LETTER

To dip or not to dip: Reconciling optical imaging and fMRI data

Several optical studies have reported a brief initial increase of deoxyhemoglobin (1), which is consistent with an initial dip observed in the functional MRI (fMRI) signal, evoked by local neuronal activity. This effect is small and not always present (2), but it has stirred great interest because it may reflect a rapid increase of oxidative metabolism before increases in blood flow and, thus, may have a narrower spatial spread than the main positive hemodynamic response.

In a recent elegant and comprehensive study, Sirotin et al. (3) investigated the spatiotemporal specificity of intrinsic optical imaging signals at different wavelengths and for different chromophores (oxygenated [HbO], deoxygenated [HbR], and total hemoglobin [HbT]) in the primary visual cortex of macaque monkeys. They found that the early light intensity drop is due to HbT change and not due to an increase in HbR (i.e., caused by oxygen metabolism). Although both HbO and HbR have been determined to evolve monophasically, the light intensity change at certain wavelengths can be multiphasic. Nevertheless, the early and poststimulus changes in HbO and HbT were observed to be spatially narrower than the oxygenation and HbT changes during "rebound." This initial increase in HbT was solely due to HbO, indicating that the volume change occurs in blood vessels with high oxygen saturation of hemoglobin, i.e., in arteries and arterioles, in agreement with recent fMRI studies (e.g., ref. 4).

The authors point out that their results are in apparent discrepancy to some fMRI results showing an initial dip commonly thought to reflect an increase in HbR. However, the fMRI signal also depends on cerebral blood volume (CBV) (5). Interestingly, an increase in CBV with no change in HbR creates only a signal decrease for some MRI parameter combinations. In this scenario, the intravascular MRI signal increases and the extravascular MRI signal decreases due to changes in the amount of protons in both spaces. If the baseline intravascular relaxation time is shorter than the one of the tissue, then the total MRI signal decreases. Using the recently developed fMRI signal model (5), one can theoretically show that an arterial CBV increase is not associated with an initial dip at 1.5 Tesla (T), with a very small dip at 3 T, or with increasing dip amplitude relative to the positive fMRI response with increasing field strength. Hence, this might explain why at 1.5 and 3 T not many studies have found an initial dip in the fMRI signal.

In summary, there is an emerging consensus from optical spectroscopy and fMRI regarding the spatiotemporal specificity of physiological events underlying imaging signals: (*i*) an early arterial/arteriolar volume increase is followed by changes in volume and oxygenation in capillaries and venules/veins; (*ii*) regardless, if the initial and late changes of the signal are dominated by metabolism or volume, their effective spatial resolution is superior to the main oxygenation and volume changes. Note, however, it remains to be shown whether data from other imaging approaches can be reconciled with this view (1).

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