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Subcutaneous Lactate Correlates With Arterial Lactate in Severe Combined Trauma and Shock in Swine



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ABSTRACT

Introduction: Changes in blood lactate (Lac) carry prognostic value in pathologic processes and guide decision-making on therapeutic interventions. This feasibility study evaluated a new wearable continuous lactate monitor (CLM) currently undergoing preclinical validation in severe combat-relevant porcine trauma models. **Purpose:** Assess the performance of CLM compared to arterial blood gas (ABG) analysis. **Hypothesis:** CLM-derived Lac values correlate with ABG Lac.

Methods: Female Yorkshire swine (50–60 kg, N = 6) were anesthetized, mechanically ventilated, subjected to a combination of the following injuries: bilateral pulmonary contusion (PC), traumatic brain injury (TBI), or hemorrhagic shock (HEM): (PC N = 3, PC + TBI N = 1; PC + HEM N = 1; PC + TBI + HEM N = 1). Animals were managed with immediate application of veno-venous extracorporeal life support. Two CLMs were placed in the skin of the lower abdomen. ABG analysis was performed using a GEM Premier 4000 [Werfen, Bedford, MA]. Raw CLM data were retrospectively calibrated using ABG values. Pearson Correlation Coefficient ($P < 0.05$) was calculated to compare CLM and ABG Lac values. Bland-Altman analysis was performed to assess device agreement before and after injury for up to 72 h.

Results: Three hundred ninety-four paired measurements were accepted for analysis. Retrospectively calibrated CLM Lac correlated with ABG Lac, Pearson Correlation

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Coefficient = 0.687, $P < 0.0001$; however, a Bland-Altman analysis showed moderate agreement between the methods.

Conclusions: CLM positively correlated with ABG Lac values, with moderate agreement between devices. Future optimization and utilization of CLM may significantly enhance sensor performance and reliability, making it suitable for monitoring and decision support during patient management.

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Introduction

Lactate (Lac) is a clinically significant anaerobic metabolite that reflects underresuscitation in respiratory failure, infection, sepsis, trauma, hemorrhage, and shock, serving as a key biomarker for evaluating the severity of metabolic derangement in these conditions.¹⁻⁵ Elevated prehospital Lac and poor Lac clearance in emergency departments are predictive of both short- and long-term mortality in preclinical and clinical studies.^{1,2,4,5} Prehospital Lac levels are related to outcomes despite normal vital signs,^{6,7} and decreases in Lac levels are associated with improved outcomes in patients.^{8,9} As demonstrated by Abramson et al., trauma patients whose Lac levels normalized within 24-48 h had a 75% survival rate, compared to only 14% for those whose levels remained elevated for more than 48 h.¹ An early Lac measurement within 2 h after injury and a 15% per hour Lac clearance rate were equally effective in predicting mortality.⁴ These studies utilized intermittent invasive blood sampling and Lac analysis using traditional blood gas analyzers. They also highlight the clear and present need to continuously monitor Lac dynamics to improve patient outcomes.

Dynamic or continuous Lac monitoring may offer real-time insights into a patient's metabolic state without repeated blood draws, facilitating timely clinical interventions.^{3,10} *In situ* Lac sensors have demonstrated rapid and accurate performance in intravascular applications.^{11,12} In contrast, subcutaneous monitoring, particularly in high-shock states, faces limitations, including delayed response and differences between levels measured in tissue and blood.¹³ Continuous monitoring approaches like microdialysis¹⁴ and microneedle platforms¹⁵ have also shown promise. While Lac sensors are typically electrochemical,^{3,10-12,14} optical Lac sensing¹⁶⁻¹⁸ has emerged as a promising alternative. However, although several iterations of continuous Lac monitoring technologies have been developed, none have determined their clinical efficacy in clinical practice.¹⁰

