Masks, False safety and real dangers, Part 3:
Hypoxia, hypercapnia and physiological effects

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Abstract

Wearing a mask causes physiological changes to multiple organ systems, including the brain, the heart, the lungs, the kidneys and the immune system. We examine changes in oxygen and carbon dioxide concentrations in masked airspace that is available to the airways over the first 45 seconds of wear. Our findings of reduced oxygen and increased carbon dioxide in a masked airspace are not inconsistent with previously reported data. We also consider the range of injuries known to occur to the above-named organ systems in a state of hypoxia and hypercapnia. As an excretory pathway, carbon dioxide release by cells throughout the body, and then past the alveoli and then the airways and orifices, has not been previously challenged by deliberate obstruction in the history of the animal kingdom, except for relatively rare human experiments. Self-deprivation of oxygen is also unknown in the animal kingdom, and rarely attempted by humans. We examine the physiological consequences of this experiment.

MASKS and HYPERCAPNIA

Do masks cause systemic hypercapnia?

Airway obstruction is a long recognized cause of retention of carbon dioxide and respiratory acidosis. A sustained level of increased carbon dioxide stays inside of masked air, compared to room air, which in turn sustains a low level of hypercapnia. Rebreathing of exhaled air has been found to quickly elevate [CO2] in available air above 5000 ppm, and to increase arterial CO2 concentration and to increase acidosis.[1] The mechanism of mask-induced hypercapnia may also include the moisture on a mask trapping carbon dioxide from exhalation. Some carbon dioxide diffuses in the air, more so if dry, but some portion of it, trapped by water vapor and mask moisture, would form a weak, unstable acid with water, for re-circulation to the airways and lungs. The mechanism is that retention of CO2 causes an increase in PCO2. This is the primary disturbance in respiratory acidosis. It results in an increased concentration of both HCO3- and H+, which is measured as a lower pH.

Masks increase respiratory drive and bronchodilation in mild hypercapnia, from sensitive chemoreceptors picking up changes in pH of cerebrospinal fluid. Ultimately in severe hypercapnia, respiratory drive is actually depressed.

Hypercapnia is widely recognized to be an independent risk factor for death. [2 3 4 5] A number of organ systems are negatively impacted, including the brain, heart, lungs, immune system and musculoskeletal system. [6 7]

How quickly do masks increase carbon dioxide in the masked airspace?

We used a new calibrated carbon dioxide meter to measure ambient carbon dioxide in room air, and then inside the masked airspace of three different masks after donning each in turn. This experiment involved a disposable surgical mask, a N-95 mask and a cloth mask. We recorded carbon dioxide parts per million inside the masked airspace. The meter refreshed its readings at 5-second intervals, and we used those same intervals in recording CO2 parts per million. The maximum CO2 reading on the meter is 10,000 parts per million.

