Normalising renal tissue oxygen tension with higher inspired oxygen concentration may be falsely reassuring. Reply to Br J Anaesth 2020;125 (2):192-200

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***Summary**: A recent study by Iguchi et al (Anaesth 2020;125(2):192-200) showed that measured renal tissue oxygen tension falls under anaesthesia and may apparently be normalised by increasing arterial oxygen tension. In reality tissue oxygen is a balance between supply, demand and diffusion and is not spatially homogeneous at capillary length scales. This apparent normalisation may be falsely reassuring as such measurements reflect a macroscopic spatial average and being disproportionately influenced by regions of peri-arterial hyperoxia with other areas of tissue remaining unaffected and potentially hypoxic. Therefore, clinicians should not caution before translating the apparently beneficial effects of supraphysiological arterial oxygen levels on measured renal tissue oxygen tension into clinical practice.*

Keywords: Renal perfusion; Tissue oxygenation; Anaesthesia; FiO2; Tissue Hypoxia

Editor- Iguchi and co-workers are to be congratulated on an interesting and well conducted piece of experimental work elucidating the effect of anaesthetic conditions on renal perfusion and oxygenation[1], which I read with interest. As part of their work they demonstrate reductions in renal tissue oxygen tension (PtO_2) in response to reduced renal under anaesthesia. However, the finding that PtO_2 can be restored non-anaesthetised levels by increasing inspired oxygen fraction (FiO_2) merits some further discussion.

As the authors quite correctly point out, PtO_2 is determined by a balance between oxygen delivery and consumption and is therefore sensitive to reductions in oxygen delivery.[2] However, oxygen diffusion is also an important factor which complicates the interpretation of this parameter.

Implantable probes of local oxygen tension have been successfully used clinically in the management of conditions such as traumatic brain injury for some years[3]. Although often thought of as localised probes, in reality their design inherently senses a macroscopic region of tissue (many capillary units). Such regions are not homogeneous. Tissue autofluorescence microscopy experiments have elegantly demonstrated substantial variation in redox state with periarterial tissue emission intensity consistent with higher levels of oxidative metabolism[4]. The PtO_2 measured with invasive probes reflects a spatial average over both periarterial and non-arterial tissue.

Whilst increasing renal blood flow could increase oxygen delivery, this seems unlikely as no such increase was demonstrated in a haemorrhage model when FiO_2 was increased.[5] Unlike the effect of increasing tissue blood flow, high arterial blood oxygen tensions (PaO_2, e.g. achieved by increasing FiO_2 as in reference[1]) do not substantially increase oxygen delivery because of the shape of the oxy-haemoglobin dissociation curve.

In silico simulations[6] suggest that whilst PtO_2 may be increased with supra-physiological PaO_2, this effect is predominantly due to peri-arterial hyperoxia with little or no change occurring in nonarterial regions. Thus substantial volumes of tissue remain unaffected by this manoeuvre and may even be hypoxic even when the PtO_2 is reassuring. This may be particularly undesirable given the potentially harmful effects of supra-normal PaO_2[7].

In summary, caution should be exercised before concluding that improvements in PtO_2 due to increasing FiO_2 necessarily represent a true state of metabolic rescue as this may be falsely reassuring. Clinicians should exercise caution before translating the apparently beneficial effects of supraphysiological FiO_2 on renal PtO_2 demonstrated in this work into clinical practice.

Declaration of interests

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Author contributions

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References

[1] Iguchi N, Kosaka J, Iguchi Y, et al. Systemic haemodynamic, renal perfusion and renal oxygenation responses to changes in inspired oxygen fraction during total intravenous or volatile anaesthesia. Br J Anaesth 2020;125 (2):192-200

[2] Kuper M, Soni N. Oxygen transfer: cascade or whirlpool? Current Anaesthesia & Critical Care 2003;14:58-65

[3] Menon DK, Ercole A. Critical care management of traumatic brain injury. Handb Clin Neurol. 2017;140:239-274.

[4] Chisholm KI, Ida KK, Davies AL et al. In Vivo Imaging of Flavoprotein Fluorescence During Hypoxia Reveals the Importance of Direct Arterial Oxygen Supply to Cerebral Cortex Tissue Adv Exp Med Biol 2016;876:233-239.

[5] Dyson A, Stidwill R, Taylor V et al. The impact of inspired oxygen concentration on tissue oxygenation during progressive haemorrhage. Intensive Care Med. 2009;35(10):1783-91.

[6] Kohler K, Nallapareddy S, Ercole A. In Silico Model of Critical Cerebral Oxygenation after Traumatic Brain Injury: Implications for Rescuing Hypoxic Tissue. J Neurotrauma 2019;36:2109-2116.

[7] Palmer E, Post B, Klapaukh R, et al. The Association between Supraphysiologic Arterial Oxygen Levels and Mortality in Critically Ill Patients. A Multicenter Observational Cohort Study. Am J Respir Crit Care Med. 2019;200(11):1373-1380.