Our collaborators at Beckman Laser Institute & Medical Clinic (BLI), a research laboratory at the University of California, Irvine, developed a preproduction optical subcutaneous sensor for continuous lactate monitoring (CLM).^{16,17} The CLM is a prototype of an opto-chemical continuous sensing platform that is under development at BLI. The operating principles of the sensing platform have been described previously^{16,17} and a technical description of the CLM is provided in section 2.3. The CLM is a research device undergoing active development to provide continuous Lac values for use in emergency and critical care medicine. Testing the CLM in large animals (swine) undergoing trauma, using well-

established models at our Institute,¹⁹⁻²³ constitutes a pilot study of the CLM's characteristics in a relevant use environment. Results from this testing are intended to inform CLM hardware and software modifications and refinements needed for technology development. Previous studies evaluated prior prototypes of this device for a different use case in a study involving healthy volunteers undergoing exercise. Retrospectively calibrated Lac levels were compared to plasma Lac measurements. They showed strong correlation, minimal delay (<5 min), and no adverse effects (i.e., no infection or significant signs of erythema or edema at insertion site).¹⁷

Despite its potential demonstrated in a human exercise model,¹⁷ dynamic subcutaneous Lac monitoring in a trauma model remains understudied. Moreover, others have reported challenges due to issues like sensor accuracy and response times.^{10,11} In addition, there is still insufficient understanding of the clinical value of continuous subcutaneous Lac measurements in the presence of injury.¹⁰ Herein, we assessed the feasibility and accuracy of CLM compared to the gold standard arterial blood gas (ABG) Lac analysis following trauma up to 72-h postinjury. We hypothesized that subcutaneous Lac measured via the CLM correlates with ABG Lac levels in a large animal model of trauma and resuscitation.

Materials and Methods

Swine

Animal studies were conducted at the Autonomous Reanimation and Evacuation Research Institute and Innovation Center (San Antonio, TX), in a facility accredited by the Association for the Assessment and Accreditation of Laboratory Animal Care and were conducted in compliance with the Animal Welfare Act, the principles of the *Guide for the Care and Use of Laboratory Animals*, and all local, state and federal guidelines. Data are reported in accordance with ARRIVE 2.0 guidelines. The animal protocol was approved by the University of Texas at San Antonio Institutional Animal Care and Use Committee (protocols SU001-10-25 and SU002-03-26) with secondary approval from the US Army Medical Research and Development Command Animal Care and Use Review Office (protocols DM180202.e002 and PR171562.e002).

Anesthetized, mechanically ventilated female Yorkshire swine ($N = 18$, *Sus Scrofa domestica*) weighing between 50 and 60 kg were used in this study. The swine included in the study were a part of ongoing investigations at Autonomous

Reanimation and Evacuation, with upto 72-h follow-up in a continuously staffed animal intensive care unit.^{24,25}

Experimental design

Animal instrumentation and injury were carried out as previously reported by our Institute.^{19–23} Injuries included combinations of pulmonary contusion (PC), hemorrhagic shock (HEM), and traumatic brain injury (TBI); and recapitulated clinically relevant management scenarios while providing a testbed for investigation of Lac dynamics after trauma. The pigs were induced, intubated, mechanically ventilated, and intravenously anesthetized. Next, they underwent tracheostomy, placement of bilateral femoral arterial and venous lines, and urinary catheterization, followed by baseline data collection and measurements. Tracheostomy was performed to provide definitive airway security during positional manipulations of the animal during the subsequent injury. Due to the anatomy of male swine preventing urinary catheter placement without additional surgical intervention, only female swine were included in this study, as the parent protocols required urinary catheter placement. Swine subsequently received bilateral PC using a modified captive bolt device^{22,23} with or without TBI, and in those swine that did not develop hypotension (mean arterial blood pressure ≤ 40 mmHg) after injury, a 12 mL blood/kg manual blood withdrawal was carried out until mean arterial blood pressure ≤ 40 mmHg (Fig. 1). Swine then received a 30-min shock period, during which animals remained under constant observation but no treatment was provided, immediately followed by a resuscitation period with autotransfusion of shed blood (if any) and 0.9% normal saline with the immediate application of veno-venous extracorporeal life support. Ventilator settings, intravenous anesthetics, and fluid rates were modified as needed throughout the ECLS period based on the swine's vital signs, ABGs, and repeat physical

examinations. Throughout the experimental period, the animal was closely monitored under 24-h surveillance by trained technicians with instruction from the primary physician investigator. The end of the study was determined by the completion of the 72-h follow-up period or early study termination if the swine did not survive to 72 h.

