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PLASTIC BAGS AS PERSONAL PROTECTIVE EQUIPMENT DURING THE COVID-19 PANDEMIC: BETWEEN THE DEVIL AND THE DEEP BLUE SEA

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The COVID-19 pandemic has placed health care systems worldwide under strain unprecedented in recent times. Personal protective equipment (PPE) shortages in many countries have led to increasing reports on mainstream and social media (including the widely publicized #GetMePPE movement on Twitter) of improvised methods featuring household items.

One such setup featured the use of a transparent plastic bag placed around heads of practitioners with an airtight seal around the neck to protect against aerosolized droplets during endotracheal intubation, in lieu of goggles and an N95 respirator (Figure 1). This allows the operator to rebreathe his expired (but hopefully uncontaminated) air for a limited time during the procedure. Although this might offer better protection from infection than current Centers for Disease Control and Prevention recommendations for homemade cloth masks in situations of last resort, it also introduces risks of hypoxia and hypercarbia due to rebreathing (1,2).

Experiments on rebreathing have previously been reported, but were performed under sufficiently different conditions (breathing directly into a bag placed around the mouth) that extrapolation of results to the above setup might not be meaningful (2,3).

To study the limitations of the described setup, two of the authors (one male and one female, in their thirties with no prior cardiorespiratory disease) volunteered to have 70-L plastic bags prefilled with environmental air placed around their heads with an airtight seal around their necks. Heart rate and rhythm, respiratory rate, and oxygen saturation were monitored. The gas composition in the bag (fraction of inspired oxygen and carbon dioxide partial pressure) was continuously sampled with the gas analyzer module of an anesthesia machine (M-CAIOV, Datex Ohmeda, General Electric Company, Boston, MA) via a sampling line inserted into the bag. Each run was aborted when symptoms experienced were felt to be significant enough to impair the capacity to safely carry out a medical procedure, such as endotracheal intubation. At termination, time elapsed and subject's end-tidal carbon dioxide partial pressure were recorded. The experiments were then repeated, with the same bags prefilled with oxygen prior to use (results in Table 1).

In all cases, bag partial pressures of carbon dioxide rose quickly, resulting in significant hypercarbia at termination. This accounted for the breathlessness (the primary symptom that resulted in termination of the experiments), anxiety, and distress that both authors reported nearing the end of each run. Overall, the mean duration tolerated was short, although longer when bags were prefilled with oxygen (5 min vs 7.5 min). Only the environment in bags prefilled with air became hypoxic, although no oxygen desaturation below 94% occurred. These findings are consistent with our understanding of physiology, with hypercarbia being the major contributor of dyspnea and

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Figure 1. The described form of personal protective equipment as seen on a life-sized mannequin.

limiting factor for tolerance in this situation, secondarily compounded by hypoxia (4).

Our study demonstrates that users under real-life conditions will be under time pressure to complete all but the shortest procedures and may be subjected to distressing physiological and psychological effects during more prolonged use. They also may risk hypoxia (especially if the bag is not prefilled with oxygen) and serious carbon dioxide toxicity in situations where the option to abort an unexpectedly prolonged procedure may not be possible without resulting in significant patient harm (5). In addition, our findings suggest that prefilling the bags with oxygen may obviate the need for continuous oxygen insufflation via additional tubing during use because hypercarbia will limit use in this context long before hypoxia develops. This will have the advantage of simplifying the setup and reducing the risk that an already-vulnerable seal quality may be further compromised by the need to allow for additional inflow tubing.

If faced with no alternative but the use of such PPE, we suggest the following: choosing as generously sized a bag as possible without sacrificing functionality, trial runs to assess individual tolerance prior to actual use, and preoxygenation of bag and user and possibly mild hyperventilation prior to donning, to delay the onset of hypoxia and hypercarbia. Where possible, we also suggest having a second operator available to spot and keep time for the first, and to don and take over as a contingency during longer procedures. Capnography monitoring, if available, may be considered, although use must again be weighed against the disadvantages of increasing unwieldiness and complexity of the setup.

Risk-mitigation measures notwithstanding, the improvised PPE described above is manifestly inappropriate for all but the most dire of circumstances. Yet, that is the reality confronting many of our colleagues worldwide, who continually inspire us with their courage. We join the call urging that every effort be made to protect the safety of

Table 1. Physiological Parameters and Bag Gas Composition During Rebreathing Experiment

Bag Prefilled with:	Air				Oxygen			
	Subject A		Subject B		Subject A		Subject B	
Time Elapsed	Bag PCO_2 (mm Hg)	Bag FiO_2 (%)	Bag PCO_2 (mm Hg)	Bag FiO_2 (%)	Bag PCO_2 (mm Hg)	Bag FiO_2 (%)	Bag PCO_2 (mm Hg)	Bag FiO_2 (%)
1 min	23	18	12	19	15	64	11	71
2 min	32	16	22	17	28	61	18	69
3 min	48	14	29	16	35	60	26	64
4 min	51	12	34	15	42	58	31	60
5 min	55	10			47	56	35	57
6 min					51	55	42	54
7 min					55	53		
8 min					58	52		
Subject's $EtCO_2$ at termination (mm Hg)	59		50		67		52	
Subject's SpO_2 at termination (%)	94		98		98		100	
Time elapsed at termination (m:s)	5:20		4:40		8:37		6:31	
Mean time elapsed at termination (m:s)	5:00				7:34			

PCO_2 = partial pressure of carbon dioxide; FiO_2 = fraction of inspired oxygen; $EtCO_2$ = partial pressure of end-tidal carbon dioxide; SpO_2 = peripheral arterial oxygen saturation.
Subject A: Male, 38 years old, 184 cm, 80 kg.
Subject B: Female, 36 years old, 159 cm, 46 kg.

health care providers and patients by ensuring that appropriate PPE is made available where needed.

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