EDITORIAL

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_2 setting calibration on the air/oxygen blender. If nitrogen is to be employed to replace air in the mixer, a mixer FiO_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_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_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_2s (e.g. profound hypothermia).

We measured the actual FiO_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_2 from a mathematical regression is included also. A mixer setting of .43 FiO_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

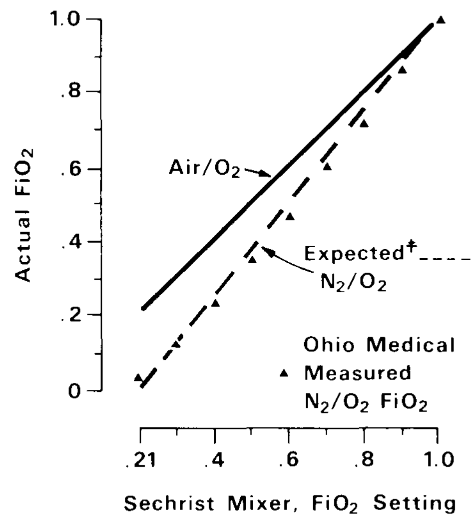

FIGURE 1. The actual FiO_2 from an air/O_2 mixer when nitrogen gas is substituted for air. The mixer is from Sechrist Medical Products, Model 3500HL, Anaheim, CA 92806, and the % oxygen gas monitor from Ohio Medical, Model 5100, Madison, WI 53707.

is that a much lower FiO_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_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

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and not altered when nitrogen gas is substituted for oxygen to ventilate bubble oxygenators,[1,2] Emboli counts from membrane oxygenator circuits are lower than those of a bubbler circuit.[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 deletrious and fatal than oxygen or carbon dioxide.[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.[5] However, the nitrogen gaseous emboli that do perfuse the CPB patient are probably more harmful than oxygen emboli. Spencer documented the cardiotomy 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 cardiotomy reservoirs that are effective in gas emboli entrapment. Closed or open venous blood reservoirs, with or without integral cardiotomy return, should be evaluated in terms of their ability to trap gaseous emboli. (Personal communication, James Pacek) An integral cardiotomy reservoir should be a minimal source of emboli to an otherwise "closed" system.

The possible hazardous effects of high arterial blood pO_2s have been measured and referenced in regard to minimizing ECC arterial line emboli.[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.[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 Dearing). 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.[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.[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 [2] and [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.[7]

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