Subcutaneous continuous lactate monitors

CLMs [BLI, Irvine, CA] comprise an optical probe inserted via a lancet under the skin, an optical detector attached to the skin surface above the probe (Fig. 2, left), and a data acquisition and control system. CLM fabrication and operation are reported elsewhere,¹⁶ but briefly, the Lac optical sensor (optode) is comprised of an oxygen-sensitive luminescent molecule (luminescence is quenched by oxygen molecules) and lactate oxidase. Lactate oxidase catalyzes the oxidation of Lac in the presence of oxygen to pyruvate and H_2O_2 . Thus, an increase in Lac results in a local decrease in the partial pressure of oxygen (pO_2), and an increase in the intensity and lifetime of the oxygen-sensitive molecule's luminescence. The change in luminescence lifetime can be assessed by exciting the molecule with sinusoidal light and measuring the phase shift of the luminescence. The local decrease in oxygen caused by the presence of Lac is compared to the background reference oxygen level at the sensor probe site to account for changes in oxygen not related to Lac concentration. Each subcutaneous optical probe has five optical sensors: three Lac optodes and two pO_2 reference optodes (Fig. 2, right). Two subcutaneous CLMs were inserted in the skin of the lower abdomen, bilaterally.

Arterial blood gas measurements

Arterial Lac measurements were determined via a whole blood gas analyzer (GEM Premier 4000, Werfen, Bedford, MA).

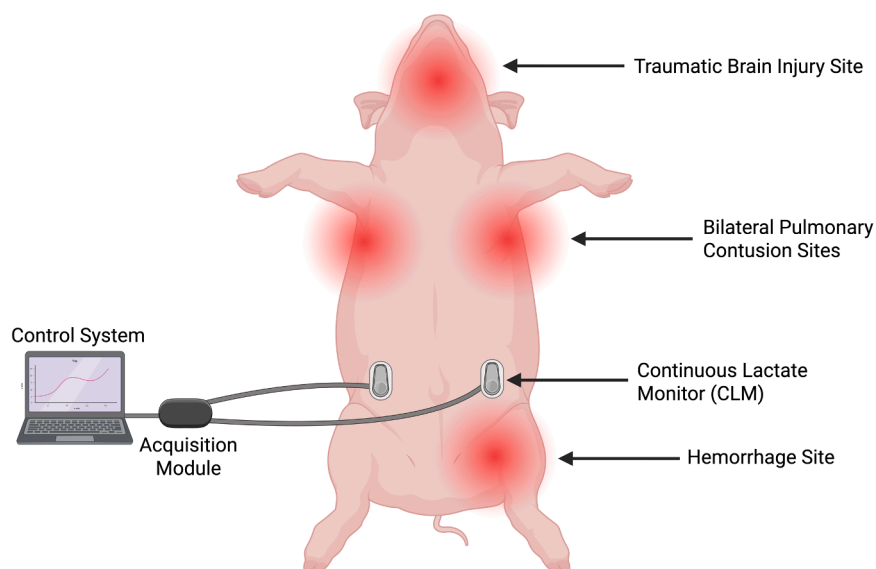


Fig. 1 – Study design highlighting CLMs bilateral implantation in the lower abdomen, acquisition module, and control system with injury sites.

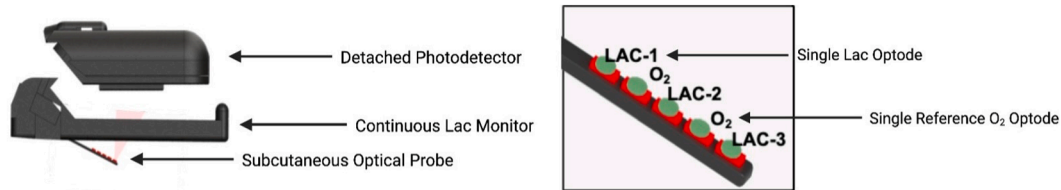


Fig. 2 – (Left) 3-D rendering of CLM and detached optical probe. (Right) Close-up diagram of optical probe highlighting 3 Lac sensors and 2 reference oxygen (O₂) sensors. 3-D, three-dimensional.

1 mL of arterial blood was drawn into a heparinized syringe and measured within 5 min of collection. Whole blood was drawn at the following timepoints based on the animal protocol: baseline, post-PC, post-TBI, post-HM, postshock, post-ECLS initiation, and every 6 h until the end-of-study period. Additional ABGs were drawn at the discretion of the principal investigator to provide the highest standard of care for the swine.

