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H Touho, J Karasawa, T Tazawa, J Nakagawara, K Yamada, K Kobayashi, M Asai, M Kagawa and H Yasue

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Intraarterial Digital Subtraction Angiography for Definitive Diagnosis of Intracranial Aneurysms

Hajime Touho[1]
Jun Karasawa
Toshiaki Tazawa
Jyoji Nakagawara
Keisuke Yamada
Keisuke Kobayashi
Masaaki Asai
Masaaki Kagawa
Hiroshi Yasue

Comparisons between digital subtraction angiography and conventional angiography have frequently been made in the radiologic literature, and the high quality and several advantages of the former have been reported. In this study, 101 patients with intracranial aneurysms were examined only by intraarterial digital subtraction angiography; no conventional angiography was used. High-quality images were consistently obtained, facilitating an accurate and definitive diagnosis of intracranial aneurysm. Magnification radiography and stereography using intraarterial digital subtraction angiography were done to obtain a more precise diagnosis. Five small intracranial aneurysms with diameters of 1.0 to 2.0 mm could be detected. The procedure was considered to be as reliable and as safe as conventional angiography, used previously. Important advantages of intraarterial digital subtraction angiography include reduced procedural time and decreased contrast agent burden, factors that will ensure broader application of this procedure for definitive diagnosis of intracranial aneurysms as experience with the technique accumulates.

Angiography is the primary radiologic procedure for diagnosis of diseases affecting blood vessels. Conventional angiography is popularly used to detect these abnormalities. However, IV digital subtraction angiography (IV-DSA), introduced in 1980, is now available and widely used for detecting cervicocerebrovascular lesions [1–5]. DSA is fundamentally different from conventional angiography, beginning with the X-ray source and method of image acquisition. Photon flux radiated through the patient is detected by an image intensifier rather than by a film-screen device. The video signal is rapidly digitized and stored in a computer memory, which is composed of 512 × 512 distinct elements. The composite of all the pixels yields an image. The obtained composite images are electronically subtracted from a mask image. Low-contrast sensitivity enables the technique to be used to visualize arteries after IV injection of contrast material, but selective arterial studies that use conventional angiography are still necessary for definitive diagnosis of many intracranial lesions. Prior to March 1985, we also used conventional angiography for detecting cerebral aneurysms in all patients with subarachnoid hemorrhage. However, since recent advances have extended to diagnostic and therapeutic intraarterial DSA (IA-DSA), we undertook the current investigation, in which 101 patients with intracranial aneurysms were studied with IA-DSA.

Materials and Methods

One hundred one patients with subarachnoid hemorrhage, cerebral infarction, or hydrocephalus were admitted to our service between March 1985 and November 1987. Eighty-six patients had subarachnoid hemorrhage, 14 had cerebral infarction, and one patient was found by CT to have obstructive hydrocephalus caused by a large cerebral arteriovenous malformation. The study group consisted of 59 women and 42 men, ranging in age from 31 to 81 years old. All the patients were examined only by IA-DSA with a Becton Dickinson no. 7636 catheter* by means of Seldinger's technique, and all were found to have intracranial aneurysms, of which the total number was 117.

* Becton Dickinson Co., Rutherford, NJ.

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[1] All authors: Department of Neurosurgery, Osaka Neurological Institute, 2-6-23 Shonai-Takara-machi, Toyonaka 561, Osaka, Japan. Address reprint requests to H. Touho.

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The equipment used was a production model Digital Fluorikon 5000 digital subtraction unit.† The digital images were acquired on a 512 × 512 × 10 matrix. Specific equipment included a 1000 mA X-ray generator, a 0.9/0.3-mm focal spot water-cooled X-ray tube, a trimode (4½, 7, and 9 in.) cesium iodide image intensifier coupled to a 1000:1 signal-to-noise ratio television camera. Typical exposure factors were 75–85 kV, 640 mA with 75–90 msec exposure times. Image quality was maximized by using remasking, reregistration of the mask, and pixel shift in reference to the contrast to correct for patient motion. Spatial resolution was 1.2 lp/mm when CTF was at the level of 0.5 using our DSA system, and spatial resolution was 1.8 lp/mm when CTF was at the level of 0.5 using conventional filming.

Generally, the volume of the contrast agent (metrizamide) injected in selective angiography was 3–4 ml (250 mg I/ml) and the rate of injection was 3–4 ml/sec. The conventional exposure sequence for a cerebral aneurysm was 4/sec for 2½ sec and 2/sec for 4 sec. This film sequence, to a total of 6.5 sec, could cover the venous phase in all patients. A special exposure sequence was 4/sec for 1½ sec for magnification radiography and stereography using IA-DSA. In all instances, standard patient positioning was used and oblique positioning, magnification radiography, and stereography using IA-DSA were usually done to obtain a more precise diagnosis. The radiographic findings were compared with intraoperative findings for all the patients. No conventional angiography was done.

