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Editorial

In the light of COVID-19 oxygen crisis, why should we optimise our oxygen use?

COVID-19 oxygen crisis
Sustainable development
Oxygen production
Oxygen delivery
Oxygen wastage
Lack of oxygen

The current pandemic that is devastating the world has put our health systems to the test. Aside from the colossal influx of patients into hospitals and specifically intensive care units, we have constantly needed to be capable of adapting to new situations; from discovering and understanding a new pathology, to determining new therapeutic strategies, and developing as well as rolling out a large-scale vaccination operation.

Among these complications was the supply of oxygen, especially to patients in critical condition. Due to the key role of oxygen therapy, worldwide medical oxygen usage shot up [1]. One hospitalised COVID-19-positive patient takes up an estimated 14–43 cubic meters of oxygen over a two-week period [2]. In those patients that do become symptomatic, approximately 15% develop severe disease that requires oxygen support [3]. The importance of the supply of medical oxygen can be seen in India, in which a shortage of oxygen due to the pandemic resulted in the death of thousands. From March to mid-May 2021, the demand for oxygen in India rose by more than 14 times [2].

Albeit less dramatically, other countries also felt the consequences of oxygen shortages. In Mexico, containers of oxygen were stolen, and in Brazil, families denounced the death of their loved ones in videos turned viral [4,5]. In Peru, where the black market inflated oxygen prices, patients' families waited in the street for hours under surveillance to receive oxygen for their relatives in order to avoid violence and thievery [6]. Even richer countries like the United Kingdom were affected, and hospital had to be rationed at the peaks of the pandemic [7].

Faced with the amplitude of this worldwide oxygen crisis, several questions are brought to light:

1) What are the methods of medical oxygen production?
2) Is there an economic, environmental, or human impact to this super-production?
3) What can we, as professionals, do to limit overconsumption?

Since 2017, medical oxygen has been classified as an essential medication by the World Health Organization (WHO). Oxygen is primarily made up by liquification followed by fractional distillation of air. Air contains about 21% oxygen (O_2), 78% nitrogen (N_2), 0.93% argon (Ar), water vapour, and carbon dioxide (CO_2). Firstly, the air is filtered, then cooled to -200 °C. The water and CO_2 are retrieved, then the various gasses are liquified: O_2 at -183 °C, Ar à-186 °C, and N at -196 °C. The air then passes through a fractionating column and is slowly reheated to separate the various components at their respective melting points [8]; this process is highly energy consuming [9]. Air Liquide, one of the two giants that share 80% of the world oxygen market (the second being Linde), has bought back the world largest factory situated in South Africa in July 2020 for 440 million euros. Their main ambition is to reduce CO_2 emissions from this factory of about 30–40% by 2030 by modernising its installations, which is equivalent to 1.5 million tons CO_2 [10]. These numbers suggest the importance of the current environmental impact of the production of medical oxygen in this factory, as well as on a world-scale since the set-off of the pandemic. The transport, storage and all other steps involved in the usage of oxygen in a clinical setting, taking into account the carbon footprint of this treatment, also worsen the environmental impact of O_2 consumption [9]. Thus, Air Liquide only has 7 units of production spread throughout metropolitan France. Faced with increased demand, the rotation of cryogenic trucks transporting liquid oxygen from sometimes-distant production units to hospitals must be increased, which further worsens the carbon footprint.

Certain alternatives allow for a more environmentally friendly use of oxygen therapy. Medical oxygen can be produced thanks to oxygen generators at the heart of hospitals installed using PSA (Pressure Swing Adsorption) technology. This technology reduces the need for transport of oxygen and hence reduces the environmental footprint of oxygen production. These allow the separation of gasses from ambient air, the way that fractional distillation usually does. The air is compressed, filtered, and then passed through a zeolite sieve where nitrogen is adsorbed and released, leaving only oxygen. The generators pay for themselves in 2–3 years on average depending on the hospital. This period may even be shortened given the current climate and need for oxygen consumption. A French company, NOVAIR Médical, specialises in this domain for the last 40 years and exports these generators across the world.