Data processing and statistical analyses

Data preprocessing was conducted using MATLAB R2023a, and statistical analysis was performed in Python (v3.13.0), utilizing the packages NumPy (v2.1.3) and SciPy (v1.14.1). Data were visualized using Seaborn (v0.13.2) and Matplotlib (v3.9.3) packages. A post hoc power analysis was conducted using G*Power (v3.1.9.7) with a two-tailed paired t-test. First, raw phase data were processed by applying a Gaussian filter. Then, points were extracted from the continuous datasets that aligned in time with the intermittent ABG. Paired points were considered valid and included in the analysis based on pre-determined acceptable signal-to-noise ratio limits. The sensor signal (β) was then calculated as the ratio of the normalized difference between the tangents of the Lac and pO₂ (reference) optode phases. The β parameter is derived from the Stern-Volmer equation and quantifies the oxygen gradient between the two optodes.¹⁶ For each Lac optode, a retrospective calibration to ABG values was performed by applying linear regression to the six valid paired points, skipping the first six pairs due to suspected disequilibrium. The fit parameters were then applied to all the paired measurements for that optode, along with a linear drift in slope. The distributions of both ABG and CLM from paired measurements were graphically evaluated for normality. For single Lac optodes, a pairwise linear correlation analysis was calculated. All the valid paired measurements—across all optical probes and animals—were concatenated and filtered for the ABG and CLM Lac values greater than 0 mmol/L and less than or equal to 20 mmol/L. The pairwise linear correlation analysis was performed, and the Pearson Correlation Coefficient (PCC) was calculated to compare the two measurements for every paired measurement (strong correlation = $\text{PCC} \geq 0.7$; moderate correlation = $0.7 > \text{PCC} \geq 0.4$; weak correlation = $\text{PCC} < 0.4$).²⁶ In addition, a Bland-Altman analysis was performed to assess the agreement of the Lac measurements. This method evaluates the agreement between two paired measurements by

plotting the difference of the measurements against their mean, allowing for identification of systematic bias, the limits of agreement, and any relationship between measurement discrepancies and magnitudes.²⁷

Results

After data validity checks, there were 593 paired measurements across 13 optical probes (38 Lac optodes) and $N = 9$ animals. The uncalibrated sensor signal (β) had a poor correlation with ABG Lac with an $R^2 = 0.14$ from linear regression analysis and a $\text{PCC} = 0.373$ ($P < 0.0001$). After retrospective calibration and filtering (*vide supra*), there were 394 paired measurements across 9 optical probes (20 Lac optodes) and $N = 6$ animals (PC $N = 3$, PC + TBI $N = 1$; PC + HEM $N = 1$; PC + TBI + HEM $N = 1$). Physiological characteristics of the swine included in the study are shown in Table 1. A total of twelve animals were excluded from analysis due to an insufficient number of valid data points for retrospective calibration. In the final data set, 30.5% of the paired calibrated measurements were also used in the retrospective calibration. In the post hoc power analysis, using a calculated Cohen's effect size of $d = 0.331$, an alpha level of $\alpha = 0.05$, and a sample size of $N = 394$ paired measurements, the achieved power was >0.999 , indicating the study was well powered to detect a moderate effect size.

The optode lifetime, defined by the elapsed time to the final paired measurement, is shown in Figure 3 (left). The most frequently observed sensor lifetime fell within the 0.0–9.5-h range. Neither ABG nor CLM Lac graphically displayed normal distributions. The mean ABG Lac concentration was 5.2 ± 5.2 mmol/L (median: 2.45, interquartile range: 8.4, range: 0.6–18.4), while the mean CLM Lac concentration was 6.6 ± 5.2 mmol/L (median: 5.26, interquartile range: 8.23, range: 0.05–19.81). Figure 3 (right) displays histograms of the distribution of Lac concentration data measured by ABG and CLM. Both methods exhibited right-skewed distributions, with the majority of values residing below 5 mmol/L. The majority of measured ABG Lac values were in the 0.05–1.69 mmol/L range bin, while the CLM measurements were more evenly distributed across a wider range of numbers, indicating a general overestimation of Lac by CLM compared to ABG.

