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Essay

Cerebral oximetry: Three questions to ask☆

Lingzhong Meng[a,*], *Adrian W. Gelb*[b]

[a] *Associate Professor, Department of Anesthesia and Perioperative Care, University of California, San Francisco, California, United States*
[b] *Professor, Department of Anesthesia and Perioperative Care, University of California, San Francisco, California, United States*

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ABSTRACT

Cerebral oximetry based on near-infrared spectroscopy can non-invasively measure hemoglobin oxygen saturation in mixed arterial, venous and capillary blood in the brain. In order to determine if this is a clinically desirable monitor, we need to answer three questions in order. The first question is if cerebral oximetry monitors an important aspect of physiology. The second question is if the physiology can be optimized based on this monitor. The third question is if the outcome can be improved based on cerebral oximetry-guided clinical care. In this review, we share our answers to these three questions.

Oximetría cerebral: tres preguntas esenciales

Palabras clave:
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Fisiología esencial
Optimización de la fisiología
Mejora resultados

RESUMEN

La oximetría cerebral basada en la espectroscopia cercana al infrarrojo puede medir demanera no invasiva la saturación de oxígeno de la hemoglobina en la sangre mixta arterial, venosa y capilar en el cerebro. A fin de determinar si este monitor es deseable en la clínica, es preciso responder 3 preguntas, en su orden. La primera es si la oximetría cerebral monitorea un aspecto importante de la fisiología. La segunda es si se puede optimizar la fisiología con base en este monitor. La tercera es si se puede mejorar el desenlace mediante una intervención clínica basada en la oximetría cerebral. En esta revisión presentamos nuestras respuestas a estas 3 preguntas.

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* *Corresponding author at*: Department of Anesthesia and Perioperative Care, University of California San Francisco, 521 Parnassus Avenue, Suite C450, San Francisco, CA 94143, United States.
E-mail address: MengL@anesthesia.ucsf.edu (L. Meng).

Cerebral oximetry based on near-infrared spectroscopy (NIRS) is a non-invasive, easy-to-use and still evolving monitoring modality. The technology itself and the status of its clinical application have been recently reviewed.[1] Philosophically, the following three sequential qualifications characterize any monitor as being desirable (Fig. 1). The first is that it monitors an essential or important aspect of physiology. The second is that it facilitates the optimization of that essential physiology. The third is that it improves outcome based on monitoring and optimization of the physiology. In this review, we examine if cerebral oximetry meets these qualifications.

Question 1: Does cerebral oximetry monitor essential and important physiology?

The first question asks if what cerebral oximetry monitors qualifies as essential physiology. Different to pulse oximetry which monitors arterial blood hemoglobin saturation (SpO_2), cerebral oximetry monitors hemoglobin saturation in mixed arterial, venous, and capillary blood in cerebral tissue ($SctO_2$). As a result, $SctO_2$ is determined by two physiological considerations. The first is the proportional volumes of the arterial, venous and capillary blood in the brain region illuminated by cerebral oximetry. $SctO_2$ is higher if the saturated arterial blood is more and/or the desaturated venous blood is less, and vice versa. The volume percentage of different cerebral blood compartment is not fixed. It varies inter-individually and possibly between different brain regions in the same individual.[2] Moreover, it was suggested that it may change during hypoxia,[2] hypercapnia/hypocapnia,[3] neural excitation,[4] and phenylephrine administration.[5] The second consideration is the balance between cerebral oxygen supply and demand. Cerebral oxygen supply is determined by cerebral blood flow (CBF) and arterial blood oxygen content. If arterial blood oxygen content is stable, an increase in CBF will expand arterial blood volume and shift the volume ratio toward more arterial blood. Cerebral oxygen demand is determined by cerebral metabolic rate of oxygen. If cerebral oxygen supply is stable, an increase in cerebral metabolic rate of oxygen will expand venous blood volume and shift the volume ratio toward more venous blood. These physiological processes alter $SctO_2$ reading. Therefore, it can be challenging to decipher the exact cause of a change in $SctO_2$ when the needed supplementary information is not available. When cerebral metabolic rate of oxygen, arterial blood oxygen content, and the volume percentage of different blood compartments are all relatively stable, $SctO_2$ can be regarded as a surrogate of cerebral perfusion.

Tissue perfusion and oxygenation are essential physiological components because ischemia and hypoxia are (rapidly) harmful. Tissue perfusion and oxygenation are arguably the end point of all physiological management in the operating room and intensive care unit. However, they are not routinely monitored. Therefore, any device that can monitor indices of tissue perfusion and oxygenation may be useful. Cerebral oximetry is viewed as such a technology because (1) if the same brain region is monitored continuously in the same patient, the trend of change in $SctO_2$ reflects the balance between cerebral oxygen supply and consumption, and (2) if cerebral metabolic rate is relatively constant, $SctO_2$ is determined by oxygen delivery to the brain. Therefore, it can be stated that NIRS-based cerebral oximetry monitors essential and important physiology – the perfusion and oxygenation of cerebral tissue as long as all components of $SctO_2$-determing physiological processes are known or at a minimum considered.

Question-2: Can cerebral oximetry optimize the essential physiology?

Monitoring is clinically meaningless if nothing can be done about the physiology it monitors. The universal feature among the standard monitors such as blood pressure and pulse oximetry used in anesthetized patients is that something can be done based on the monitoring. For NIRS-measured $SctO_2$, intervention protocols aiming to increase $SctO_2$ when it is decreased (also known as cerebral desaturation) have been adopted in cardiac[6,7] and non-cardiac surgeries.[8] The protocols adopted by various studies are similar but with some variations.[6–8] An algorithm was proposed to treat intraoperative cerebral desaturation in a more systematic approach.[9] However, its validation is still awaiting multicenter study.

The guiding principle in the treatment of cerebral desaturation is to increase oxygen delivery to the brain, and/or decrease cerebral metabolic rate of oxygen. Increasing CBF can augment cerebral oxygen supply. Interventions that can be considered for CBF augmentation include: (1) increasing cerebral

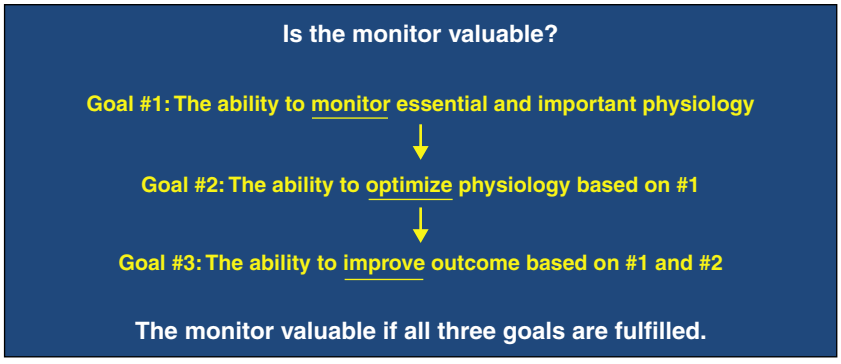

Fig. 1 – The three goals to qualify a monitor as a valuable one.

Source: Authors.