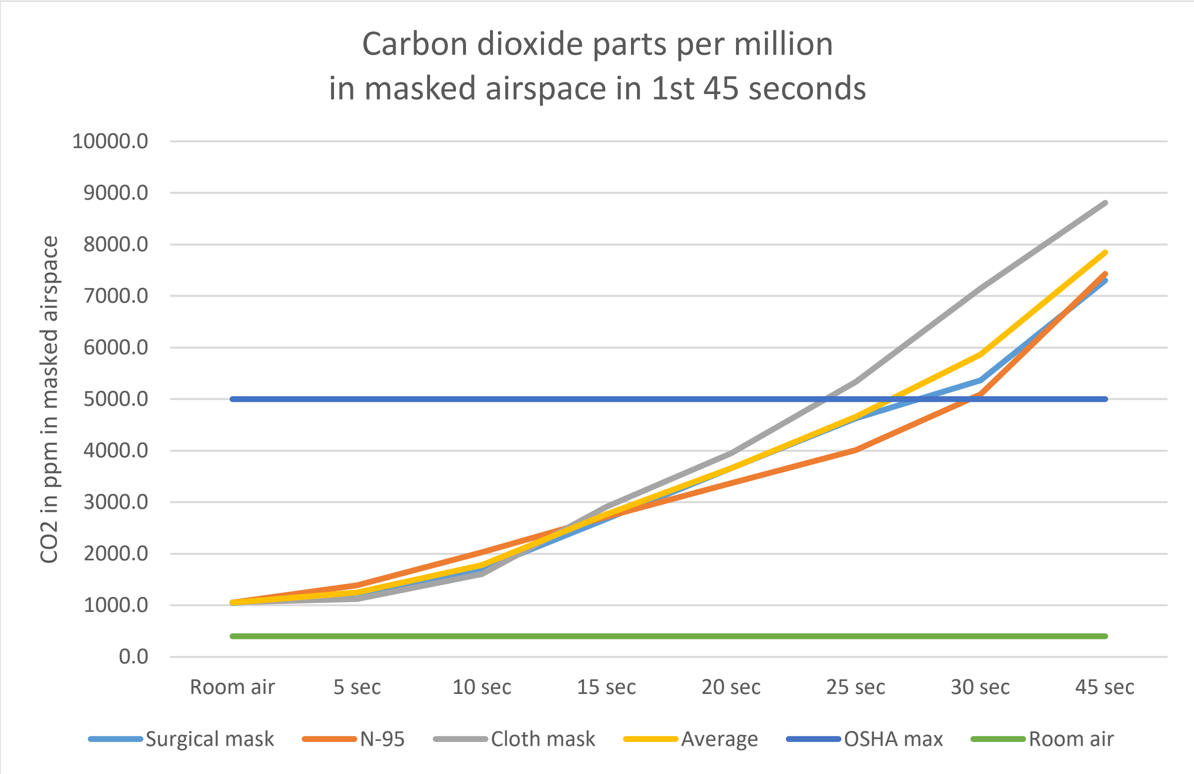
The table of those values are shown in Table 1, with the mean values shown for each 5-second interval in the first 45 seconds. After 45 seconds, the readings passed the maximum meter reading of 10,000 ppm [CO2], and were thereafter indeterminate from the meter.

Table 1: Measured [CO2] in masked airspace

	Room air	**5 sec**	**10 sec**	**15 sec**	**20 sec**	**25 sec**	**30 sec**	**45 sec**	**60 sec**	**75 sec**	**90 sec**
Surgical mask	1072	1298	1757	2256	2995	3215	3306	3074	3378	5483	7472
	1022	1086	1317	1667	2221	2792	3526	6479	7755	9964	>10000
	1074	1202	1502	2400	2619	2746	2948	4794	5994	8095	>10000
	1089	1211	1357	3090	5520	8230	9381	>10000			
	989	1265	1700	3257	4221	5412	6764	9465	>10000		
	1026	1363	2590	3392	4384	5377	6263	>10000			
Mean	**1045.3**	**1237.5**	**1703.8**	**2677.0**	**3660.0**	**4628.7**	**5364.7**	**7302.0**			
N-95	1050	1323	1834	2518	3184	4281	4689	7042	9684	>10000	
	1037	1517	3360	4133	4708	5315	5394	9082	>10000		
	1049	1475	1599	1800	1911	2773	6346	6563	>10000		
	1083	1292	1834	3312	3730	3901	4140	5692	7855	>10000	
	1073	1450	1975	2621	3820	4407	5629	7279	9240	>10000	
	1033	1266	1583	1926	2874	3392	4371	8921	>10000		
Mean	**1054.2**	**1387.2**	**2030.8**	**2718.3**	**3371.2**	**4011.5**	**5094.8**	**7429.8**			
Cloth mask	1084	1115	1718	2218	2725	3300	4914	6494	8410	>10000	
	1066	1057	1558	2467	3644	6369	8480	>10000			
	1050	1189	1686	3573	4400	5080	5768	8966	>10000		
	1062	1200	1685	4129	5848	7863	>10000				
	1051	1078	1430	2301	3580	5087	8555	>10000			
	1044	1115	1569	2772	3503	4321	5149	7385	9260	>10000	
Mean	**1059.5**	**1125.7**	**1607.7**	**2910.0**	**3950.0**	**5336.7**	**7144.3**	**8807.5**			

If we look at the time in which our readings did not yet exceed the maximum of the meter, then we have the following graph, Graph 1, of the average rise in carbon dioxide concentration inside the masked air for each mask, as [CO2] rose over the first 45 seconds of wear.