A linear regression analysis of all postcalibration paired measurements yielded a moderate correlation ($R^2 = 0.47$), indicating moderate variability around the fitted line (Fig. 4,

Table 1 – Combined physiological data of included animals over experimental period including, heart rate, mean arterial pressure (MAP), fraction of inspired oxygen (FiO₂), tidal volume (V_T), respiratory rate (RR), lactate (Lac), and total infused fluids (fluid total).

Variable	BL	pShock	pECLS	3H	6H	12H	18H	24H	30H	36H	42H	48H	54H	60H	66H	72H
Heart rate* (bpm)	117 ± 23	138 ± 24	142 ± 27	140 ± 15	132 ± 13	108 ± 13	103 ± 19	103 ± 16	115 ± 22	106 ± 13	99 ± 15	95 ± 16	93 ± 19	96 ± 13	90 ± 11	89 ± 21
MAP* (mm Hg)	85 ± 9	65 ± 13	66 ± 8	68 ± 10	61 ± 6	75 ± 13	80 ± 12	79 ± 15	78 ± 15	83 ± 23	81 ± 23	91 ± 18	90 ± 18	82 ± 8	82 ± 8	90 ± 5
FiO ₂ * (%)	21 ± 0	52 ± 23	48 ± 25	48 ± 25	55 ± 21	55 ± 21	55 ± 21	57 ± 21	63 ± 27	60 ± 23	72 ± 25	70 ± 28	74 ± 22	84 ± 21	88 ± 22	88 ± 22
V _T * (mL)	557 ± 70	557 ± 70	437 ± 68	430 ± 63	475 ± 100	467 ± 103	432 ± 57	413 ± 67	382 ± 64	388 ± 66	388 ± 66	392 ± 65	398 ± 62	398 ± 62	403 ± 69	405 ± 71
RR* (breaths/min)	23 ± 4	23 ± 3	22 ± 3	22 ± 2	23 ± 2	23 ± 2	22 ± 2	21 ± 2	21 ± 2	23 ± 3	24 ± 2	25 ± 2	25 ± 2	25 ± 2	26 ± 3	26 ± 3
ABG Lac [†] (mmol/L)	3.3 ± 1.4	7.2 ± 3.0	7.6 ± 2.8	11.6 ± 4.2	8.6 ± 6.1	5.0 ± 3.3	1.6 ± 0.6	1.3 ± 0.7	1.4 ± 1.0	2.5 ± 3.4	1.5 ± 1.5	0.8 ± 0.2	0.8 ± 0.2	0.8 ± 0.1	1.0 ± 0.2	1.0 ± 0.1
Optode Lac [†] (mmol/L)	2.4 ± 1.8	8.4 ± 7.2	9.1 ± 6.4	8.2 ± 5.4	9.1 ± 6.4	5.4 ± 3.8	8.6 ± 6.3	4.3 ± 6.3	1.9 ± 1.0	4.1 ± 6.2	1.2 ± 0.5	1.3 ± 0.4	5.6 ± 9.0	n/a	3.7 ± 4.5	1.0 ± 0.1
Fluid total* (mL)	193 ± 31	436 ± 90	786 ± 103	1523 ± 324	2502 ± 703	4304 ± 1490	5727 ± 2245	6453 ± 2579	7209 ± 2779	8203 ± 2843	9025 ± 3173	9087 ± 3598	9614 ± 3777	8172 ± 2382	7906 ± 2333	8128 ± 2270

* Rounded to the nearest whole number.

† Rounded to the nearest tenth.

left). The Bland-Altman analysis of the same postcalibration measurements reveals a relatively broad distribution of paired measurements with a mean difference of 1.36 mmol/L (Fig. 4, right). The 95% limits of agreement (95% confidence interval [CI]) were large and ranged from −6.71 to 9.43 mmol/L, which contained 93.4% of the paired points. All the paired measurements outside the 95% CI were those that were not used in the retrospective calibration. For all paired measurements, the PCC = 0.687 ($P < 0.0001$), suggesting a moderate positive correlation between the two measurements. However, the Bland-Altman analysis indicates a moderate variability between the two methods, even after retrospective calibration. Calibrated sensor performance for a single CLM optical probe shows retrospectively calibrated data for each optode (Fig. 5, left) and corresponding pairwise correlation analysis between CLM and ABG Lac values (Fig. 5, right). All three optodes demonstrated strong agreement with intermittent blood gas measurements, with coefficients of determination (R^2) ranging from 0.734 to 0.882.

