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LETTER TO THE EDITOR

The use of end-tidal argon to detect venous air embolism: foiled by "fake oxygen!"

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Abstract

Venous air-embolism (VAE) potentially catastrophic complication surgery. Based on previous data using changes in end-tidal nitrogen as an indicator of VAE, we surmised that changes in end-tidal argon (EtAr) may be an indicator of VAE. We sought to determine if a commercial mass-spectrometer (PCT Proline Analyzer 61700-8 Class 85, Ametek, Pittsburgh, PA 15238) could be used to detect changes in EtAr in an invitro model. A Drager Apollo™ (Drager, Lubeck, Germany) anesthesia machine was used to ventilate a dummy lung (2 L bag) with a minute ventilation of 6 L/min in 100% oxygen. The quadrupole mass-spectrometer (sampling at 0.0004 atm-cc/sec) was attached to the end-tidal inlet of the machine. Room air (1–60 mL) was injected into the dummy lung to simulate VAE. A strong baseline ion-current (1.2×10^{-12} amps) of argon was noted. Due to this contamination we were unable to detect "VAE" events of injected air. Argon represents approximately 0.93% of room air, or about 9300 parts per million (ppm). We detected about 2000 ppm argon in medical-grade oxygen (or 0.2%), limiting our ability to detect changes in EtAr. This is a USP-accepted contaminant, rendering this technology is insensitive for early, rapid detection of VAE. We assumed medical grade oxygen was pure and were surprised to learn otherwise. We want to share this likely largely unknown finding with the medical community.

Keywords Medical grade oxygen contaminant · Venous air embolism · USP oxygen · Impureoxygen · End-tidal argon

We discovered a curious finding involving medical grade oxygen while conducting an experiment aimed at validating a mass-spectrometer in an in-vitro setting for use detecting venous air embolism. Previously, changes in end-tidal nitrogen proved to be a sensitive and high-performance indicator of VAE events in experimental conditions [1–4]; however, based on our previous work its clinical use was prohibited by interference by nitrous oxide and volatile anesthetics. Argon represents approximately 0.93% of atmospheric air. We felt, logically, that end-tidal argon (EtAr) would be simple to detect given its relative abundance in air compared to other inert gasses and in theory there should be no interference of its detection based on known chemical structures of common anesthetic vapors and gasses.

A Drager Apollo™ (Drager, Lubeck, Germany) anesthesia machine was used to ventilate a dummy lung, a 2 L reservoir bag, with a minute ventilation of 6 L/min (tidal volume 500 mL, respiratory rate 12/min) in 100% oxygen. A commercially available compact quadrapole mass spectrometer (PCT Proline Analyzer 61,700-8 Class 85, AMETEK, Pittsburgh, PA) was used as the detector of EtAr. This analyzer's sample line tubing (sampling at a rate of 0.004 atm-cc/s) was connected to the Apollo's gas sample inlet water trap of the gas analyzer, thereby capturing any Argon "exhaled" from the dummy lung.

Air was introduced in amounts ranging from 1 to 60 mL through a three-way stopcock on the distal end of the anesthesia reservoir bag to simulate VAE events. A strong baseline current of 1.2×10^{-12} amps was detected in the m/z 40 band. The mass spectrometer was flushed with 100% oxygen without change in baseline current. The capillary tubing was moved as proximally in the circuit as 15 cm from the oxygen E-cylinder to correct any system leak, again without a change in the baseline current. 1–60 mL boluses of room air were injected into the system; no change in the measured argon was observed at any volume of air.

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Room air introduced in this system produced no change in measured argon. There was a strong, unexpected baseline ion current of argon, which initially was suspected as a leak in the circuit. After troubleshooting for several causes of artifact, including circuit leak and residual air in the mass spectrometer, it was determined that the background current of argon was most probably real and not an artifact, likely due to the contents of the E-cylinder of oxygen. We learned that the USP accepts up to 1% (10,000 PPM) contamination of this medical-grade gas [5]. Our group suspects that this study would have been positive if the oxygen used was pure. This impurity of medical grade oxygen is clinically irrelevant, but likely largely unknown amongst practicing anesthesiologists. As such, we hope to increase awareness of this finding with the medical community.

Compliance with ethical standards

Conflict of interest TS is a former employee of Ametek, the manufacturer of the mass spectrometer used in our study. JCM, RJ, MB, and JBU declare that they have no conflicts of interest.

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