Graph 1



The blue horizontal line in Graph 1 represents the maximum allowable average CO2 concentration in workspace air during an 8-hour work shift, by the Occupational Safety and Health Administration (OSHA) of the US Department of Labor.[8] The green horizontal line represents typical [CO2] in room air, which is 400 parts per million.

After donning each mask, we see that [CO2] in the masked airspace rose above acceptable OSHA limits within the first 30 seconds.

The concentration of carbon dioxide rises similarly during the time of wearing each kind of mask. These findings are consistent with known data on the carbon dioxide concentration of available airspace inside of a mask.[9]

Industrial workspace standards established by OSHA for carbon dioxide concentration in the workspace are for ambient room air, and these have been established since 1979. It is not the case that OSHA has mandated specific CO2 concentrations for masked airspace. However, we examine these standards for available room air, and compare masked airspace to them, because in both cases we may consider [CO2] concentration in the air that is available to the airways and the lungs.

The Food Safety and Inspection Service of the United States Department of Agriculture notes that carbon dioxide gas is used to euthanize both poultry and swine.[10] Concentration of this gas is therefore of concern regarding the use of masks by human beings. That government agency publishes the following warnings:

5,000 ppm = 0.5% is the OSHA Permissible Exposure Limit (PEL) for 8-hour exposure, [11] averaged over the workday. Each of our masks surpassed that level within the masked airspace in the first 25 to 30 seconds of wear.

At 10,000 ppm of short exposure, OSHA says there are typically no effects, possible drowsiness.

At 20,000 ppm, the Food Safety and Inspection Service advises: "Do not enter areas where CO2 levels exceed 20,000 ppm until ventilation has been provided to bring the concentration down to safe levels." We should remember here that each of the masks we studied rose to half of this concentration within the first minute alone.

At 30,000 ppm = 3% [CO2], there is "moderate respiratory stimulation and increased heart rate and blood pressure."

At 40,000 ppm = 4%, OSHA finds [CO2] to be "immediately dangerous to life or health." [12]

Hypercapnia is known to rapidly cause intracellular acidosis in all cells in the body. There is no way to wall off the damage to only affect the lungs, due to constant gas exchange. That is, there is no known way to restrict hypercapnic effects to only the lungs.

The effects of hypercapnia progress in this order: Compensatory attempt at respiratory ventilation, labored breathing, hyperpnea; nervous system changes with changes in motor skills, visual acuity, judgment and cognition, cerebral vasodilation with increasing pressure inside the skull and headache, stimulation of the sympathetic nervous system, resulting in tachycardia, and finally, in case of extreme hypercapnia, central depression.[13] [14]

Hypercapnia effects on the lungs and immune system

Exhaled breath contains about 5% = 50,000 ppm carbon dioxide. This is more than 100 times the average of room air which is about 0.04% [CO2]. Exhaled [CO2] is 10 times the upper limit permitted by OSHA in ambient air. Yet each of us exhales this concentration with every breath. Should we re-breathe our own exhaled breath?

A study of healthy healthcare workers found increased [CO2] and decreased [O2] in the respiratory dead space inside a N95 filtering respirator while walking on a treadmill. Within one hour of use, these were “significantly above and below, respectively, the ambient workplace standards.”[15] The exhalation valve of the N95 masks did not significantly change its impact on P(CO2).

