 *	7.02 ± 0.07 *
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- pCO₂ increased starting at hour 2 in treatment group

No gas exchange =

Increase in pCO₂ =

Increased acidity

	Group	BL	1hr	2hr	3hr	4hr	5hr	6hr
Activated Clotting Time (secs)	Treat	968.3 ± 30.7	999 ± 0	940.8 ± 58.2	911 ± 80.8	999 ± 0	999 ± 0	904.5 ± 94.5
	Ctrl	999 ± 0	999 ± 0	999 ± 0	999 ± 0	973.8 ± 25.2	999 ± 0	999 ± 0
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- pO₂ decreased in both groups from hour 1 until the end of the study.

	Group	BL	1hr	2hr	3hr	4hr	5hr	6hr
Activated Clotting Time (secs)	Treat	968.3 ± 30.7	999 ± 0	940.8 ± 58.2	911 ± 80.8	999 ± 0	999 ± 0	904.5 ± 94.5
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- Plasma free hemoglobin
- Treatment group:
 - Increased at hour 4 compared to BL
 - 37% increase between BL and hour 6
- Control group:
 - Increased at hour 3 compared to BL
 - 75% increase between BL and hour 6
- Blood donor variability

	Group	BL	1hr	2hr	3hr	4hr	5hr	6hr
Activated Clotting Time (secs)	Treat	968.3 ± 30.7	999 ± 0	940.8 ± 58.2	911 ± 80.8	999 ± 0	999 ± 0	904.5 ± 94.5
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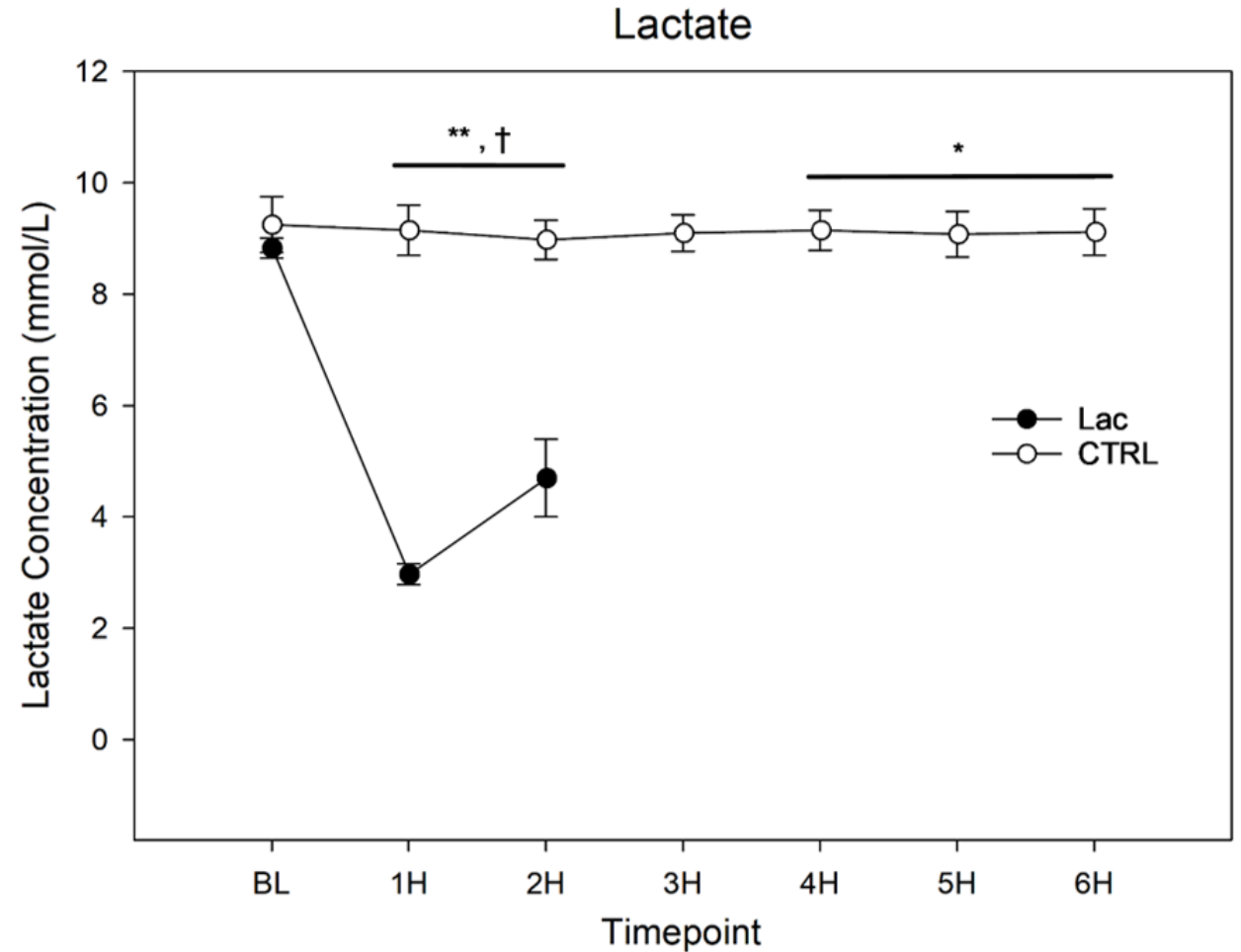
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SAS 9.3 $p < 0.05$



