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Running Title: A Call to Modernise Oxygen Regulator.

INTRODUCTION:

The Unexplained Physiological Episode (UPE) remains a concern across various fleets of high-performance aircraft. Enormous efforts have been made by investigators from various physiological and technical backgrounds aiming to uncover its root cause. Whilst the reports on PE/UPE are common for these types of aircraft, interestingly there are no similar troubling accounts from transport air fleets that use analogous oxygen equipment.

This work compares the principles to achieve ventilation and oxygenation in traditional cockpit oxygen regulators and mechanical ventilator technology, used in critical care. The author questions whether current aviation breathing systems are optimal in catering for two main reasons for breathing: CO_2 elimination and oxygenation.

KEYWORDS: Oxygen regulator, OBOGS, CO_2 narcosis, UPE, Assisted breathing.

We compared oxygen regulators for fast jets with a similar purpose device: medical mechanical ventilator (MMV). Both devices are used for life support and user oxygenation. The primary role of an aircraft breathing system was defined by Harding[3] as a system that maintains adequate oxygenation, whilst at minimum resistance.

Currently, oxygen regulator specifications detail that in normal mode, inhalation is triggered by suction (negative pressure) in the range of -0.40…-1.00inH_2O. Inhalation then continues, facilitated by the pilot's continuous effort[6]. Military standards[8], however, do not consider associated work of breathing (WOB), actual ventilatory rates and airway pressure in normal operation mode. The required inhalation effort means *laboured* breathing — an additional burden on already stressed pilots and impairment to the CO_2 elimination component of external respiration. Pilots themselves describe breathing as a process of "pulling out" the air from the mask, sometimes struggling to pull out any![1].

On the other hand, MMVs, first emerging in the 1960s to compensate for a novel problem caused by advances in general anaesthesia, are designed to solve two main problems: oxygenation and CO_2 elimination (the single most physiologically important reason for breathing). MMV technology clearly demarcates these two aims, as outlined in their operational manuals, e.g.[2]. MMV provides unrestricted breathing with *constant positive airway pressure*, an important factor in counteracting alveolar collapse (de-recruitment). Whereas oxygen regulators provide constant positive pressure only in "Safety pressure" and "Emergency" modes.

In the anaesthesiology practices of older days, narcosis caused relaxation and suppression of spontaneous ventilation, thereby causing CO_2 retention. This, in combination with high oxygen, led to CO_2 narcosis, acute respiratory distress, loss of consciousness, coma and death[4]. These serious health outcomes have startling parallels with the Unexplained Physiological Episodes reports[5]. This observation has not yet gained due attention of aviation medical and flight specialists, who do not register CO_2 retention as an immediate threat to pilots in their research[6]. Given laboured, inadequate ventilation plus high oxygen, when combined with acceleration atelectasis[7], it is conceivable that pilots may occasionally develop CO_2 narcosis, causing UPEs unpredictably.

Unlike oxygen regulators, MMVs are designed for *assisted* ventilation and have multiple programmable modes to perform according to the clinical situation at hand, e.g., to remove or reduce WOB, to prevent alveoli de-recruitment and/or assist with their recruitment[2]. Strikingly, today's military oxygen standards do not take full advantage of respiratory medical knowledge acquired over the past 70 years, as they primarily focus on the oxygenation problem. Consequently, aviation breathing systems do not incorporate best respiratory science practices.

External resistance is undesirable, but until now it had been perceived as an inevitable feature of any aviation breathing system. Previously defined ideal oxygen systems would have no resistance, "a condition that is impossible to fulfil"[3]. Perhaps this long-term notion that breathing system resistance is technically unavoidable, having resulted in conservation of existing oxygen regulators designs up until now.

We hypothesize that at least in one scenario UPE can be caused by a combination of these three factors:

1. Laboured breathing dictated by high-resistance nature of legacy breathing systems.
2. Acceleration atelectasis.
3. High oxygen.

Whereas G-maneuvers and accelerations are to remain part of normal jet flights, their breathing systems can be modernized. Oxygen level in breathing mix can be efficiently controlled in accordance with approved schedules and pilots' physiological needs in changing environments.

Adverse outcomes of UPEs could be reduced by developing a new generation of breathing systems that employ continuous *assisted breathing* and thus eliminate limitations of mechanical devices of the WWII era. Efficient breathing systems are used widely in intensive care; hence, it is technically possible to give aviators the same advantage.

This is a call for a fruitful cooperation between respiratory medical and engineering specialists, to endeavor on developing initial specification, and then conceptual and working prototypes of such new breathing systems for approval by medical and flight experts.

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