Hypercapnia has a number of damaging effects on the lungs. Those effects seem to begin with disruption of Na+-K+-ATPase, which leads to impaired alveolar fluid reabsorption. This results in alveolar edema, which in turn obstructs optimal gas exchange.[16] Hypercapnia also inhibits repair of alveoli by impairing proliferation of alveolar epithelial cells via inhibition of the citric acid cycle and resulting mitochondrial dysfunction.[17]

Cilia are made immotile by hypercapnia, along with mask changes in humidity and temperature in the upper airway. This leads to predisposing mask wearers to lower respiratory tract infections by allowing deep seeding of oropharyngeal flora.[18] The lower respiratory system is usually sterile because of the action of the cilia that escalate debris and microorganisms up toward the orifices. Impairment of this process, such as in hypercapnia, may partly explain a correlation of hypercapnia with increased mortality from pulmonary infections.

Hypercapnia correlates with increased mortality in hospitalized patients with community-acquired pneumonia.[19] This seems to be due to a number of factors, including that hypercapnia inhibits IL-6 and TNF as well as inhibiting immune cell function generally,[20] including alveolar macrophages.[21]

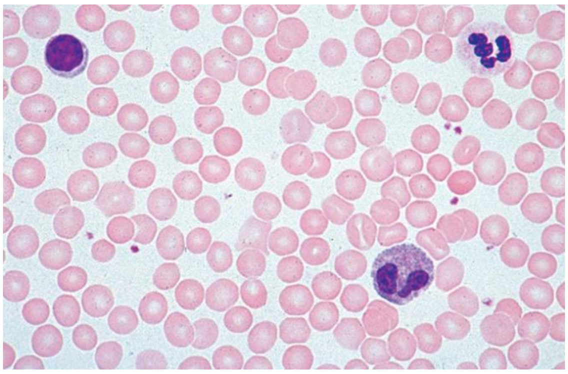
Hypercapnia was found to downregulate genes related to immune response. The researchers that had studied this in depth found that “hypercapnia would suppress airway epithelial innate immune response to microbial pathogens and other inflammatory stimuli.”[22] They also found suppressive effects of hypercapnia on macrophage, neutrophil and alveolar epithelial cell functions. Hypercapnia was found to decrease bacterial clearance in rats.[23]

In our previous paper in this series, we found a historical correlation with a hypercapnic practice, specifically mask-wearing, and a severe surge of bacterial pneumonia deaths.[24] This time period was mis-named the Spanish Flu, due to a number of reasons, too extensive for this paper. Dr. Anthony Fauci’s research team found that every cadaver exhumed from that time in 1918 – 1919 showed the cause of death was bacterial pneumonia, secondary to typical upper respiratory bacteria.[25]

Common and life-threatening diseases of impeded air flow include both obstructive disorders such as asthma, COPD, bronchiectasis and emphysema, as well as restrictive disorders, such as pneumothorax, atelectasis, respiratory distress syndrome and pulmonary fibrosis.

Hypercapnia effects on the blood

Excess carbon dioxide is buffered exclusively in the intracellular fluid, especially in red blood cells. CO_2 crosses cell membranes by diffusion, and combines with water to convert to H^+ and HCO_3^-. The hydrogen is then buffered by intracellular proteins such as hemoglobin and organic phosphates. The price paid by the red blood cells for this buffering is seen in the comparison of normal red blood cells on the left versus the damaged and depleted red blood cells on the right.



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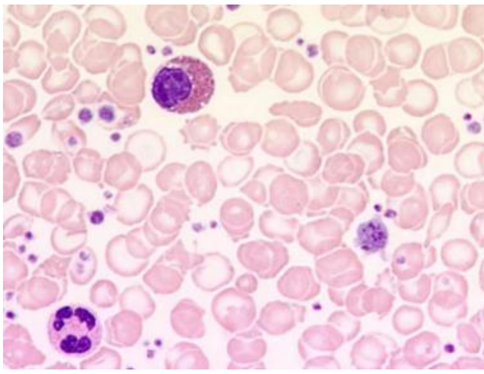

