Science Letter

Financial and environmental impacts of using oxygen rather than air as a ventilator drive gas

Concern regarding 'wasting' oxygen as a drive gas for anaesthesia machines has been raised during the COVID-19 pandemic, and is associated with acute worsening of longstanding oxygen shortages in low and middle-income countries [1-3]. The American Society of Anesthesiologists has encouraged conversion of anaesthesia machine drive gas from oxygen to air [4]. We estimated the annual financial and environmental impacts of using air rather than oxygen as a drive gas for anaesthesia machines in an Australian metropolitan hospital.

Pneumatic ventilation, for mandatory or supported spontaneously-triggered ventilation, involves the use of a drive gas separate and in addition to fresh gas flow, which enters the compartment that houses the bellows to compress them during inspiration. The drive gas used exceeds the patient's minute ventilation for mandatory ventilation, but is not used when a patient is spontaneously breathing while attached to the circuit containing the reservoir bag. The drive gas can be a pressurised supply of air or oxygen, routinely with oxygen as the default. Some anaesthesia machines have in-built electrically-driven ventilators instead of drive gas.

At our six theatre hospital we estimated 1,200,000 l of anaesthesia machine drive gas is used annually, assuming all six operating theatres are in use on weekdays and two at weekends, eight hours per day, 48 weeks per year and assuming that mechanical ventilation was utilised for one-third of the time, with the drive gas of 5 $l.min^{-1}$. We were unable to obtain the energy cost of oxygen production directly from the supplier; however, published figures indicate that the process of producing liquid oxygen, without considering any transport, requires 1 $Wh.l^{-1}$ [5]. Medical air is produced at the hospital via compressors. We viewed the hospital air compression system and sourced the associated machine specification sheets. We averaged the power and efficiency of multiple compressors, and included air cooling and drying requirements (Table 1).

Oxygen production requires approximately seven times the energy of air production. The annual difference of 1046 kWh at our site, when supplied by our local energy grid, is roughly equivalent to 1.12 tonnes of carbon dioxide [6], comparable to the emissions from a return flight between Melbourne and Kuala Lumpur [7].

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The financial cost of oxygen is relatively small, and an inadequate incentive for the conversion of anaesthesia machine drive gas from oxygen to air. We obtained cost data for converting drive gas from oxygen to air from our hospital's anaesthesia machine provider and this was more than A$1000 (£580, €686) per machine. Since using oxygen vs. air costs A$282 (£160, €189) more annually for all six machines, the simple payback time is approximately 30 years.

However, we also considered the moral aspect of resource efficiency. The COVID-19 pandemic has strained health services globally, including oxygen supply. Using oxygen, which requires energy and money to produce, for such a low-value function, is careless. In countries with uncertain oxygen supply, using it as a drive gas consumes a scarce resource when there is a readily available alternative. In high-income countries, addressing wasteful practice and being conscientious in our resource use are important responsibilities.

In conclusion, there is a relatively modest environmental benefit associated with changing ventilator drive gas from oxygen to air at our hospital, although this could be considered significant when applied throughout all hospitals globally. There is also only a weak financial benefit. More importantly though, in the global healthcare context, there is a moral rationale that high income countries should be more accountable for consumption and avoid unnecessary waste. We propose purchasing ventilators that either have in-built air compressors for drive gas, or are driven electrically; installing air as the drive gas for new, pneumatically driven ventilators; and individual anaesthetists and anaesthesia colleges/societies collectively advocating and engaging with ventilator manufacturers in order to reduce the cost of drive gas conversion.

E. Balmaks

S.E. Kentish

R. Seglenieks

J.H. Lee

F. McGain

Western Health, Footscray and University of Melbourne

Melbourne, Australia

Email: emilybalmaks@gmail.com

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Table 1. Annual energy and cost data for oxygen and air production for use as drive gas by six anaesthesia machines.

	Air				**Oxygen**	**Difference**
	Compression	*Cooling*	*Drying*	*Total*		
kW (machine design)	14.5 (average)	0.2	1.4			
Design flowrate (l gas.s^{-1})	32.4 (average)	32.4	156			
l gas.kWh^{-1}	8 050 (average)	600,000	400,000			
Wh.l gas^{-1}	0.124	0.0017	0.0025	0.13	1	0.87
kWh required for 1,200,000 l (one year's drive gas supply)				154	1200	1046
cents.l gas^{-1}					0.026	
cents.kWh^{-1}				19.2		
Cost for 1,200,000 l gas				AUD$30 (£17, €20)	AUD$312 (£180, €213)	AUD$282 (£160, €189)