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In addition to reducing the environmental cost of production, those using medical oxygen need to be wary of economising this precious gas. There are several possible routes of amelioration: firstly, in the operating theatre, during pre-oxygenation before administration of anaesthetic, it is common to find that respirators deliver very elevated levels of oxygen (up to 18 L/min) and without specific recommendation by societies with expertise in this area. The conference of experts concerning "difficult intubation" published by the French Society of Anaesthesia and Intensive Care (SFAR) in 2006 only recommends pre-oxygenation "at a sufficient flow rate" or at 10 L/min if the technique so-called "of the 8 vital capacities" [11].

Concerning the maintenance phase of anaesthesia, a study realised at the Curie Institute in Paris measured the average hourly consumption of O_2 according to different fresh gas flow rates (FGF's). It was found to be on average from 201 L/h for an FGF set above 1 L/min to 76 L/h in Concentration Objective Inhaled Anaesthesia (FGF 0.5 L/min) and decreased to 43 L/h for an FGF of 0.2 L/min, flow rate used in military anaesthesia due to oxygen contingency during external operations. Overconsumption at induction and the high flow rates per operation account for these outstanding figures. The use of low or even very low FGF's during the maintenance of inhaled anaesthetics also allows reducing the environmental impact of halogens by diminishing their consumption.

Few findings have been published concerning the consumption of oxygen of an operating theatre because until this pandemic, the deposit seemed infinite and of little economic and ecological importance. For example, the Princess Grace Hospital of Monaco consumed 213,000 m^3 of O_2 in bulk between May 2020 and 2021, and 975 m^3 of O_2 in bottles over the course of 2021! Of course, it was a special period of time. Other answers brought to us by the Institut Gustave Roussy allow us to estimate the consumption of oxygen of an operating theatre: for the entirety of the operating theatre (12 anaesthesia machines), oxygen consumption reached 1,800,000 L/year. In 2015, 84,051 m^3 of O_2 were consumed at this hospital. Anaesthesia machines therefore appear to consume only about 2% of hospital wall-mounted oxygen per year, which seems negligible. However, these numbers only take into account the oxygen consumption of anaesthesia machines in the operating theatre. Added onto this is that of patients under anaesthesia in spontaneous ventilation. For these patients, oxygen flow meters can remain open to high flow even when the patient is gone, since no system exists to cut flow when demand is gone. The measurement and reduction of oxygen consumption in hospitals should henceforth become an indicator of quality in healthcare establishments due to the shortage of resources and the resulting increase in prices.

On the environmental level, some sources report a carbon footprint of 67 $kgCO_2/m^3$ of liquid oxygen (unpublished Air Liquid data), in part linked to transport. Knowing that 1 L of liquid oxygen turns into 840 L of gaseous O_2, we can deduce a carbon footprint of 6.7 tons of CO_2 for oxygen at the Gustave Roussy Institute, which is not negligible. If we extrapolate this cost to 11 million anaesthesia procedures performed each year in France and to the total quantity of O_2 consumed in the world, heightened by the COVID-19 pandemic, this carbon cost is far from desirable.

These data thus provide a strong rationale for initiating a reflection on reducing the consumption of medical oxygen. In addition, perioperatively, hyperoxia has no impact on infection and wound healing at the operative site [12] and favours the development of atelectasis [13].

The COVID-19 crisis has therefore led us to question the environmental, economic, but above all human and ethical impact of oxygen. How can we accept to waste this vital resource, so costly from all points of view, when its absence has cost human lives and the situation could be improved simply enough? Just because water flows endlessly from our taps does not mean we should not conserve it. The same is true for all resources, including course oxygen. An orientation towards a more virtuous production from an environmental point of view is also desirable on the part of manufacturers.

Given the scale of the problem and the impending environmental and human challenges, it is therefore necessary to adopt a responsible attitude. Apprehension and action are needed!

Conflicts of interest

The authors have no competing interest to declare.

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