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The above photo on the right demonstrates secondary polycythemia.. This is a known consequence of hypoxia. This abnormal blood finding may also correlate with dehydration from wearing a mask. The US National Institute of Occupational Safety and Health (NIOSH) says that “particular features of PPE can impose a physiological . . . burden on the healthcare worker.” And “dehydration can be a significant problem while wearing PPE.”[26] Individuals suffering from dehydration are at risk for relative erythrocytosis, which can manifest as polycythemia vera.[27] Polycythemia vera is an independent risk factor for other cancers, commonly treated with lifelong blood thinning medication. Polycythemia develops slowly over years. Are today’s mask wearers at future risk of developing this blood cancer?

Hypercapnia effects on the kidneys

The kidneys are tasked with compensating for the damage inflicted on the blood stream by respiratory acidosis. They must excrete hydrogen ions and reabsorb the newly made HCO_3^-. The Henderson-Hasselbalch equation indicates the extent to which increased HCO_3^- compensates for the acidic condition.

$$pH = pK + \log[HCO_3^-]/(P_{CO_2})$$

The [HCO3-] is a reflection of renal or metabolic compensation, whereas the PCO2 reflects the primary disturbance, where airway obstruction created an acidemia.[28]

The kidneys show decreased GFR and decreased urine output, as well as increased renal vascular resistance, as a result of hypercapnia.[29] Aciduria increases as a compensatory mechanism to excrete acid. This in turn damages tubules and has been shown to worsen kidney function in those with established chronic diseases.[30]

Hypercapnia effects on the cardiovascular system

A hypercapnic patient may be warm, flushed and tachycardic. A bounding pulse and sweating may also be present. Arrhythmias may be present if there is significant hypoxemia. Arterial pCO2 above 90 mmHg is not compatible with life, because hypercapnia is necessarily accompanied by hypoxemia, in this case by pO2 = 37.[31] It has been noted that masked patients are often found to be tachycardic, to be discussed more further on in this paper.

Hypercapnia effects on the central nervous system

Central nervous system effects, such as headache, fatigue, dizziness and drowsiness are common effects of chronic obstructive pulmonary disease (COPD),[32] In this patient cohort we also see defects in proprioception, instability of posture and gait, as well as falls, with strong evidence that these result from hypercapnia.[33] There is a progressively increasing sedation from mask use and increased intracranial pressure. Headaches are a common complaint of mask wearers, and are found to be attributable to hypercapnia.[34] Increases in PCO2 lead to increases in cerebral flood flow and cerebral blood volume, as well as a resulting intracranial pressure.[35] These are consistent with findings through the rest of the body.

Slowed performance of reasoning tasks was observed at 20 minutes of inhaling 4.5% to 7.5% [CO2]. [36] When subjects were exposed to 2,500 parts per million carbon dioxide in room air, it was found that their decision-making ability declined by 93%, which was comparable to being drunk or having a head injury.[37] At this same level of [CO2], it was also found that visual performance suffered.[38] We measured this same level of [CO2] inside masked airspace at 15 seconds.

Even smaller CO2 concentrations had deleterious effects. CO2 exposure beginning at 1000 ppm affected cognitive performance, such as problem resolution and decision-making.[39] We measured 1000 ppm [CO2] in masked airspace within the first few seconds of wear.

MASKS and HYPOXIA

Masks create hypoxia in the wearers

A study of 53 surgeons who were non-smokers and without chronic lung disease were shown to have a decrease in saturation of arterial pulsations (SpO2) when performing surgery while masked. Oxygen saturation decreased significantly after the operations in both age groups, with a greater decrease in surgeons over the age of 35.[40]

A study of 39 end-stage renal disease patients wearing N-95 masks for 4 hours during hemodialysis were found to have significantly reduced PaO2 over that time. The average drop in PaO2 was from a baseline PaO2 of 101.7 to 15.8, $p = 0.006$. Respiratory rate increased from 16.8 to 18.8 respirations per minute, $p < 0.001$. Chest discomfort and respiratory distress were also reported by the subjects.[41]

