Cortical Perfusion Measurement by Indocyanine-Green Videoangiography in Patients Undergoing Hemicraniectomy for Malignant Stroke

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Background and Purpose—Assessment of cerebral perfusion during neurosurgical procedures would be beneficial to identify areas at risk and to guide placement of monitoring probes. Therefore, we have adapted near-infrared indocyanine-green (ICG) videoangiography to assess cortical perfusion intraoperatively.

Methods—ICG videoangiography was performed intraoperatively in 6 patients after decompressive hemicraniectomy for middle cerebral artery stroke. Flow maps of cortical perfusion were generated with IC-CALC 1.1 software by calculating the ratio of difference in fluorescence intensity and rise time.

Results—Excellent visualization of cerebral arteries, cortical perfusion and collateral circulation via leptomeningeal anastomoses could be demonstrated in all cases. Flow maps revealed high spatial resolution and showed heterogeneous maple-leaf-shaped hypoperfusion. 26.5±13.7% and 29.0±9.1% of the exposed cortical surface (141±18 cm²) demonstrated core and penumbral flow, respectively.

Conclusions—ICG videoangiography appears to be a valuable tool to precisely detect relative cortical tissue perfusion. Thus, it may provide useful research data on the pathophysiology of human stroke, help surgeons to maintain adequate brain perfusion intraoperatively, and simplify adequate placement of tissue probes to monitor critically hypoperfused brain tissue. (Stroke. 2006;37:1549-1551.)

Key Words: angiography ■ cerebrovascular circulation ■ indocyanine green ■ stroke

Data on the spatial distribution and the pathophysiology of cerebral perfusion in human stroke is scarce. Advanced monitoring strategies using locally implanted probes are used to further characterize the hypoperfused tissue in patients with malignant stroke. The critically hypoperfused tissue, ie, the penumbra, has been suggested as a potential probe target to maximize the clinical benefit of monitoring.1,2 Currently, however, no method is available for intraoperative determination of the cerebral areas at highest risk.

Fluorescence angiography has been applied to assess capillary blood flow in various experimental set-ups.3 During neurosurgical procedures commercially available indocyanine-green (ICG) videoangiography has been used.4,5 The following study was performed to adapt high resolution capillary blood flow measurements by ICG videoangiography to patients with malignant middle cerebral artery (MCA) infarction undergoing decompressive hemicraniectomy.

Materials and Methods
Intraoperative ICG videoangiography was performed in 6 patients after decompressive craniectomy for malignant MCA infarction as described previously.5 In brief, the surgical field was illuminated using a commercially available laser-fluorescence imaging device (IC-View; Pulsion Medical Systems). The fluorescence signal after intravenous bolus injection of ICG (0.3 mg/kg body weight; ICG-Pulsion; Pulsion Medical Systems) was recorded (25 images/second) with a digital camcorder. Pictures were generated with Windows Movie Maker 5.1 and Adobe Photoshop 5.0. Using IC-CALC 1.1 Software (Pulsion Medical Systems) a cerebral blood flow index (BFI) was calculated according to Kuebler et al.6 The BFI was defined as ratio of difference in fluorescence intensity and rise time, which is the time interval between 20% and 80% of maximum fluorescence intensity. For standardization purposes and to allow interindividual comparisons, the BFI was expressed in relation to an area of suspected undisturbed perfusion.7 Flow maps were then generated by calculating the BFI in 1 mm² squares, and flow areas of ischemic core (<20%), penumbra (20% to 40%) and oligemia (40% to 80%) were determined by volumetric analysis.8 Postoperative computed tomography (CT) was used to volumetrically determine the volume of infarction, the degree of hemispheric swelling and the craniectomy size. Outcome was evaluated after 6 months using modified Rankin Scale and National Institutes of Health Stroke Scale (NIHSS). Statistical analysis for correlations between infarct size and hypoperfused tissue was performed using Pearson χ² test. Significance was defined as P<0.05.

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Results

The pial arteries, the superficial brain tissue and the pial veins were visualized by ICG filling (Figure 1). Image quality and spatial resolution were high. Retrograde filling of pial arteries via leptomeningeal anastomoses could be observed in the MCA territory. Relative blood flow could be measured for all visible brain regions (Figure 2). The signal-to-noise ratio amounted to ≈50 in 10 mm² squares, 20 in 1 mm² squares and 10 in 0.1 mm² squares.

The infarct volume amounted to \(255 \pm 100\) mL, which corresponded to \(38.9 \pm 11.4\%\) of the hemisphere and caused hemispheric swelling of \(18.6 \pm 4.4\%\) (Table). \(26.5 \pm 13.7\%\) and \(29.0 \pm 9.1\%\) of the exposed cortical surface (\(141 \pm 18\) cm²) demonstrated core and penumbral flow, respectively, whereas

Figure 1. Imaging studies obtained in a 41-year-old woman experiencing left-hemispheric malignant stroke (Case 1). Upper left to lower right: Preoperative CT, intraoperative photograph, ICG videoangiograms in 4-second intervals and postoperative CT. The cortical cerebral perfusion demonstrates a marked and heterogeneous delay particularly close to the Sylvian fissure.

Figure 2. Illustration of blood flow analysis in a 37-year-old man who was transferred to our department because of deterioration of consciousness 3 days after right MCA infarction (Case 3). Upper: Intraoperative photograph (left) and ICG videoangiogram (right) after decompressive hemicraniectomy. Lower left: Time course of fluorescence intensity in 3 arbitrary 1 mm² squares marked in the upper figures by insets A, B and C. The straight lines indicate the 

BFI calculated by the ratio of difference in fluorescence intensity and rise time. Lower right: Flow map generated by calculating the BFI in all visible 1 mm² squares. Relative values compared with a reference area (green square) are given.
Monitoring probes, when areas at risk, like the penumbra in stroke patients, are intended to be studied.

Summary

ICG videoangiography has been applied to measure relative cerebral perfusion in patients undergoing decompressive hemi-craniectomy for malignant stroke. Heterogeneous hyperperfusion could be demonstrated with excellent spatial resolution.

References

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