The Authority of CO₂

In

Acute Adaptation to Acute Hypoxia

Environmental Biomedical Stress Data Center
University of Pennsylvania
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Background for Stimulus of Research

- Three different types of inert gas O₂ depletion agents exist, not one. These are (a) any inert gas without CO₂, (b) any inert gas with CO₂, and (c) CO₂ alone.

- The term “inert gas” includes 100% CO₂ in the process of fire extinguishing.

- In relation to human exposure, CO₂ is not inert, and ranges from strictly beneficial, active physiologic effects of low CO₂% to lethal acidosis of high CO₂%.

- An EPA aim has been to use the degree and stability of internal oxygenation induced with different agents as an index of comparative safety of inspired O₂ levels. EPA recognized from the weight of decades of hypoxia physiologic research unrelated to fire that O₂ depletion by any inert agent without CO₂ inevitably lowers arterial CO₂, and that an inert agent with CO₂ sustains or increases arterial CO₂.

- The focus upon rapid exit in fire situations made it sensible to put aside the differences between inert O₂ depleting agents without and with CO₂ in very brief exposures of 60 to 90 seconds as not practically distinguishable in effect.

- While not immediately large, the physiological effects of inspired hypoxia or hypoxia/CO₂ in fact are each known to begin measurably within a few seconds or breaths and proceed along statistically separate measurable pathways of increasing degrees of responses to the different inspiratory gases. The result becomes either a stable or deteriorating situation of hypoxia, depending upon the degree of internal oxygenation induced initially.

- The pathway for initial and consequent effects of exposure to hypoxia alone is a tendency to progressive decrease of internal oxygenation.

- Exposure to an agent with CO₂ results in an essentially immediate measurable cascading of interlocked, complimentary physiologic effects of combined CO₂ and hypoxia on respiratory and brain circulatory regulation. The process of acute adaptation to hypoxia begins immediately and leads to stabilization of internal oxygenation at levels higher than with hypoxia alone. These results are well documented in the usual 6 to 10 minute classical physiologic stable state exposures, and are now visible within 1 to 3 to 5 minutes with modern breath-by-breath and heart beat by beat measurements.

- The consequence is that 10% O₂ with CO₂ provides internal oxygenation at least equivalent to 12% O₂ alone, initially and in sustained exposures. Therefore 10% O₂/CO₂ and 12% O₂ deserve equivalent prolonged exposure durations, and 10% O₂ alone does not rationally deserve equal exposure guidelines with 10% O₂/CO₂ and 12% O₂ alone.
(CO₂ with 8% to 8.5% O₂ sustains consciousness and prevents orthostatic hypotension fainting in standing subjects (Gellhorn, Ann. Internal Med. 10: 1267, 1937.)

It would be a major general loss of investment for an Agency or research field to miss the opportunity for improving technologic communication and recognition of the realities of relevant physiologic adaptations to hypoxia, in its scientific and engineering associations concerned with fire prevention advancement via oxygen depletion.
Key Points of Scientific R and D Stimulus

- Effects of inspiratory Hypoxia without CO\(_2\), or Hypoxia with CO\(_2\) do occur within 1, 3 and 5 minutes exposure and thereafter.

- The degrees of internal hypoxia (lung, arterial blood, body) resulting from inspiratory hypoxia alone (12% or 10% O\(_2\)) are larger at 1, 2 and 5 minutes exposure and thereafter than resulting from inspiratory hypoxia with CO\(_2\) (12% O\(_2\)/CO\(_2\) or 10% O\(_2\)/CO\(_2\), respectively).

- The degree of internal oxygenation (lung, arterial blood, body) resulting from 10% O\(_2\) with CO\(_2\) is equivalent to that resulting from exposure to 12% O\(_2\) alone at 1, 2 and 5 minutes exposure, and is superior thereafter, since deterioration of internal oxygenation occurs with hypoxia alone.

- At durations longer than 1, 2 and 5 minutes of exposure with inspired hypoxia of 10% O\(_2\) alone, further deterioration of internal oxygenation occurs, while essentially stable superior level of internal oxygenation occurs for 10% O\(_2\) with CO\(_2\) (PO\(_2\), %Hb Saturation, organ (tissue) O\(_2\) flow).
Prevention of Hypocapnea in Acute Atmospheric Hypoxia

Prevention of hypocapnea in acute atmospheric hypoxia results in an essentially immediate sequence of interlocked, complimentary physiological effects of CO₂ on respiratory and circulatory regulation.

The consequences of improved respiratory and circulatory responses to hypoxia, with resulting increase in arterial PO₂, %Hb Sat, and O₂ content, thereby provides a supporting of whole body oxygenation, and oxygenation of critical functions and organs including heart and brain.

This cascade of acute adaptation begins within seconds of the first breath and leads to stabilization of internal oxygenation at levels higher than with hypoxia alone. The result within is higher levels of oxygenation in blood, body and brain with 10% O₂ / 4% CO₂ than with 12% O₂ alone.

The use of CO₂ has been known for 60 years to prevent the tendency to fainting which occurs with hypoxia alone in standing subjects with inspired oxygen as low as 8 to 8.5% (Gellhorn, E., Ann. of Internal Med. 10: 1267, 1937).

It would be a failure of technologic communication to withhold these large adaptative factors from the awareness of major Government Agencies and University Scientists interested in fire protection methods. Large amounts of published research support these physiological benefits.

Blurring the extensive background science underlying CO₂ effects in acute hypoxia would also not serve the groups forced with using and improving oxygen depletion methods in fire protection and extinguishment.