Hypoxia is a health hazard

Hypoxia is deadly. Each year, many workers are injured or die due to oxygen deficiency.[42] "There have been reports of workers who have opened a hatch to an O2-deficient atmosphere and died with only their head inside the hazard. The low level of O2 resulted in a feeling of euphoria and the workers could not comprehend that they only needed to lean back out of the hatch to save their lives."[43]

The issue of mask wearing is especially critical for children. In children, any hypoxic condition is even more of an emergency than it is for an adult. This is partly due to their more horizontal ribs and barrel-shaped chest, resulting in children relying primarily on diaphragm muscles for breathing, not nearly so much intercostal muscles, as in adults. These diaphragm muscles have proportionately fewer type I muscle fibers, resulting in earlier fatigue.[44] Also, a child's tongue is relatively large in proportion to the size of the pharynx, and the epiglottis is floppy.[45] These anatomical differences make a child potentially more vulnerable than an adult to injury from hypoxic assault.

We consider it urgent for children to be released from mask "mandates," based on this information.

Hypoxia in masked airspace

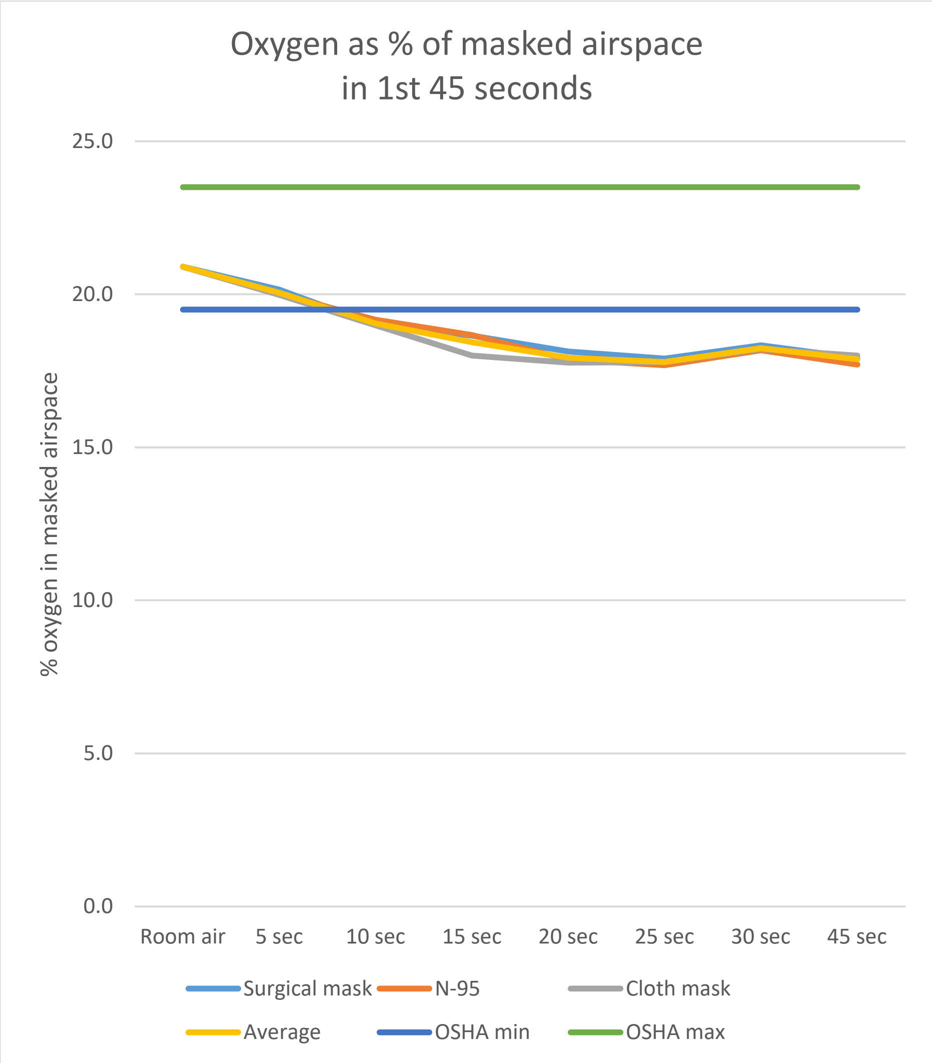
In order to determine the percent of oxygen in masked airspace, we ran 6 trials each for 45 seconds of 3 types of masks: a disposable surgical mask, a N-95 mask and a laundered cloth mask.

