Spatial specificity of deoxy-hemoglobin signal as studied by optical imaging of intrinsic signals

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Introduction

The BOLD response, which is proportional to changes in deoxy-Hb concentration, is commonly used to visualize neural activities in the brain. Optical imaging spectroscopy (Malonek and Grinvald, 1996) demonstrates that the early increase of deoxy-Hb signal is better localized than the late decrease of deoxy-Hb signal and suggests that late blood inflow and the conventional late positive BOLD signal has poor specificity. However, this result does not necessarily mean that poor specificity is due to blood inflow changes. It may be because with time, deoxy-Hb moves a substantial distance from active sites due to draining, thus blurring the spatial specificity of the signal even without blood inflow changes. Here, we minimized the changes of blood flow and volume during visual stimulation to examine spatial specificity of the deoxy-Hb signal using optical imaging of intrinsic signals.

Material and Methods

We recorded light reflection changes (intrinsic signals) from cat visual cortices induced by visual stimulation. The wavelengths used were 570 nm, which is mainly sensitive to total hemoglobin changes, and 620 nm, where light absorption by deoxy-Hb is dominant. To mitigate the contribution of blood flow and volume changes to the intrinsic signals the mean arterial blood pressure (MABP) was reduced by intravenous injection of a vasodilator (nitroprusside, 0.32 – 0.59 mg/kg). Visual stimulus consisted of a high-contrast, moving full-field square wave grating (0.15 cycle/deg, 2 cycle/sec) of one orientation presented binocularly for 10 sec. A stationary grating of identical spatial frequency and orientation was presented during control periods.

Results

The intrinsic signal at 570 nm decreased by 80 - 90 % during low blood pressure (Fig. 1A). In contrast to this, magnitudes of the intrinsic signal at 620 nm did not decrease during the stimulation (Fig. 1B). To quantify the spatial specificity of the intrinsic signal during low blood pressure, we first divided cortical regions into active iso-orientation domains, where spiking activity occur, and non-active domains. We then calculated spatial specificity index, where the difference between the signal magnitudes in the active and non-active domains was divided by the signal magnitude in the domain with the highest signal. Thus, if the signal is only observed in one domain, the index will be 1.0. On the other hand, if the magnitude of the signal in the active domain is the same as that in the non-active domain, the index will be 0.0. Since multiple components are probably involved in the intrinsic signal with normal blood pressure, each with a different specificity, here we only quantify the spatial specificity of the signal with low blood pressure. While the spatial specificity of the signal at 570 nm did not change, that of the signal at 620 nm decreased with time (Fig. 1C).

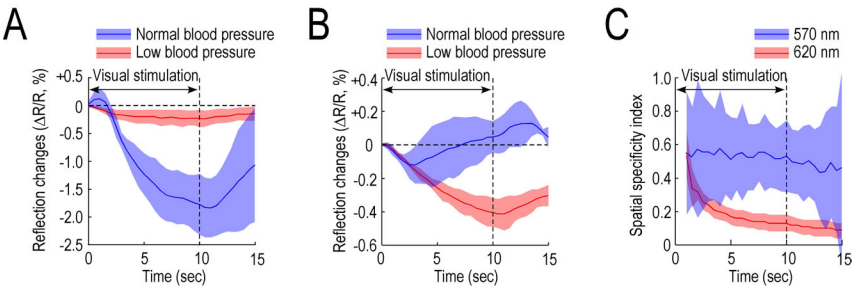

Figure 1. Spatial specificity of the intrinsic signal. A: Time courses of the signal at 570 nm. MABP: 79.1 ± 5.7 mm Hg (normal), 47.1 ± 5.4 mm Hg (Low), B: Time courses of the signal at 620 nm. MABP: 77.8 ± 4.1 mm Hg (Normal), 47.1 ± 4.4 mm Hg (Low), C: Time courses of spatial specificity index at 570 nm and 620 nm during low blood pressure. A-C: Error bars indicate one standard deviation of mean (n=3 cats for 620 nm, n=5 cats for 570 nm).

Discussion

Monotonic decreases in light reflection at 620 nm induced by visual stimulation during low blood pressure suggest increases in deoxy-Hb content because of negligible changes in blood volume during stimulation. Thus, the poor specificity of the signal (i.e., the signals in both active and non-active domains) during low blood pressure is not due to blood flow and volume changes, but rather to deoxy-Hb movement itself (draining of deoxy-Hb from the active sites). If the poor specificity is instead due to sub-threshold activity or scattering of light, there should be no time dependence of the spatial specificity.

Acknowledgements

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Reference

Malonek D, Grinvald A, Science (1996) 272:551-554.