- Control group: lactate remained above 8 mmol/L
- Treatment group: lactate decreased in 1 hour from 8.8 ± 0.2 to 3.0 ± 0.2 mmol/L ($p < 0.0001$)
- Over 50% decrease in lactate concentration in 1 hour



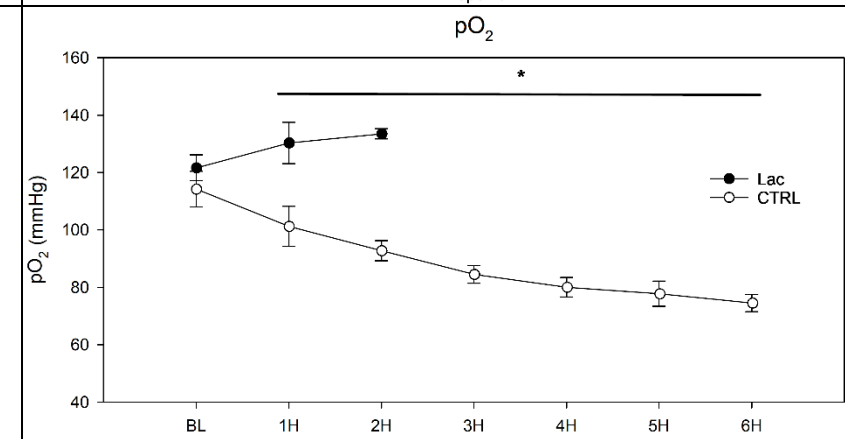