We charted the results as follows, showing the average for each type of mask, compared to OSHA workspace requirements for air available to the airways.

Table 2 Measured [O2] in masked airspace

	Room air	**5 sec**	**10 sec**	**15 sec**	**20 sec**	**25 sec**	**30 sec**	**45 sec**	**60 sec**
Surgical mask	20.9	20.2	19.2	19.1	18.5	19.1	18.4	18.1	17.7
	20.9	20.1	18.9	18.7	18.1	17.7	18.1	17.9	17.4
	20.9	20.3	18.7	18.1	18.1	18.2	17.9	17.6	17.7
	20.9	19.6	19.1	18.7	17.7	17.1	18.5	17.1	17.5
	20.9	19.8	19.1	18.9	18.2	17.4	18.7	18.6	16.7
	20.9	20.9	19.0	18.4	18.2	17.9	18.4	18.2	18.6
Average	**20.9**	**20.2**	**19.0**	**18.7**	**18.1**	**17.9**	**18.3**	**17.9**	**17.6**
N-95	20.9	20.0	19.1	18.1	17.7	18.2	18.4	17.2	17.4
	20.9	19.7	19.3	18.5	17.3	18.0	18.3	18.2	16.7
	20.9	19.6	18.1	18.6	18.4	18.2	17.8	17.5	17.1
	20.9	20.1	19.4	19.1	18.0	17.6	18.3	17.2	17.8
	20.9	19.8	19.3	19.0	17.8	16.9	18.1	18.2	17.4
	20.9	20.9	19.8	18.7	18.0	17.2	18.1	17.9	17.7
Average	**20.9**	**20.0**	**19.2**	**18.7**	**17.9**	**17.7**	**18.2**	**17.7**	**17.4**
Cloth mask	20.9	19.6	19.5	17.7	16.7	17.5	17.5	16.7	17.5
	20.9	20.1	19.2	17.2	17.1	16.9	17.1	17.0	17.4
	20.9	20.2	19.3	18.4	18.4	18.2	19.0	17.9	17.1
	20.9	20.0	18.9	18.6	19.0	19.8	19.3	18.8	18.7
	20.9	20.1	18.4	18.3	17.7	17.3	17.9	18.1	17.7
	20.9	19.9	18.6	17.8	17.7	17.0	18.5	19.5	17.1
Average	**20.9**	**20.0**	**19.0**	**18.0**	**17.8**	**17.8**	**18.2**	**18.0**	**17.6**

Graph 2



It can be seen from Graph 2 that all of the masks showed similar results, and that in each type of mask, available oxygen as a percentage of available air volume decreased to less than the OSHA required minimum of 19.5%[46] in less than 10 seconds of wear, and stayed below that threshold. Breathing seemed to be shallow until 30 seconds of wear. Then the wearer's responsive drawing of air through pores and side gaps and top gaps around the mask appeared to occur mostly at 30 seconds, but did not compensate adequately to return [O2] in the masked airspace back above the OSHA minimum requirement of 19.5% [O2] in available air.

