IS THIS THE SUMMIT OF EXTRACORPOREAL GAS EXCHANGE PERFORMANCE?

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Introduction

Modern extracorporeal life support (ECLS) applications often incorporate extracorporeal gas exchange systems that carry out the necessary oxygen and carbon dioxide transfer between blood and gas phases. Customarily, these systems are outfitted with artificial semipermeable membranes that keep the liquid and gas phases apart, yet without impeding gas exchange between them. This exchange is a mass transfer manifestation that can be neatly exemplified by Equation 1:

$$\dot{Q}_j = K_j \cdot A_m \cdot \Delta p_{j(b-g)} \qquad (1)$$

where, K_j the overall mass transfer coefficient, A_m the effective surface area of the membrane and Δp_j the concentration gradient between blood - gas phase (expressed in partial pressure).

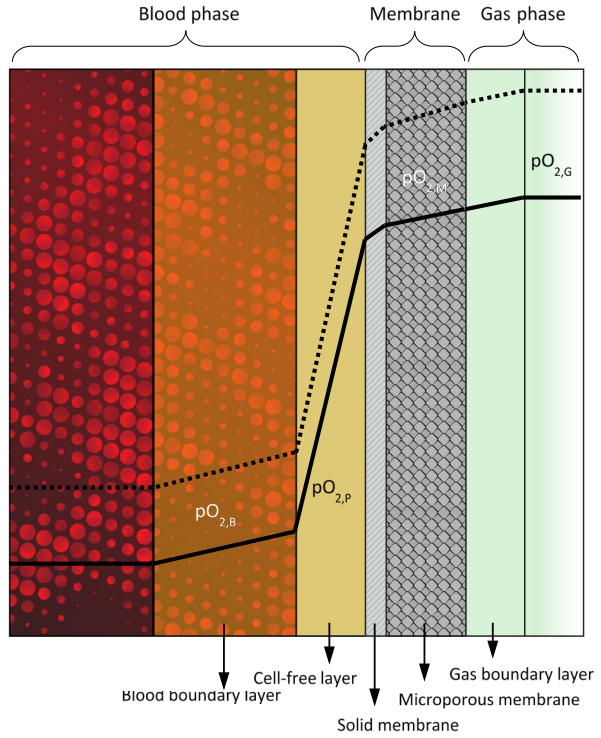

Figure 1: Graphic illustration of the diverse strata spanning between blood and gas phases during extracorporeal membrane gas exchange. Simultaneously, a qualitative representation of the resistance to gas transfer in terms of oxygen partial pressure (pO_2). Continuous and dashed lines denote normobaric and hyperbaric gas delivery, respectively.

Amplification of one or more of these parameters ought to augment the product and result in enhanced gas exchange performance. Nevertheless, any increase in the membrane's surface area will be accompanied by protracted blood - foreign surface interaction and elevated risk of blood trauma. Likewise, mass transfer coefficient is already optimized, both in terms of material permeability [1,2] and fluid dynamic efficiency (packing density, hydraulic diameter, etc.).

Hence, the sole manipulated variable remaining is the difference in the partial pressure of gas between the two fluid phases. For instance, implementation of pure oxygen (FiO_2 = 1.0) as sweep gas instead of air (FiO_2 = 0.21), will most definitely improve oxygen transfer rate (OTR). Similarly, the concentration of oxygen can be artificially increased by employing a mechanism that constricts the oxygenator's gas outlet, leading to pressure buildup in the oxygenator's gas compartment (see Figure 1).

Methods

This novel approach makes use of modern, purely diffusive membrane materials, and takes advantage of the elevated concentration gradient ensuing from hyperbaric gas supply. An assortment of silicone membrane gas exchangers were tested in vitro as per a modified protocol in pursuance of assessing their gas exchange efficiency under both regular (normo-) and hyperbaric aeration conditions.

Results

The findings point to a stark performance gain when pressurization of the gas compartment is involved; a 40% rise above atmospheric pressure (300 mmHg) elevates oxygen transfer rate (OTR) by nearly 30%. Carbon dioxide transfer rate (CTR) does not benefit as much from this principle, yet it retains a competitive edge when higher gas flow/blood flow ratios are employed. Moreover, implementation of purely diffusive membranes warrants a bubble-free circulation.

Discussion

Further optimization of the introduced method ought to pave the way for in vivo animal trials, which in turn may potentially unveil new realms of gas exchange performance for therapies associated with extracorporeal circulation.

References

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