Use of Nitrogen in Ventilation of Artificial Blood Oxygenators: A Potential Hazard

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Introduction

Perfusionists have adapted nitrogen gas sources to air/oxygen mixers—in most cases, simply because the nitrogen gas source pre-existed in the OR suite and was more convenient than obtaining a compressed air source. The use of nitrogen gas nullifies the FiO\textsubscript{2} setting calibration on the air/oxygen blender. If nitrogen is to be employed to replace air in the mixer, a mixer FiO\textsubscript{2} setting no lower than .43 should be employed and the mixer gas exit percent oxygen must be continuously monitored. The use of nitrogen gas to replace air in the air/oxygen mixer does not adhere to manufacturer’s recommendations.

Technique

Perfusionists employ air/oxygen mixers to obtain fine control of the arterial blood pO\textsubscript{2} leaving a membrane oxygenator. Membrane oxygenator manufacturers have endorsed the use of mixers as an integral component of their oxygenator hardware. Membrane advocates purport the finer independent control of arterial pO\textsubscript{2} with the mixer to be safer, thus providing added benefit over bubble oxygenation. However, some perfusionists utilize air/oxygen mixers with bubble oxygenation, especially in cardiopulmonary bypass accompanied with high arterial pO\textsubscript{2}s (e.g. profound hypothermia).

We measured the actual FiO\textsubscript{2} of the mixer exit gas with a percent oxygen monitor to create the line in Figure 1 when nitrogen is substituted for air. The expected FiO\textsubscript{2} from a mathematical regression is included also. A mixer setting of .43 FiO\textsubscript{2} is comparable to a percent oxygen monitor reading of 21% when 100% nitrogen gas is adapted to the compressed air connection of the mixer. The result is that a much lower FiO\textsubscript{2} is delivered than blender settings would indicate. An uninformed user may induce hypoxia and ischemia with mixer settings lower than .43 when substituting nitrogen for compressed air.

The air/oxygen mixer manufacturer and membrane manufacturers recommending the use of a mixer warn users to continuously monitor the percent oxygen exiting the mixer. When nitrogen is substituted for air, the mixer user at best can only estimate the actual FiO\textsubscript{2}. Therefore, percent oxygen leaving the mixer must be directly monitored when 100% nitrogen is employed.

Discussion

Mandl and Sakauye have demonstrated that the gaseous microemboli count and volume are low
and not altered when nitrogen gas is substituted for oxygen to ventilate bubble oxygenators.\textsuperscript{1,2} Emboli counts from membrane oxygenator circuits are lower than those of a bubbler circuit.\textsuperscript{3} Mandl proposes that nitrogen ventilating gas should be avoided in bubble oxygenators though the emboli counts are not different for nitrogen and carbogen. His recommendation was based on In Vivo demonstration that equal volumes of nitrogen gaseous emboli are more deleterious and fatal than oxygen or carbon dioxide.\textsuperscript{4}

A nitrogen gas user may rationalize the safety of this technique when using a membrane oxygenator and ECC arterial line filtration or bubble trap.\textsuperscript{5} However, the nitrogen gaseous emboli that do perfuse the CPB patient are probably more harmful than oxygen emboli. Spencer documented the cardiectomy reservoir as the greatest source of nitrogen emboli to the patient in the absence of venous drainage aero-embolism. Proponents of a "closed circuit" should select cardiectomy reservoirs that are effective in gas emboli entrapment. Closed or open venous blood reservoirs, with or without integral cardiectomy return, should be evaluated in terms of their ability to trap gaseous emboli. (Personal communication, James Pacek) An integral cardiectomy reservoir should be a minimal source of emboli to an otherwise "closed" system.

The possible hazardous effects of high arterial blood $pO_2$'s have been measured and referenced in regard to minimizing ECC arterial line emboli.\textsuperscript{7,8} The exact mechanism and the deleterious physiologic consequences during CPB due to patient perfusion with high arterial $pO_2$'s have not been documented. True oxygen toxicity is not a reality during routine CPB.\textsuperscript{9} It is easy to argue that the microemboli that we do accept in the arterial line should be oxygen rather than nitrogen. Therefore, we should accept high $paO_2$'s (personal communication, James Deering). These facts complicate the decision to employ nitrogen in the ventilating gas of artificial blood oxygenators with or without a blood gas interface.

### Technique Recommendation

With regard to the scientific literature and the practical application of "innovative ECC hardware", the following recommendations are appropriate.

1. ECC arterial line filtration and/or bubble entrapment is indicated.\textsuperscript{5} Arterial line filter or bubble trap "bleed lines" should remain open at about 200 ml/min for adult CPB and exit to a reservoir always open to atmosphere.

2. Air/oxygen mixer manufacturer/endorser directions for use should be followed.
   a. Nitrogen gas should not be substituted for air in the mixer.
   b. An external device should continuously monitor mixer gas exit $FiO_2$ with the alarm mode employed. The $FiO_2$ monitor should be calibrated with a gas source (ambient air and 100% $O_2$) other than the mixer inlet gases.

3. Actual arterial blood $pO_2$ less than 200 mmHg should be maintained during CPB.\textsuperscript{7}
   a. A well maintained, externally monitored air/oxygen mixer is indicated in conjunction with membrane oxygenation.
   b. $FiN_2$ up to .50 is indicated in bubble oxygenator ventilating gas only after decreasing the gas to blood flow ratio fails to decrease $pO_2$ and/or adequately remove carbon dioxide (deduced from \textsuperscript{2} and \textsuperscript{4}).

4. Venous to arterial temperature increases greater than 5-6°C in heat exchangers on the market today should be avoided. Large velocity changes in the ECC arterial line especially at the arterial cannulation site should be avoided.\textsuperscript{7}

### References