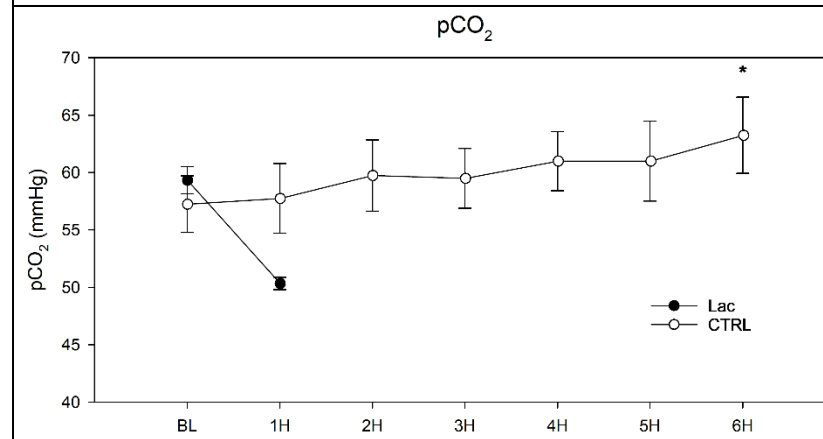
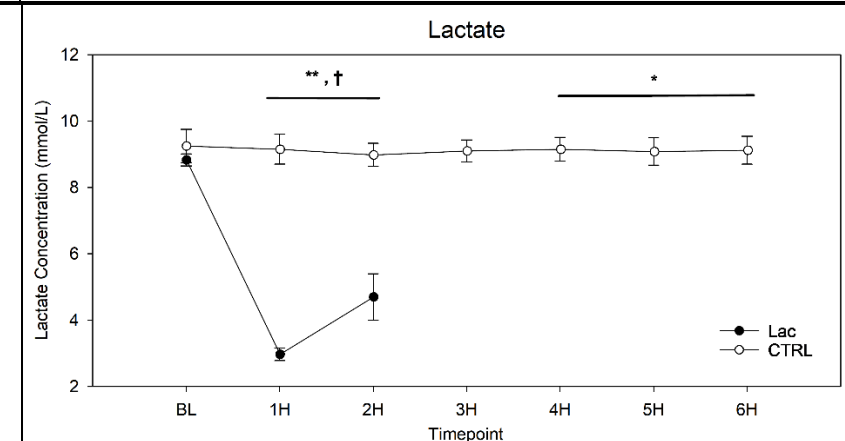
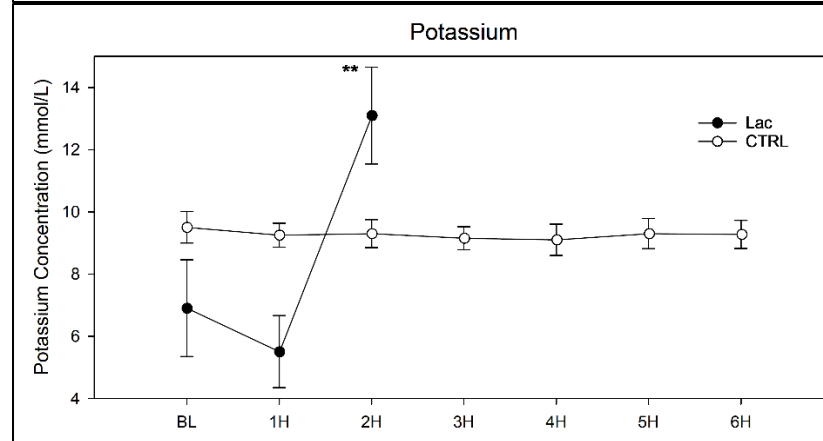
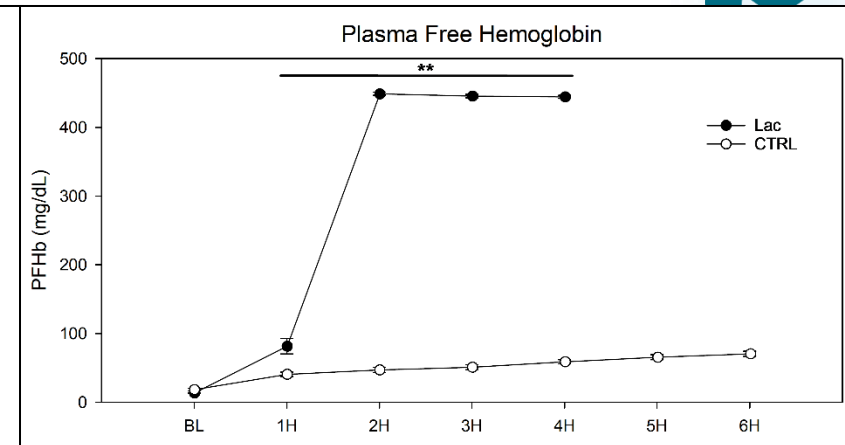
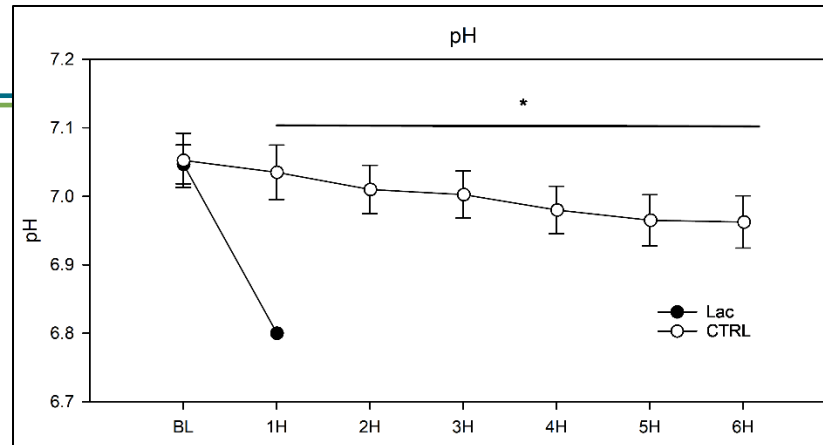
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RESULTS

