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Novel Intraoperative Indocyanine Green Angiography Analysis Quantifies More Rapid Vessel-to-Tissue Perfusion Following Direct Extracranial-Intracranial Bypass for Moyamoya Disease

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Introduction

Indocyanine green (ICG) angiography is widely used in cerebrovascular neurosurgery to verify vascular patency. Currently ICG does not produce quantitative metrics for cross-patient comparison. Using the dynamic nature of the ICG intensity signal, we outline a novel algorithm for calculating the dynamic properties of blood flow from ICG. This is then applied to quantitatively describe perfusion changes pre- and post-anastamosis during extracranial-to-intracranial bypass surgery for Moyamoya disease (MMD).

Methods

The algorithm (MATLAB) is applied to the ICG intensity temporal profile from selected vascular or cortical regions in a cohort of 8 MMD patients. Each profile is first normalized by subtracting off baseline intensity, and dividing by the magnitude of the first pulsatility trough. Next, normalized profiles from pairs of regions are convolved with one another,to calculate which time difference produces the highest correlation between the two signals. This quantifies perfusion latency and direction of flow. This robust metric for perfusion latency accounts for differences in average ICG intensity inherent to vascular and cortical tissue types.

Results

The ratio of pre-to-post anastamosis vessel-to-cortex perfusion latencies provides a new metric that can be used to quantify surgical efficacy across patients. This ranged from 2-to-9-fold increase. The ensemble of perfusion latencies and directions across branching of vessels provide a clear map and quantitative visual representation for change in vascular flow after anastomosis. (e.g. when directions of both retrograde and anterograde flow within the vascular tree are reversed from the bypass).

Conclusions

This method provides a concrete metric to understand patient-to-patient variability in the efficacy of the bypass procedure in MMD,. This generates directional maps that illustrate changing flow dynamics. This technique could also be applied in a wider set of neurosurgical procedures such as assessment of partial occlusion following aneurysm clipping, stroke penumbra examination during hemicraniectomy, and tumor perfusion quantification.

Learning Objectives

By the conclusion of this session, participants should be able to:

1) Describe the concept of using time-resolved ICG to quantify time-delays in vascular perfusion.

2) Describe how this time-delay quantification illustrates bypass efficacy in extracranial-intracranial bypass surgery for moyamoya disease.

3) Discuss, in small groups, how this technique might be used in other contexts for cerebrovascular neurosurgery.

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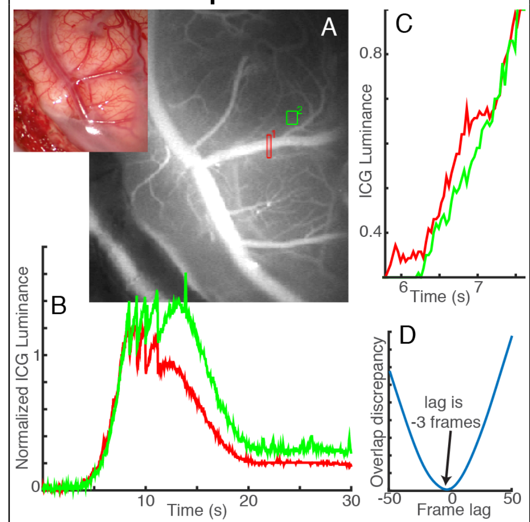
ICG quantification of vessel-to-tissue perfusion



(A) Pre-anastamosis ICG, shown mid run. Upper left inset is the plain photograph of the same anatomy (B) The red trace is the normalized ICG timecourse from the red box vessel seed region shown in panel A. The green trace is the normalized ICG timecourse from the green box brain tissue seed region in A. (C) Magnified trace of panel B, focusing on the initial rising phase of the ICG. (D) Calculated overlap discrepancy as a function of lag, showing a 3 frame (100 ms) lag between vessel and tissue.