Discussion

In this study, we assessed the feasibility of using a novel optode-based CLM to monitor Lac in injured swine model that reproduces the clinically relevant large swings in Lac seen in trauma patients. After retrospective calibration and filtering, there were 394 paired measurements with a PCC = 0.667 ($P < 0.0001$), but the Bland-Altman analysis showed moderate agreement between the two methods.

Lac dynamics are prognostic of mortality in trauma and critical care patients and serve as a better predictor of survival than single Lac values alone. However, only single-point measurements via intermittent blood draws and conventional blood gas analysis are available, which are invasive, costly, and reduce circulating blood volume if done densely. Continuous noninvasive or minimally invasive Lac monitoring could improve decision-making with temporally dense data and trends without multiple invasive blood draws. Previous findings have shown that continuous monitoring technologies can provide reliable data for clinical decision-making in trauma care^{12,14}. From a military perspective, the most recent Joint Trauma System Clinical Practice Guidelines on Damage Control Resuscitation in Prolonged Field Care²⁸ lists point-of-care Lac testing as an essential “best practice” approach to managing the injured. Current methods for Lac assessment are considered an “advanced capability” and are not readily available.²⁸ The guidelines also specifically state that in the field setting, following Lac trends every 60 min until the patient is stabilized and then every 6 h is useful to obtain a more exact clinical picture,²⁸ as well as to assess response to prehospital resuscitation and transfusion.²⁹ In civilian emergency medicine, blood Lac levels have demonstrated potential for refining triage severity classifications (ranging from low to high disease severity) and supporting decisions on treatment prioritization and patient transport in civilian emergency departments for various disease states, including lung cancer, lacunar infarction, sepsis, myocardial infarction, and cardiac failure.³⁰

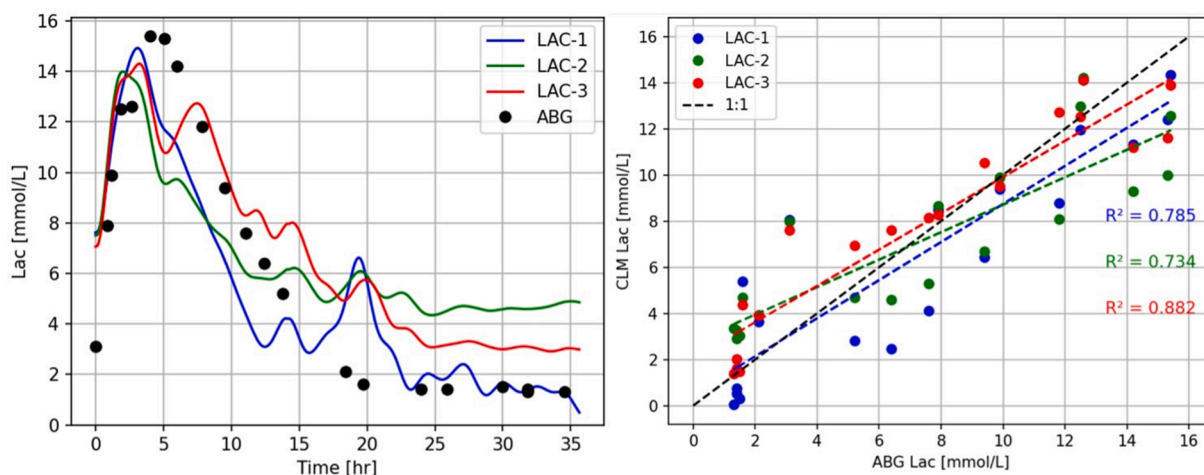


Fig. 3 – (Left) Histogram of optode lifetime, defined as the elapsed time to the last paired measurement. (Right) Histogram of ABG and CLM Lac values as bars with overlaid KDE (kernel density estimation) curves highlighting the nonnormal distribution shapes of the data.