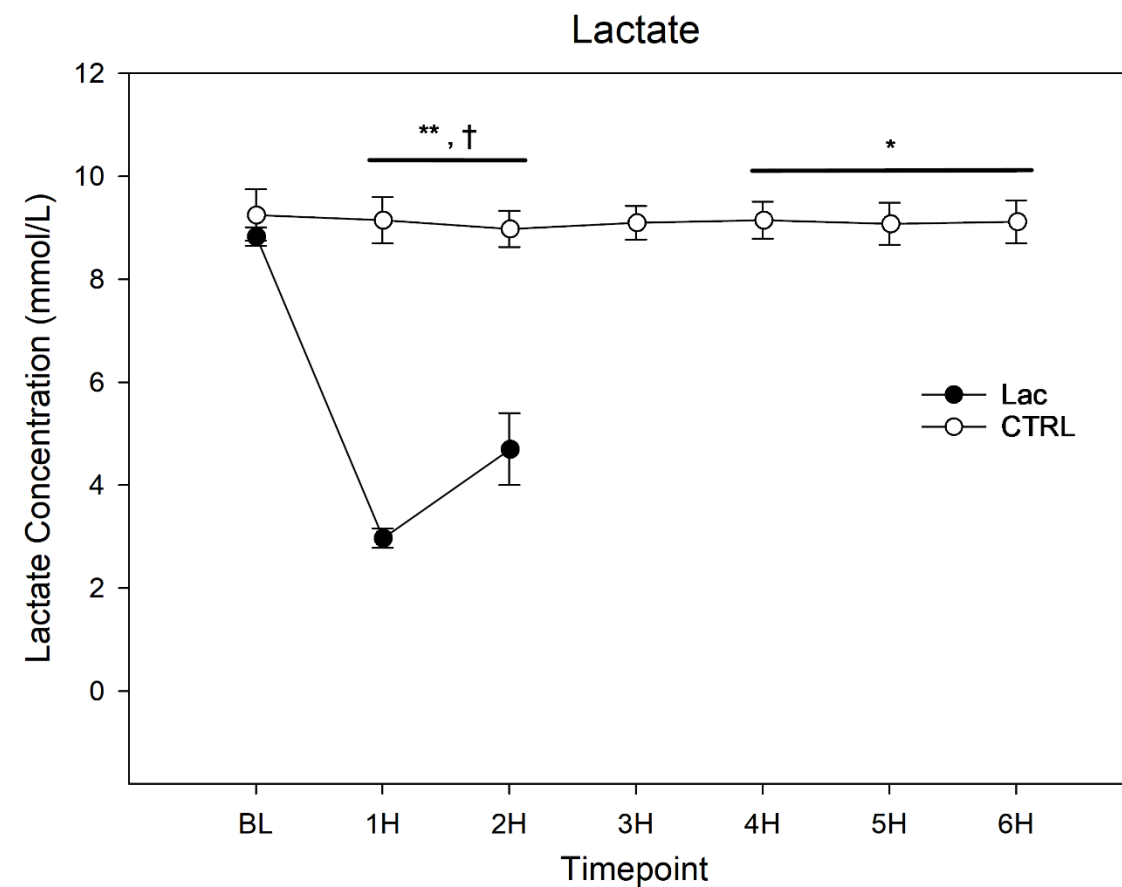
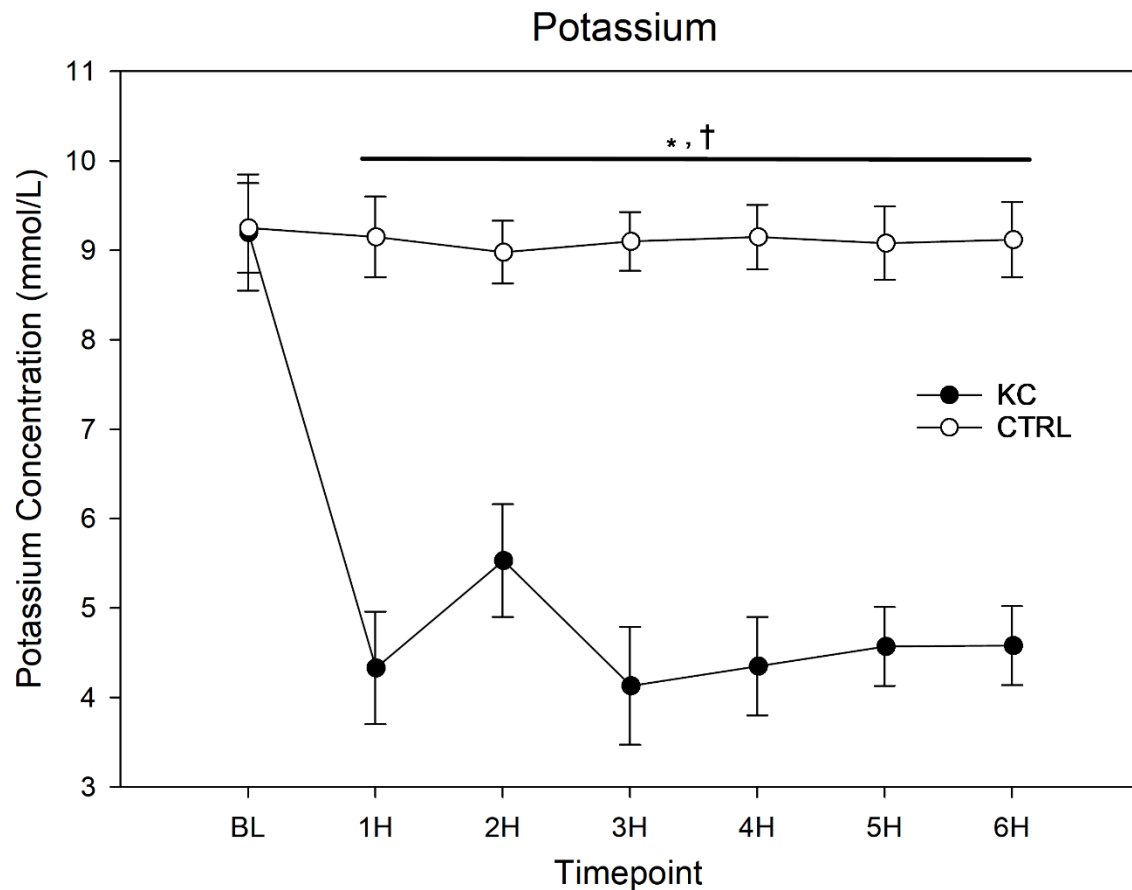


Treatment group:

- Decrease in pH at the 1H timepoint.
- Increase in potassium and plasma free hemoglobin (PfHb) levels at the 2H timepoint
 - Indicates cell destruction



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 SAS 9.3 $p < 0.05$



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- K+ontrol (Potassium sorbent) device effectively reduced K+ levels from ~9 mmol/L to ~4 mmol/L in one hour
- Lactate sorbent device reduced Lac levels by 50% or more (from ~9 mmol/L to ~3 mmol/L), but led to reduced blood viability
 - Device requires further development / testing
- K+ontrol is a promising new adjunct for metabolic management of injured patients with ischemia reperfusion injury and multiorgan failure
- Due to casualty evacuation delays in Ukraine, tourniquet times exceed 3 hours and often go beyond days
- This means that the use of devices that mitigate hyperkalemia and ischemia reperfusion injury is now a priority for the current and future battlefields