

Restoring Carbon Dioxide Homeostasis Through Low-Level Laser Applied Over Jugular

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Abstract

Carbon dioxide (CO₂) homeostasis is essential for maintaining acid–base balance and cellular function, yet strategies to enhance CO₂ clearance remain limited. This study investigated whether jugular-applied coherent low-level laser therapy (LLLT) could modulate arterial CO₂ in dogs with chronic hypercapnia. Ten Beagles were randomized under a double-blind protocol to receive a single 15-minute session of 640 nm LLLT (n = 5) or a sham placebo device (n = 5).

Arterial PaCO₂ was measured before and after treatment. The LLLT group exhibited a significant reduction in PaCO₂ (-1.28 ± 0.80 mmHg; $p = 0.023$), whereas the placebo group showed no meaningful change. Between-group comparison confirmed a significant treatment effect ($p = 0.027$; Cohen's $d = 2.01$). These findings suggest jugular-applied LLLT may acutely promote systemic CO₂ clearance, potentially through mitochondrial activation and vascular modulation.

Keywords: Carbon Dioxide Homeostasis, Low-Level Laser Therapy, Jugular Application, Hypercapnia in Dogs, Mitochondrial Activation

1. Introduction

Maintaining arterial carbon dioxide (CO₂) levels within a narrow physiological range is essential for systemic homeostasis in all mammalian species. CO₂ plays a critical role in regulating blood pH, driving respiratory rhythm, and enhancing oxygen release to tissues via the Bohr effect [1,2]. Disruptions in arterial CO₂, whether elevated (hypercapnia) or reduced (hypocapnia) can lead to significant clinical consequences. Hypercapnia, defined by an elevated arterial partial pressure of CO₂ (PaCO₂), contributes to respiratory acidosis, impaired oxygen transport, altered neurological activity, and, over time, widespread cellular dysfunction [3]. In contrast, hypocapnia can trigger cerebral vasoconstriction, diminished oxygen delivery to the brain, and systemic alkalosis [4]. In veterinary medicine, chronic hypercapnia is frequently observed in dogs and cats with conditions such as chronic bronchitis, upper airway obstruction, or neuromuscular weakness, often presenting as lethargy, shallow breathing, or cognitive dulling. Horses may develop hypercapnia secondary to obstructive airway disease, compromising performance and recovery. Similarly, in livestock, poor ventilation or respiratory illness, particularly in intensive production settings, can result in CO₂ buildup, negatively impacting growth, feed conversion, and overall productivity [5].

Low-level laser therapy (LLLT) has emerged as a potential non-invasive approach to enhance systemic metabolism and gas exchange. By delivering coherent light, photons interact with the mitochondria, thus stimulating oxidative phosphorylation and promoting vasodilation [6]. These photobiological effects may collectively enhance tissue oxygenation and accelerate CO₂ elimination. This study investigates whether a single 15-minute session of jugular-applied LLLT can acutely reduce arterial PaCO₂ in Beagle dogs with chronic hypercapnia, relative to a placebo control. By targeting a high-flow vascular region, the intervention is designed to elicit systemic metabolic responses that improve overall respiratory efficiency.

2. Methods

Ten adult Beagle dogs (5 males, 5 females; ages 4–10 years; weight 9–12 kg) with confirmed chronic hypercapnia (baseline arterial PaCO₂ >45 mmHg) were randomized into LLLT or placebo groups (n = 5 per group). The LLLT group received a single 15-minute session of coherent 640 nm line-generated laser (Erchonia Corp.) applied over the jugular vein. The placebo group underwent an identical protocol using an inactive sham device designed to mimic the appearance and application of treatment without laser emission. Procedures were performed at the National Center for Laboratory Animal Production (CENPALAB). Arterial

blood samples were collected immediately before treatment and again 10 minutes post-treatment to assess changes in PaCO₂ (mmHg), measured using standard blood gas analysis. All procedures were conducted under a double-blinded protocol, whereby both the individuals' administering treatments and those performing laboratory analyses were blinded to group allocation. Statistical analysis included paired t-tests within each group to evaluate pre-post changes and Welch's t-test to compare differences in Δ PaCO₂ between groups. Effect sizes were calculated using Cohen's d, and statistical significance was set at $\alpha = 0.05$.

3. Results

All ten dogs completed the study without adverse events.

Baseline PaCO₂ values confirmed mild to moderate chronic hypercapnia in all subjects (PaCO₂ >45 mmHg). In the LLLT group, arterial PaCO₂ decreased significantly following treatment, with a mean reduction of 1.28 ± 0.80 mmHg (pre-treatment: 49.20 ± 0.59 mmHg; post-treatment: 47.92 ± 0.54 mmHg; $p = 0.023$; Cohen's $d = 1.60$). In contrast, the placebo group showed no statistically significant change ($\Delta = 0.10 \pm 0.23$ mmHg; pre-treatment: 47.36 ± 1.69 mmHg; post-treatment: 47.26 ± 1.92 mmHg; $p = 0.394$; Cohen's $d = 0.43$). Between-group comparison of the change in PaCO₂ revealed a statistically significant difference favoring the LLLT group ($t = 3.17$; $p = 0.027$; Cohen's $d = 2.01$), indicating a large treatment effect beyond the variation expected from handling or placebo exposure.

