Combined effects of hypoxia, carbon monoxide and acute lung injury on O₂ transport and aerobic capacity

George H. Crocker* and James H. Jones

Department of Surgical and Radiological Sciences, School of Veterinary Medicine, University of California, Davis

Abstract

This study determined how three factors interact to limit cardiopulmonary O₂ delivery, O₂ extraction and maximal aerobic capacity (VO₂max). 1) breathing hypoxic gas; 2) impairing pulmonary gas exchange; and 3) breathing CO, which reduces respiratory capillaries for O₂, and increases hemoglobin affinity for O₂. Five goats ran on a treadmill at 15W/kg following either 1) acute hypoxic-induced lung injury (ALI) or with 2) lung injury (NLI). Goats breathed normoxic or hypoxic inspired gas fractions (F₂O₂, 0.21 or 0.12) with and without small amounts of CO to maintain cardiopulmonary gas fractions (F₂O₂) of 0.12 or 0.30. Hypoxia and ALI induced hypoxemia and reduced O₂ delivery by different mechanisms: hypoxia induced reduced O₂ availability per ventilated alveolus (PAO₂), whereas, ALI increased alveolar-arterial O₂ difference. Elevated F₂CO lowered O₂ delivery by decreasing capillary O₂ extraction for O₂ and reduced CO₂ extraction by increasing affinity for O₂. All combinations of hypoxia, ALI and elevated F₂CO altered the reduction in VO₂max compared to the sum of each treatment’s individual effects on VO₂max, when administered separately. Hypoxia and ALI administered in combination attenuated the decrease in O₂ delivery without affecting O₂ extraction. Elevated F₂CO decreased VO₂max, and ALI attenuated the decrease in arterial O₂ concentration because increased arterial O₂ saturation partially compensated for reduced capillary O₂ content. The addition of ALI to the combination of hypoxic gas delivery and elevated F₂CO attenuated the decrease in VO₂max, because the decrease in O₂ delivery was attenuated. Results from this study apply to individuals, e.g., soldiers, rescue workers and miners, who experience traumatic lung injury while breathing hypoxic and CO-containing gases associated with fires.

Introduction

We have recently shown in goats that breathing hypoxic gas with elevated F₂CO attenuates each gas’ individual effects on O₂ delivery and VO₂max (1, 2); acute lung injury also lowers O₂ delivery and VO₂max (0). PURPOSE: To determine how acute lung injury interacts with breathing hypoxic gas and/or having elevated F₂CO to alter O₂ transport, extraction and VO₂max.

HYPOTHESES: We hypothesized that breathing hypoxic gas in the presence of acute lung injury would decrease VO₂max due to an additive effect of each factor’s individual actions on VO₂max. We also hypothesized acute lung injury with increased F₂CO would attenuate decreases in O₂ delivery and VO₂max compared to additive effects of each treatment.

Methods

Animals: Five treadmill-trained, yearling goats. 

Acute lung injury: We simultaneously infused 3 ml·kg⁻¹·min⁻¹ of oleic acid (OA) and isotonic saline at 10 ml·min⁻¹ through a dual-lumen catheter in the jugular veins into the lungs, and subcutaneously throughout both lungs. The total dose of 0.05 ml·kg⁻¹·min⁻¹ was divided into equal aliquots and infused as discrete doses at 5-min intervals. Goats ran 2 h and 1 d after acute lung injury (ALI) and ALI +1 elevated F₂CO, respectively, so that as always with lung injury (NLI).

Gas: Breathed F₂O₂, 0.21 or 0.12 in the presence and absence of low concentrations of CO to maintain F₂CO, 0.21 or 0.12.

Statistics: Values are mean ± SD for the five goats. One-way repeated measures analysis of variance (RM-ANOVA) and Holm-Sidak multiple pairwise comparison procedures tested for 1) differences from 21/0 (NLI: ALI, ALI+1; and 3) lung injury effects with each F₂CO combination. Two-way RM-ANOVA tested the interaction between factors, e.g., presence/absence of hypoxia and presence/absence of elevated F₂CO.

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References


Conclusions

The combination of hypoxia and ALI attenuated the reduction in VO₂max compared to the predicted additive effects of the two factors by attenuating the decrease in O₂ delivery, despite reduced O₂ extraction. The combination of elevated F₂CO and ALI tended to attenuate the reduction in VO₂max (P = 0.008) compared to the predicted additive effects of the two factors by attenuating the decrease in C(O₂). The combination of hypoxia, elevated F₂CO and ALI attenuated the reduction in VO₂max compared to the predicted additive effects of the three factors because the decrease in O₂ delivery was attenuated, despite reduced O₂ extraction.

*Current address for GH Crocker: Department of Kinesiology, California State University, San Marcos, gcrocker@csusm.edu