

that focuses on the tasks expected of the patient during the perioperative period is also believed to improve adherence to the guidelines and thus improve recovery.^{11–13} Prehabilitation can be perceived similarly. It is likely that patients who begin and establish a routine preoperatively find it easier to continue the routine postoperatively. Indeed, it has been found that intention increases rates of goal achievement, *only* in the absence of strong antagonistic habits.¹⁴ The preoperative period thus allows time to identify barriers¹⁵ and counterproductive habits early, which enables later adherence.

In conclusion, we would argue that the ability of the prehabilitation group to comply with the trimodal program earlier than the rehabilitation group after surgery simply suggests that prehabilitation was implemented successfully.

Competing Interests

The authors declare no competing interests.

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Effect of Thoracic Epidural Anesthesia on the Tolerance to Acute Normovolemic Anemia: Issues Warranting Comment

To the Editor:

I read with great interest the article by Pape *et al.*¹ in which the authors assessed the effect of sympathetic nerve blockade induced by thoracic epidural anesthesia (TEA) with ropivacaine on the tolerance of anesthetized pigs to acute normovolemic anemia (ANA). The authors made this assessment from a determination of the hemoglobin at which whole-body oxygen consumption ($\dot{V}O_2$) demonstrated supply dependency and decreased from the baseline value, the so-called critical hemoglobin (Hb_{crit}). Whole-body $\dot{V}O_2$ was calculated from the product of cardiac output, determined by thermodilution, and the difference in oxygen content of arterial and mixed venous blood samples. The authors found that the Hb_{crit} (2.5 ± 0.6 g/dl) was identical with and without TEA.

There are two issues pertaining to this study warranting comment. The first issue relates to the limitation inherent in using a systemic index of oxygen supply and demand. Although the authors acknowledge this fundamental shortcoming, it deserves to be underscored and more thoroughly discussed. Because the index represents an aggregate of the responses in the individual body tissues, it provides no organ-specific information. A constancy of whole-body $\dot{V}O_2$ during ANA either alone or

combined with TEA does not necessarily indicate that all organs were adequately perfused and well oxygenated. Critical decreases in oxygen supply (the product of blood flow and arterial oxygen content) in some organs could be masked by increases in oxygen supply in other organs. Canine studies in our laboratory and others have demonstrated widely heterogeneous changes in regional blood flow during ANA.²⁻⁴ The findings showed that the blood flow increases in the heart, brain, and spinal cord were sufficient to maintain oxygen supply until hematocrit was reduced to less than 10% but that the flow responses in the peripheral organs resulted in decreases in oxygen at a much higher hematocrit.⁴ Noteworthy was that renal blood flow remained constant during ANA, with the result that oxygen supply decreased in parallel with hematocrit; at a hematocrit of 10%, renal oxygen supply was only one fourth of the baseline value.⁴ Because of a diffusive shunt for oxygen (owing to the close proximity of the interlobar arteries and veins), much of the oxygen supplied to the kidney bypasses the tissue.⁵ Thus, unlike the body as a whole, the kidney cannot increase oxygen extraction to compensate for decreases in oxygen supply. A rat study has demonstrated that both renal VO_2 and tissue Po_2 declined in parallel during progressive decreases in hematocrit.⁶ These findings suggest that the kidneys may be at particular risk of hypoxic damage during ANA. The systemic endpoints used by Pape *et al.* were not sensitive to this potentially severe, localized imbalance between oxygen supply and demand.

The limited blood flow responses during ANA in the peripheral organs, including the kidney, are consistent with a countervailing vasoconstrictor mechanism to offset the effect of local metabolic vasodilation. Engagement of the sympathetic nerves has been suggested, based on their role in the reflex response to other systemic cardiovascular stresses, such as hemorrhagic shock,⁷ and the ability of diluted blood to stimulate the arterial chemoreceptors,⁸ which would provide the sensory limb for activation of these nerves. Reflex activation of the sympathetic nerves operates to support aortic pressure, and, because it is selective to the peripheral organs, blood flow redistributes toward the heart and brain. The attenuation of this pathway by TEA might favor perfusion of the kidney and other peripheral beds under sympathetic control during ANA, but it would do so at the expense of a decrease in perfusion pressure, which could jeopardize blood flow and oxygen supply to the heart and brain. These regional responses must be evaluated before it can be concluded that it is safe to use TEA in the context of ANA.

A second issue relates to the pig model used by Pape *et al.* A limitation of this model was that the baseline hemoglobin was only 7.7 ± 0.8 g/dl, which is considered severe anemia in the human. This value for hemoglobin yielded a proportionally low value for arterial oxygen content (approximately 10 ml/dl) and a high value for the systemic

oxygen extraction ratio (approximately 55%). This baseline condition would be expected to reduce the adaptive capability of the systemic circulation to the stress of ANA. The clinical applicability of the current findings must remain an open question.

Apart from the above concerns, the authors have offered provocative and interesting findings, which can serve as a springboard for further studies focusing on the tolerance of individual organs, such as the kidney and heart, to both ANA alone and combined with TEA. The use of an animal model with a hemoglobin concentration closer to that of the human would enhance the clinical relevance of such studies.

Competing Interests

The author declares no competing interests.

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In Reply:

We thank Dr. Crystal for his interest in our article entitled “Thoracic Epidural Anesthesia with Ropivacaine Does Not Compromise the Tolerance of Acute Normovolemic Anemia in Pigs,”¹ and we do very much appreciate his comments. In summary, Dr. Crystal addresses two important points: first, the limitation of the whole-body approach applied in our