Group	Pre Mean \pm SD	Post Mean \pm SD	Δ Mean \pm SD	Paired t	p-value	Cohen's d
LLLT	49.20 ± 0.59	47.92 ± 0.54	-1.28 ± 0.80	3.59	0.023	-1.60
Placebo	47.36 ± 1.69	47.26 ± 1.92	-0.10 ± 0.23	0.95	0.394	-0.43

Table 1: Comparison of Pre and Post Treatment Arterial PaCO₂ in LLLT and Placebo Groups

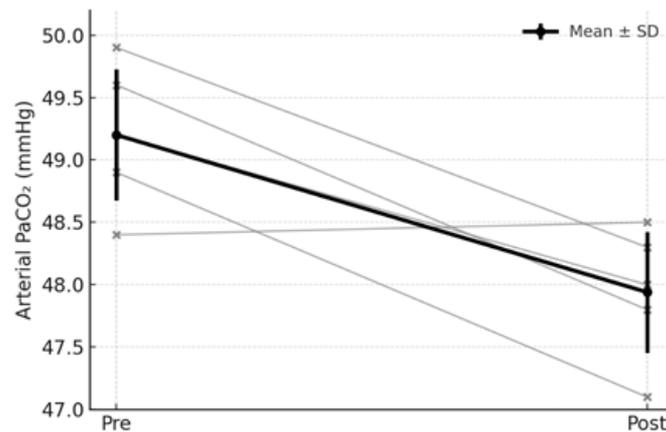


Figure 1. Individual pre- and post-treatment PaCO₂ measurements in the laser group

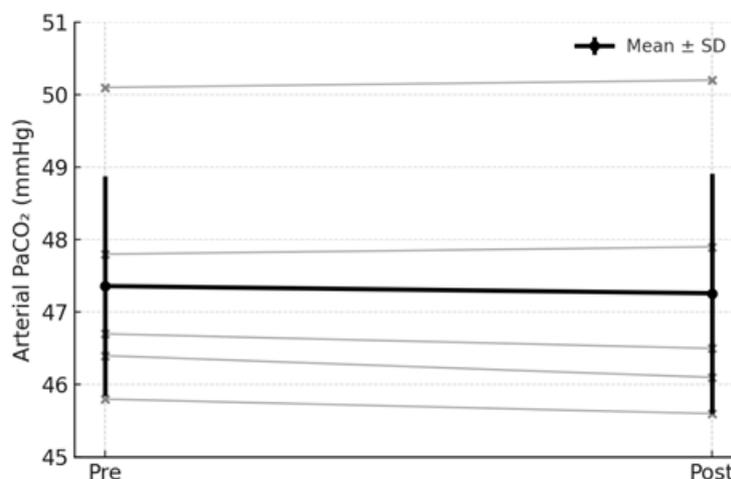


Figure 2. Individual pre- and post-treatment PaCO₂ measurements in the placebo group



Figure 3: Mean Change in PaCO₂ (Post - Pre)

4. Discussion

Physiological regulation of arterial carbon dioxide (PaCO₂) is vital for systemic homeostasis [7]. When CO₂ levels become elevated, a condition known as hypercapnia, the effects are widespread and often deleterious. Elevated CO₂ readily crosses the blood-brain barrier, acidifying cerebrospinal fluid and impairing neuronal function, which can manifest as lethargy, confusion, or even coma in severe cases [8]. In the respiratory system, hypercapnia alters ventilatory reflexes and may suppress the natural drive to breathe, especially in chronically affected individuals. Cardiovascular consequences include systemic vasodilation, reduced myocardial contractility, and impaired oxygen delivery [9]. Kidneys attempt to compensate by retaining bicarbonate, altering long-term acid-base buffering. At the cellular level, excess CO₂ inhibits oxidative phosphorylation and promotes anaerobic metabolism, which increases lactate production and cellular stress [10]. These pathological changes are not confined to one organ system, but rather affect the body globally, undermining both physiological resilience and overall quality of life.

The results of this study suggest that coherent LLLT, when applied over the jugular region, can acutely and significantly reduce PaCO₂ in dogs with chronic hypercapnia. The jugular application site is particularly strategic due to its proximity to high-flow vascular structures such as the internal and external jugular veins. These vessels provide an ideal route for delivering photon stimulation to circulating blood elements and the vascular endothelium, enabling a systemic rather than merely local effect. One proposed mechanism involves the stimulation of free-floating mitochondria found in the bloodstream. These extracellular organelles are increasingly recognized as modulators of systemic bioenergetics. Once activated, these mitochondria may travel to metabolically demanding tissues such as the lungs and heart, where they can be taken up by local cells or influence tissue-level metabolic processes. In the lungs, this could enhance alveolar CO₂ diffusion and ventilation-perfusion matching. In the heart, improved mitochondrial function may increase cardiac output and circulation, indirectly supporting more efficient CO₂ clearance.

5. Conclusion

The present study provides compelling evidence that LLLT applied over the jugular region can acutely reduce elevated arterial CO₂ levels. This effect appears to be mediated by systemic photochemical mechanisms, including enhanced mitochondrial function and improved vascular dynamics. Given the capacity of LLLT to restore homeostatic balance [11]. Rather than simply suppress one end of a physiological spectrum, may hold therapeutic potential not only for hypercapnia but also for conditions involving abnormally low CO₂ levels (hypocapnia), where normalization rather than suppression of CO₂ may be beneficial. Further studies are warranted to explore this biomodulatory potential across different CO₂ imbalances, species, and clinical contexts, as well as to determine optimal treatment duration, frequency, and long-term outcomes.

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