Confirmation of blood flow in perforating arteries using fluorescein cerebral angiography during aneurysm surgery

KYOUICHI SUZUKI, M.D., NAMIO KODAMA, M.D., PH.D., TATSUYA SASAKI, M.D., MASATO MATSUMOTO, M.D., TSUYOSHI ICHIKAWA, M.D., RYOJI MUNAKATA, M.D., HIROYUKI MURAMATSU, M.D., PH.D., AND HIROMICHI KASUYA, M.D.

Department of Neurosurgery, Fukushima Medical University, Fukushima, Japan

Object. The authors performed fluorescein cerebral angiography in patients after aneurysm clip placement to confirm the patency of the parent artery, perforating artery, and other arteries around the aneurysm.

Methods. Twenty-three patients who underwent aneurysm surgery were studied. Aneurysms were located in the internal carotid artery in 12 patients, middle cerebral artery in six, anterior cerebral artery in three, basilar artery bifurcation in one, and junction of the vertebral artery (VA) and posterior inferior cerebellar artery in one. After aneurysm clip placement, the target arteries were illuminated using a beam from a blue light-emitting diode atop a 7-mm diameter pencil-type probe. In all patients, after intravenous administration of 5 ml of 10% fluorescein sodium, fluorescence in the vessels was clearly observed through a microscope and recorded on videotape.

Results. The excellent image quality and spatial resolution of the fluorescein angiography procedure facilitated intraoperative real-time assessment of the patency of the perforating arteries and branches near the aneurysm, including: 12 posterior communicating arteries; 12 anterior choroidal arteries; four lenticulostriate arteries; three recurrent arteries of Heubner; three hypothalamic arteries; one ophthalmic artery; one perforating artery arising from the VA; and one posterior thalamoperforating artery. All 23 patients experienced an uneventful postoperative course without clinical symptoms of perforating artery occlusion.

Conclusions. Because the fluorescein angiography procedure described here allows intraoperative confirmation of the patency of perforating arteries located deep inside the surgical field, it can be practically used for preventing unexpected cerebral infarction during aneurysm surgery. (DOI: 10.3171/JNS-07/07/00068)

KEY WORDS • aneurysm surgery • blood flow insufficiency • fluorescein cerebral angiography • fluorescein sodium • perforating artery

To confirm the patency of the parent artery, perforating artery, and other arteries that branch near aneurysms, various methods of intraoperative monitoring such as Doppler ultrasonography, conventional cerebral angiography, and electrophysiological monitoring of evoked potentials have been used during aneurysm surgery. Blood flow insufficiency and perforating arteries located deep in the surgical field were hardly visible. We developed a novel pencil-type probe with a blue LED at its tip, which emits light of the corresponding wavelength to excite fluorescein sodium. We investigated the practical use of this probe to confirm the patency of the parent artery, perforating artery, and others located deep in the surgical field.

Clinical Material and Methods

The study sample consisted of 23 consecutive patients whose aneurysms were located at the ICA (12 patients), MCA (six patients), ACaA (three patients), BA bifurcation (one patient), and the VA at the PICA origin (one patient). All patients underwent intraoperative fluorescein cerebral angiography. Informed consent was obtained from all patients or their legal representatives before study enrollment and surgery.

After aneurysm clip placement, barrier filters (Scimen Design) (Fig. 1C) were introduced into the light pathway of the operating microscope (model M5000H-1, Leica). These filters were long-pass (blue-cut) filters; the light wavelength at the half-transmittance point was approximately 500 nm. The pencil-type probe with a blue LED
Fluorescein cerebral angiography during aneurysm surgery

Fig. 1. Illustration and photographs showing the setup for intraoperative fluorescein cerebral angiography. The pencil-type probe with a blue LED at its tip (A) is held by hand over the operative field. The perforating artery is illuminated by the probe’s excitatory beam (B). After the intravenous administration of 5 ml of 10% fluorescein sodium, the increase of fluorescence in the perforating artery is observed under a microscope through a barrier filter (C) that facilitates the collection of only fluorescein sodium–induced fluorescence. The barrier filter can be inserted into and removed from the light axis of a microscope by moving the tab (black arrow) by 90° (white arrow).

(peak excitatory light 466 nm) at its tip was specially designed for this study and manufactured by I-HITS laboratory (Fig. 1A). The probe was held by hand at a distance of approximately 3 cm from the aneurysm and its beam was targeted at the perforating artery (Fig. 1B). After identifying the target vessel by looking through the operating microscope, the surgeon turned on the probe. An intravenous bolus injection of 5 ml of 10% fluorescein sodium (Fluorecite, Arcon Japan) was then administered and the microscope light source was turned off. The increased fluorescence was observed under the microscope and recorded by a digital video camera through the barrier filters.

