The causes of hypoxemia and their relative contribution in COVID-19 respiratory failure: a combined MIGET and Dual-Energy CT study

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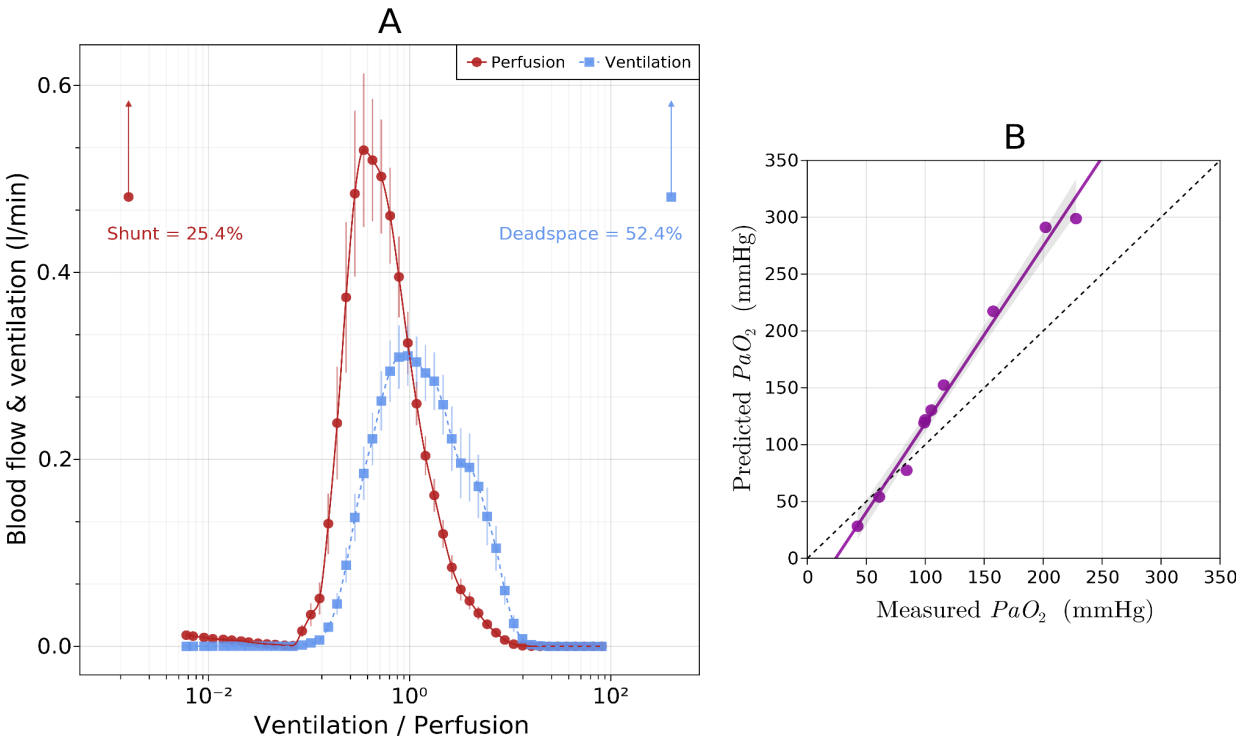
Introduction: The hypoxemia that often follows the COVID-19 infection is the most frequent cause of therapy escalation and death. While many speculations have been made over its genesis, an in-vivo assessment of its causes and their relative contribution is still lacking.

Methods: We studied 10 critically ill patients, intubated < 7 days. Infusion of 6 inert gases (SF6, ethane, cyclopropane, isoflurane, ether and acetone) took place while respiratory mechanics and hemodynamics were recorded. A time-aligned sample of arterial blood and mixed expired air through a heated mixing box were collected and analyzed with gas chromatography to recover the distribution of ventilation to perfusion (MIGET). The patient underwent a Dual-Energy Computed Tomography. The perfusion and the virtual unenhanced maps were analyzed to measure the distribution of tissue and blood volume.

Results: The population (51±15 years) had a PaO_2/FiO_2 of 172±86 mmHg and a mortality of 50%. MIGET showed a true shunt of 25±16% and a deadspace of 53±12%. The ventilation and perfusion were highly mismatched, with a LogSD, Q of 0.86±0.33 (normal ~0.3). Unexpectedly, we found also evidence of diffusion limitation and/or post pulmonary shunting. At the DECT, the lungs were heavy (1427 ± 357 g) and 100% of the patients had perfusion defects. Shunt was directly proportional to the blood volume distributed in the consolidated tissue (R^2 = 0.70, p = 0.003). We also found a homogeneous distribution along the sterno-vertebral axis of the blood volume normalized for the tissue volume.

Conclusions: Hypoxemia in COVID-19 derives from a rather unique combination of different pathological mechanisms, acting together. Blood entering the atelectasis is responsible only for shunt, but the pulmonary hypoxic vasoconstriction appears to be overall conserved.

FIGURE


A
Perfusion
Ventilation
Shunt = 25.4%
Deadspace = 52.4%
Blood flow & ventilation (l/min)
0.0
0.2
0.4
0.6
10^{-2}
10^{0}
10^{2}
Ventilation / Perfusion
B
Predicted PaO_2 (mmHg)
Measured PaO_2 (mmHg)
0
50
100
150
200
250
300
350