Nitrogen Gas: A Possible Contraindication In Bubble Oxygenators

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ABSTRACT

An ultrasonic Doppler was used to monitor embolic activity in the arterial line of an extracorporeal circuit. No differences in embolic activity were observed when either 100% N₂ or 95% O₂-5% CO₂ gases were swept through a bubble oxygenator.

Information is presented suggesting that nitrogen or air microemboli are more deleterious than oxygen or carbogen microemboli. Consequently, this article recommends that the use of compressed air or nitrogen should be contraindicated in bubble oxygenators. Since the cardiotomy suction is a major source of nitrogen microemboli, this article also emphasizes that the cardiotomy suction be minimized and that a pressurized cardiotomy return be prevented from directly entering the oxygenator.

INTRODUCTION

Oxygen and oxygen-carbon dioxide mixtures have been the principle sweep gases for bubble oxygenators. The bubbling of these gases in blood can produce pathological microemboli. A number of efforts, therefore, have been made to reduce these emboli. Improved oxygenators are now being employed which require lower gas to blood flow ratios, arterial microfilters are routinely incorporated into extracorporeal circuits, and meticulous care is being taken to prevent embolic producing events. One technique which is used to reduce high oxygen tensions and subsequent oxygen microemboli is to mix compressed air or nitrogen gas with oxygen through a bubble oxygenator. Little is known about this technique since it hasn’t been demonstrated to reduce the total number of microemboli or to render any beneficial effects. Moreover, this technique is questionable for two reasons. First, nitrogen gas is 51% as soluble as oxygen in water at 37°C. Therefore, a greater number of microbubbles per equal volume of sweep gas from nitrogen than from oxygen could be expected to remain suspended in blood in a bubble oxygenator. Secondly, air or nitrogen emboli have been observed to have a more pronounced effect than oxygen emboli. This technique, therefore, raises two questions:

1) Does sweeping nitrogen gas or compressed air through a bubble oxygenator reduce gaseous microemboli?

2) What source of gaseous microemboli is more deleterious to the patient, oxygen or nitrogen?

This article suggests answers to these questions.

Does nitrogen gas reduce gaseous microemboli?

An in vitro extracorporeal circuit using a bubble oxygenator was primed with water and maintained at normothermia. An ultrasonic Doppler probe was incorporated into the arterial line and embolic activity monitored at an 11 megaHertz frequency with a Parks 806 Doppler. This instrument does not estimate the size or number of particles detected. However, the sensitivity of ultrasound at detecting embolic activity in extracorporeal circuits has been
Figure 1. Embolic activity is recorded when 6 L/min of either 95% O2-5% CO2 or 100% N2 is swept through a bubble oxygenator. There appears to be no difference in embolic activity.

Embolic activity is recorded when 6 L/min of either 95% O2-5% CO2 or 100% N2 is swept through a bubble oxygenator. There appears to be no difference in embolic activity. Water flow was maintained at 6 L/min with a roller pump. Gas flow through the oxygenator was filtered with a 0.22 micron filter and calibrated to deliver 6 L/min. Either a 95% O2-5% CO2 mixture or 100% nitrogen gas was swept through the oxygenator at the same gas pressure. Figure 1 shows the recorded embolic activity of the two different gases at the same flow rate.

Since there was no observed difference in embolic activity between the two gases at that ultrasonic frequency, it appears as though nitrogen gas creates as many emboli as carbogen gas at equal flow rates. Clark et al., on the other hand, reported that the rates of microemboli production increased in an in vivo study when nitrogen was added. Paterson et al. also reported that helium, argon, or nitrogen produced as many particles as oxygen. Thus, mixing nitrogen with oxygen to reduce high oxygen tensions would not reduce microembolic activity. The next question, then, is whether or not nitrogen microemboli are more deleterious than oxygen microemboli.

Which gas is more deleterious?

A number of studies suggest that the effects of arterial air emboli, which is comprised of 80% nitrogen, are more pronounced than oxygen emboli. Landew et al. perfused dogs with a bubble oxygenator and incorporated a bubble counting chamber. The group perfused with compressed air had a higher mortality than the oxygen groups. They concluded that air microbubbles are more deleterious than oxygen microbubbles. Approximately twice as much oxygen as air is required to produce either post perfusion syndrome or death. Fries et al. reported that 1-1.25 cc/kg body weight of air was only necessary to kill half the dogs tested while 2-3 cc/kg of oxygen was required. Even venous air emboli evoke a greater response than oxygen or carbon dioxide emboli. Spencer and Oyama found that intravenous injections with nitrogen caused a greater evaluation in right ventricular pressure, decrease in pulmonary blood flow and lower arterial oxygen tensions than with oxygen or carbon dioxide. They also found that one out of five animals intravenously injected with oxygen and three out of five injected with nitrogen produced distinct Doppler bubble signals in the brachiocephalic artery. Carbon dioxide did not embolize the systematic circulation. One group of investigators observed a higher alveolar pH.

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and a lower pCO₂ after a venous embolus. Thus, the deleterious effects of air or nitrogen emboli are greater than oxygen or carbon dioxide emboli.

DISCUSSION

The oxygenator is not the only source of nitrogen microemboli. Cardiotomy suction is another source of arterial gaseous microemboli as a result of the decreased solubility of nitrogen. Gallagher and Pearson suggested that nitrogen emboli from the cardiotomy suction are potentially more dangerous than those originating from the oxygenator. A pressurized cardiotomy return, therefore, should not be allowed to go directly into the oxygenator because of the nitrogen content of air.

Although arterial line filters reduce gaseous microemboli, they do not totally eliminate all microemboli. Nitrogen gas or compressed air, therefore, should not be used even if an arterial line filter is employed.

The effects of nitrogen gas in a membrane oxygenator are unknown at this time and should be investigated.

CONCLUSION

Nitrogen microemboli are more deleterious than oxygen or carbogen microemboli. Therefore, sweeping nitrogen or compressed air through a bubble oxygenator should be contraindicated until the technique has been demonstrated to have a beneficial effect. Cardiotomy return should be prevented from entering the oxygenator directly.

REFERENCES