The safety of fluorescein retinal angiography using 5 ml of 10% fluorescein sodium has been well established.4,23 We considered our fluorescein cerebral angiography method to be safe because the dose was identical to that used in retinal angiography.

Results

Compared with the original image (Fig. 2A and B), the surgical field became yellowish after the long-pass barrier filter was attached to the microscope (Fig. 2C), but the field remained sufficiently illuminated to proceed with surgical manipulations. Approximately 15 seconds after the delivery of the 5 ml of 10% fluorescein sodium bolus via a peripheral venous line, both the major cerebral arteries (20 mm in diameter) and perforating arteries (0.5 mm in diameter) became yellowish-green (Fig. 2D). Fluorescence from arterioles (approximately 0.1 mm in diameter) on the surface of the brain could also be identified very clearly. Between 3 and 8 seconds after the manifestation of intra-arterial fluorescence, there was an increase of fluorescence from the venous system, which gradually decreased over the course of the next 60 seconds.

In all 23 cases, the excitatory light reached the depth where the target vessels around the aneurysm were located. In one of the three patients with an ACoA aneurysm we were unable to visualize fluorescence from the MACC and the hypothalamic artery after aneurysm clip placement (Fig. 3A–C). Repositioning the clip to release the occlusion of these vessels allowed us to confirm their patency afterwards (Fig. 3D). Overall, intraoperative real-time assessment of blood flow in the perforating arteries was possible using this new method, with excellent image quality in all 23 cases. The procedure was able to confirm the patency of the arteries near the aneurysm and their branches, making visible 12 PCoAs, 12 AChAs (Fig. 4), four LSAs (Fig. 5), three hypothalamic arteries, three recurrent arteries of Heubner, one ophthalmic artery, one perforating artery branching from the VA, and one posterior thalamoperforating artery (Table 1). None of the 23 patients showed symptoms of perforating artery occlusion and there were no complications attributable to the injected fluorescein sodium.

Discussion

Although it appears easy to detect the presence of intra-arterial stenosis or occlusion using microscopic inspection, unexpected infarction due to blood flow reduction in the parent artery and/or perforating arteries branching close to the aneurysm may occur.3,15,24 To avoid these complications, microvascular Doppler ultrasonography,1,16 intraoperative conventional angiography,2,20 and electrophysiological monitoring8,15,18,19 have been routinely used during aneu-
Aneurysm surgery, but a perfect method for monitoring blood flow disturbance in the perforating arteries has not been established to date.

Microvascular Doppler ultrasonography can detect blood flow noninvasively, but it is difficult to place the probe on the target vessels in a deep surgical field. Even if the target vessel can be touched with the probe, it may detect flow from nearby vessels because the continuous Doppler wave method detects blood flow in a relatively wide region.

Intraoperative angiography can confirm the complete obliteration of the aneurysm and the patency of parent or branching vessels. This method is invasive however, and its limited resolution does not allow complete confirmation of the patency of small perforating arteries such as the hypothalamic, LSA, and posterior thalamoperforating artery. Furthermore, a longer time (15–60 min) than other methods is required for the acquisition of angiographs using this method. For these reasons, intraoperative angiography is not always practical for protecting against postoperative sequelae attributable to blood flow insufficiency in the perforating arteries.

Motor evoked potentials during electrophysiological monitoring respond to decreased blood flow in the AChA and LSA within 60 seconds, but the motor evoked potential cannot be used to monitor blood flow insufficiency in the hypothalamic artery, PCoA, and posterior thalamoperforating artery because they do not supply the corticospinal tract. There are many reports of patients who developed cerebral infarction in the territory of perforating arteries, even though their somatosensory evoked potentials had remained unchanged throughout surgery. Any kind of electrophysiological monitoring has its limitations in detecting blood flow insufficiency in the perforating arteries. These limitations were the reason for the introduction of fluorescein cerebral angiography.

Fluorescein angiography, used extensively in ophthalmology for a long time, has been introduced to the field of neurosurgery. In 1971, Feindel and colleagues administered fluorescein sodium by intracarotid injection to study blood flow patterns in the superficial cortical vessels and in large arteriovenous malformations exposed during craniotomies of the human brain. Fluorescent imaging was subsequently used during excision of brain tumors to identify their margin. During aneurysm surgery, the patency of the cerebral arteries and the complete obliteration of clipped aneurysms have been confirmed by venous injection of fluorescein sodium or indocyanine green. In these reports, the light source was 5 to 40 cm away from the brain surface, and fluorescence was elicited only in the ICA or MCA but not in perforating arteries such as the hypothalamic artery, posterior thalamoperforating artery, or AChA. According to a recent report of fluorescent angiography using indocyanine green during aneurysm surgery, fluorescence from indocyanine green in the perforating arteries was detected in less than 5% of the patients.