Models using Lac measurements have demonstrated that prehospital Lac measurements improve the prediction of the need for immediate interventions for hemorrhage after trauma. The predictability of the need for immediate intervention is strengthened when Lac measurements are combined with physiological variables (i.e., systolic blood pressure, heart rate, respiratory rate, Glasgow Coma Scale score, and shock index), compared to using physiological variables alone. Furthermore, increasing blood Lac levels per minute from scene to hospital was associated with an increased probability of the need for immediate intervention³¹; highlighting the need for a continuous temporal, prehospital Lac monitoring capability. A recent review article on prehospital subcutaneous CLM in trauma concluded there is a knowledge gap in the use of subcutaneous Lac monitoring.¹⁰

Despite being retrospectively calibrated to ABG values, when comparing all paired measurements across all sensors and animals, there was only a moderate correlation between the methods, and the Bland-Altman analysis revealed a large concentration CI. These discrepancies could be attributed to some combination of several factors. The first is sensor material/performance degradation after implantation. This is

particularly possible because none of the optodes had valid data points at 72 h due to early optode failure. This can arise from damage to sensor materials on insertion, degradation of the implanted optoelectronic components (these points are primarily excluded by the data validity checks with the majority of failures coming from loss of light emitting diode function, as determined by frequency and intensity changes), suspected optode material delamination or cracking during or after implantation, loss of enzyme activity, or disequilibrium due to extended sensor “burn-in” time. Accumulating bio-materials on the optode could also result in poor correlation, reducing the diffusion of molecules to the sensor. However, we generally observe an overestimation of low Lac levels (primarily at later timepoints), which indicates diffusion is not a likely cause of the discrepancy between CLM and ABG Lac values. Similarly, reduced enzymatic activity would not explain the overestimation of low Lac values. In addition, bleeding and/or clotting at the insertion site may contribute to discrepancies.

Another potential cause for the discrepancy between CLM and ABG Lac values is an actual difference in Lac. Differences in blood and tissue Lac have been reported in the

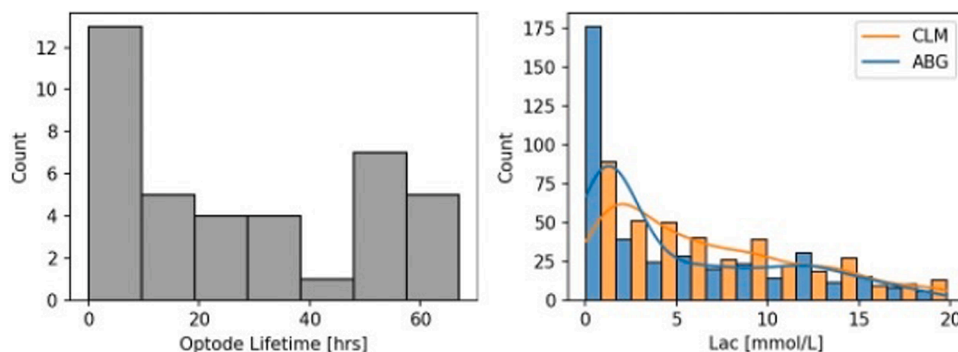


Fig. 4 – (Left) Pairwise linear correlation analysis showing all filtered paired CLM and ABG measurements with corresponding linear regressions and the ideal 1:1 line. (Right) Bland-Altman analysis for paired ABG and CLM measurements. Green shaded datapoints were used in the retrospective calibration.