The above findings are consistent with known decrease of oxygen concentration in the airspace inside of masks.[47] The standards for oxygen concentration in airspace available to workers has been so strictly enforced by OSHA that in a low-oxygen workspace, employee access must be restricted by using locks or barriers. Oxygen-level monitoring is required before entry, and the space must meet OSHA oxygen-level standards during the entire time that it is in use.[48] Is the space of available airflow to the human airways any less important to protect from low ambient O2, simply because it is the very small space between the mask and the respiratory orifices?

The United States Code of Federal Regulations in paragraph (d) of 29 CFR 1910.134 “requires the employer to evaluate respiratory hazard(s) in the workplace, identify relevant workplace and user factors, and base respirator selection on these factors.” This “shall include a reasonable estimate of employee exposures to respiratory hazard(s) . . .” Exceptions are permitted “if the employer can meet the difficult evidentiary burden of showing that the oxygen content can be controlled reliably enough to remain within the ranges specified . . .”[49] Does this leave employers liable for injuries to workers who wear masks?

Hypoxia accompanies hypercapnia

Retention of carbon dioxide reduces oxygen availability, as in COPD. As CO2 builds up in alveoli, the available volume for oxygen in the airspace is reduced. “For each increment in the PaCO2, there will be a more than one-to-one decrease in the PaO2, which will result in severe oxygen deficits, as illustrated in the following graph.”[50]

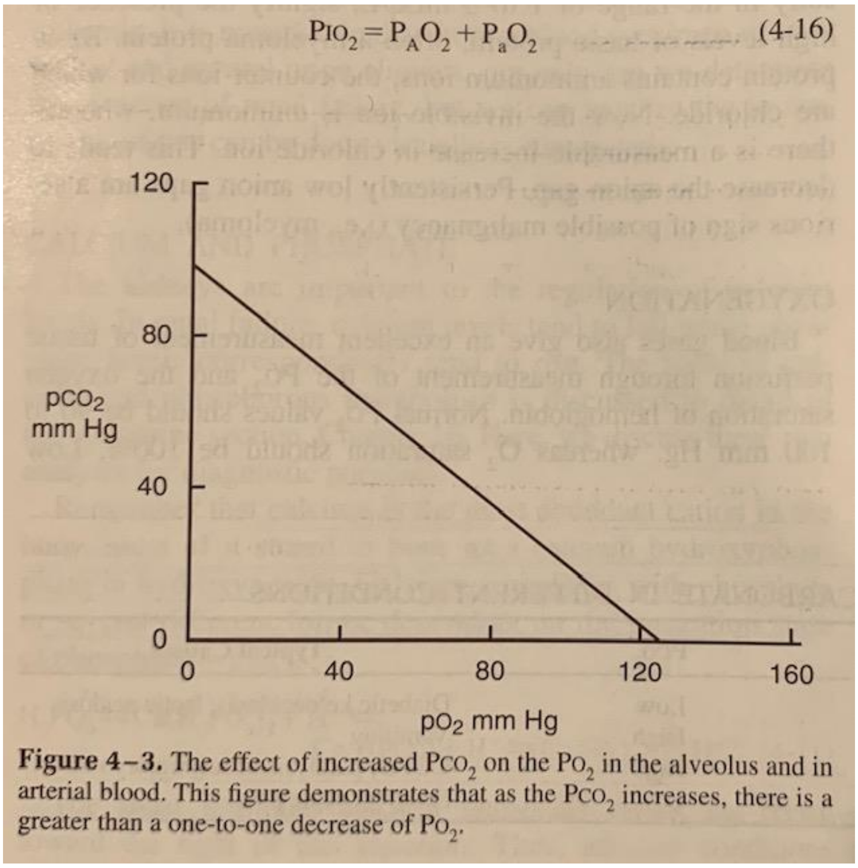


Figure 4–3. The effect of increased PCO_2 on the PO_2 in the alveolus and in arterial blood. This figure demonstrates that as the PCO_2 increases, there is a greater than a one-to-one decrease of PO_2.

From J Henry. Clinical Diagnosis and Management by Laboratory Methods. 19th ed. WB Saunders Co. © 1996.