Using our pencil-type probe with a blue LED at its tip, it was possible to direct a strong excitatory light beam at perforating arteries in the deep portions of the surgical field. After venous injection of 5 ml of 10% fluorescein sodium (a dose identical to that used in retinal fluorescein angio-

![Fig. 2. Illustration and intraoperative photographs showing clip application to the neck of an ACoA aneurysm (An) performed using a conventional microscope (A and B) and using fluorescein cerebral angiography (C and D). After insertion of the barrier filter into the light pathway of the microscope, the surgical field became yellowish (C) compared with the original image (B). Fluorescein cerebral angiography shows fluorescence within the bilateral A2 segment of the anterior cerebral artery (A2) and the hypothalamic artery (HThA) (D). Fluorescence from the aneurysm could not be observed. A1 = A, segment of the anterior cerebral artery; Lt. = left; Rt. = right.]
FIG. 3. Illustration and intraoperative photographs showing clip application to the neck of an ACoA aneurysm. After clip placement (A and B), fluorescence from the MACC and the hypothalamic artery could not be visualized (C). Repositioning the clip to release the occlusion of these vessels allowed us to confirm their patency afterwards (D).

FIG. 4. Intraoperative photographs and illustration showing clip application to the necks of the left ICA–PCoA and ICA–AChA aneurysms. After clip placement (A and B), the patency of the AChA was confirmed using fluorescein cerebral angiography (C). The ICA–PCoA aneurysm is covered with cotton and is not visible.
raphy), small perforating arteries deep within the surgical field could be observed clearly via a microscope and recorded using a digital video camera. The setup time for this procedure ranged from 1 to 3 minutes, and the time required for investigation and interpretation ranged from 30 to 40 seconds.

The intraoperative fluorescein cerebral angiography method presented in this study can be performed using any type of operating microscope if the barrier filter and the pencil-type probe with LED are prepared. It is easy to introduce the barrier filter into the light pathway of any type of microscope, and the operating microscope does not require modification. Both the barrier filter and pencil-type probe would cost approximately $10,000 (US).

In a 1984 survey of fluorescein angiography complications, 23,2400 ophthalmologists reviewed over 220,000 fluorescein angiograms. Cardiac reactions occurred in 1 of every 1300 studies, respiratory compromise in 1 of every 3800 studies, and tonic-clonic seizures in 1 of every 13,900 studies. The pathological mechanisms underlying these complications are not clearly understood, and include vasovagal phenomena, immediate hypersensitivity reaction, histamine release via a nonallergic pathway, and sympathetic discharge due to anxiety.22 Although retinal angiograms are performed on an outpatient basis without premedication, patients undergoing cerebral aneurysm surgery are usually treated preoperatively with hydrogen gas antagonists, calcium channel blockers, dexamethasone, and anticonvulsants; this preoperative treatment can be expected to reduce the risk of a severe reaction to fluorescein sodium. Thus, although the fluorescein doses used for cerebral and retinal angiograms are similar, in absolute terms we can expect that patients with cerebral aneurysms undergoing fluorescein angiography may be at a lower risk for complications than patients undergoing retinal angiography.

Fluorescein cerebral angiography can detect blood flow, but the nonquantitative information it provides is not enough to determine whether the blood flow volume is sufficient to avoid infarction. Although fluorescein cerebral angiography is not a perfect monitoring method, it is very promising because it allows confirmation of the intravas-

Fig. 5. Intraoperative photographs and illustration of clip application to the neck of a left MCA bifurcation aneurysm. After clip placement (A and B), the patency of the lateral frontoorbital artery (LFOA) and LSA was confirmed using fluorescein cerebral angiography (C). M1 and M2 = M1 and M2 segments of the MCA.
Fluorescein cerebral angiography during aneurysm surgery

cular blood flow from the outside. Based on our findings we suggest that monitoring of blood flow using fluorescein cerebral angiography will be of great help in the prevention of unexpected cerebral infarctions as well as in improving surgical outcome.

Conclusions

We have reported on a novel excitation light-emitting source developed at our institution to improve the fluorescein cerebral angiography method. With this device, we could obtain a very clear fluorescence in the main cerebral arteries, perforating arteries, and arterioles of the brain surface, clearly demonstrating the blood flow in arteries of very small caliber. This method is simple, minimally invasive, and useful for decreasing surgical complications.

Acknowledgments

We thank Mr. Tohru Teshima, I-HITS Laboratory; Mr. Akihiro Akano, Leica Microsystems Inc.; Mr. Akira Shibata, Scimen Design Limited; and Nichia Corporation for their technical support.

References


Manuscript submitted July 26, 2006. Accepted October 19, 2006.

Address reprint requests to: Namio Kodama, M.D., Ph.D., Department of Neurosurgery, Fukushima Medical University, I Hikarigaoka, Fukushima 960-1295, Japan. email: nkodama@fmu.ac.jp.

J. Neurosurg. / Volume 107 / July, 2007 73