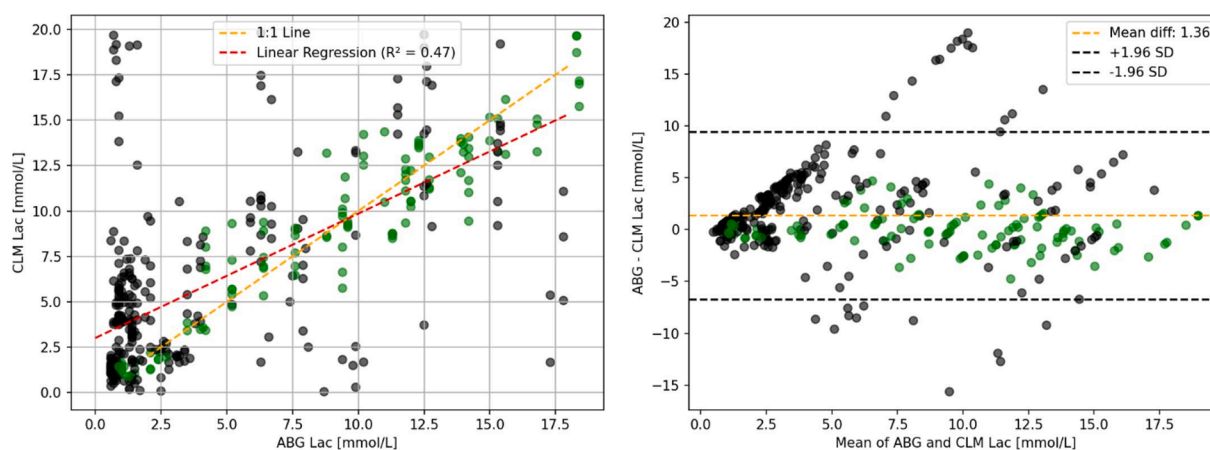


Fig. 5 – (Left) Retrospectively calibrated continuous Lac values for a single optical probe on a single animal. Each min-sensor is denoted LAC-1, -2, and -3 and colored blue, green, and red, respectively. Each black closed circle marker is an ABG value. (Right) Pairwise linear correlation analysis showing paired CLM and ABG measurements with corresponding linear regressions and ideal 1:1 line. Of note, the second through sixth data pairs were used for retrospective calibration for this optical probe.

literature.^{11,12} Subcutaneous/interstitial Lac can exceed arterial levels due to local adipose tissue production, and can be a significant source of whole-body Lac.³² In addition, one study found that 42% of subcutaneous Lac values obtained by microdialysis and 35% of Lac trends were not comparable to arterial blood values.³³ The authors suggested a physiological explanation for the discrepancy (e.g., poor tissue perfusion) because subcutaneous glucose values measured by the same method were highly correlated with arterial blood values.³³ Moreover, elevated Lac could be a result of injury during implantation. These discrepancies were attributed to several factors, including inadequate circulation or perfusion,¹¹ and loss of intercompartmental equilibrium.¹³

This study had several limitations. First, a large portion of CLM data were excluded because of insufficient valid calibration points, which reduced the number of animals used in the analysis. Second, retrospective calibration using ABG values can introduce bias, especially when calibration points are part of performance evaluation. Thirdly, only female swine were used because the studies from which samples were used for analysis required urinary bladder catheterization, which is simpler and minimally invasive in female swine as opposed to males, due to anatomical differences. Sexual dimorphism in the response to trauma is a known phenomenon and is attributed to sex hormones; for example, a prospective study of over 4000 trauma patients revealed significant sex-based differences for Lac level and Lac clearance rate.³⁴ Thus, we recognize that our study does not address the possible variations in dynamics due to sex, and thus, the results for males may have been different. Finally, sensor failures and the limited lifespan of optodes often restricted assessments to within 24 h after placement, hindering insights into the long-term performance of the device.

We conjecture that CLM has the potential to greatly impact trauma and critical care, identifying underresuscitation and informing medical care in a timelier manner. Significant technological improvements are needed to meet this potential

and are being undertaken in our respective groups. Future research should focus on refining this technology to improve accuracy, reduce lag times, and develop a better understanding of the dynamics and utility of subcutaneous Lac monitoring. Developing more robust, affordable, and user-friendly devices could lead to wider adoption among health-care providers. As CLM technology matures, it has the potential to become an integral part of critical care monitoring, enabling more personalized interventions in trauma settings.

In this feasibility study, we demonstrated that a novel subcutaneous CLM device moderately correlated with ABG lactate values in a porcine model of severe trauma and shock. While agreement between methods was limited, the findings still support the potential of CLM technology for continuous monitoring, with further optimization and studies needed to improve accuracy and reliability.

Supplementary Materials

Supplementary data related to this article can be found at <https://doi.org/10.1016/j.jss.2025.10.014>.

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Disclosure

None declared.

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Meeting Presentation

This work was originally presented at the Academic Surgical Congress in Las Vegas, Nevada, on February 13, 2025, in the Trauma and Critical Care Oral Session by Somaney, AS.

CRediT authorship contribution statement

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