Results

Table 1 shows the variety of angiographic diagnoses facilitated by IA-DSA. In the 86 patients with subarachnoid hemorrhage and the one with obstructive hydrocephalus due to arteriovenous malformation, the angiographic examination was performed as an emergency measure for immediate diagnosis and surgery.

Fourteen patients with infarction were examined 1 to 7 days after admission. All of them had either one or multiple aneurysms. (In one patient with a ruptured anterior communicating aneurysm diagnosed by IA-DSA preoperatively, a minute unruptured aneurysm with a diameter of 1 mm was incidentally found in the contralateral internal carotid artery [C_2 portion] during an emergency operation.)

† General Electric Co., Milwaukee, WI.

TABLE 1: Angiographic Diagnosis by IA-DSA*

Location of Aneurysm	No. of Cases
Middle cerebral artery	43
Internal carotid artery	37
Anterior communicating artery	23
Anterior cerebral artery	9
Basilar artery	5

* IA-DSA = intraarterial digital subtraction angiography.

The time required to examine three or four vessels with IA-DSA was 34 ± 8 min (mean ± standard deviation), and the volume of contrast medium used was 40 ± 4 ml (mean ± standard deviation).

IA-DSA was found useful for the following reasons: (1) It could be used when an emergency examination was required immediately before surgical intervention; (2) The duration of the study and the volume of contrast agent burden were reduced, especially when multiple injections were needed, such as in preoperative and definitive aneurysmal delineation; (3) The time needed for a decision on the direction of the projection was much shorter in IA-DSA than in conventional angiography; and (4) The patient's discomfort such as neck pain was negligible in metrizamide IA-DSA compared with that in conventional angiography owing to the smaller volume per injection.

The following case reports illustrate the practical applications of IA-DSA and show that aneurysms with diameters as small as 1.0–2.0 mm can be detected with this technique.

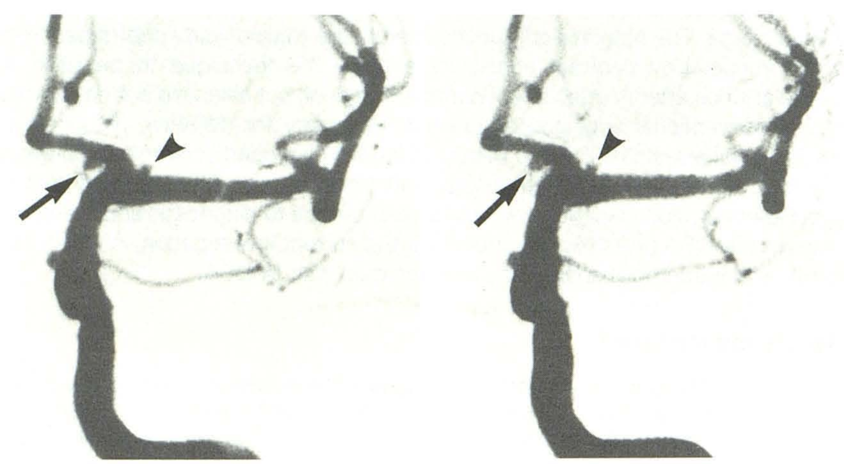

Fig. 1.—Case 1: stereographic anteroposterior carotid angiograms show internal carotid artery bifurcation aneurysm (*arrowheads*) and anterior cerebral artery aneurysm (*arrows*).

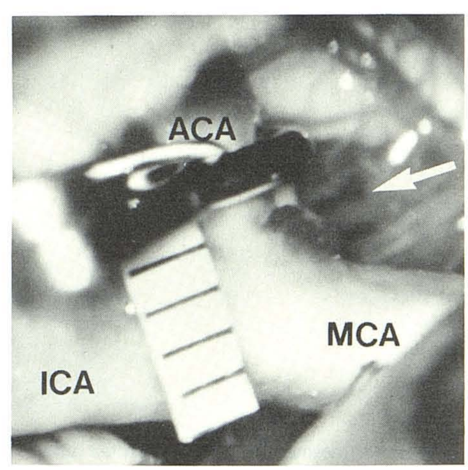

Fig. 2.—Intraoperative photograph of case 1 shows clipped anterior cerebral artery aneurysm and internal carotid artery aneurysm (*arrow*) with diameter of about 1.5 mm. ACA = anterior cerebral artery; ICA = internal carotid artery; MCA = middle cerebral artery.

Representative Case Reports

Case 1

A 71-year-old woman was admitted with left hemiparesis. CT revealed a low-density area in the right basal ganglia. IA-DSA revealed occlusion of the right internal carotid artery and unruptured aneurysms on the left (Fig. 1). The aneurysms were located at the A_1 portion of the anterior cerebral artery and the bifurcation of the internal carotid artery. The A_1 aneurysm was clipped and the other aneurysm was wrapped and coated after a right extracranial-intracranial anastomosis was done. The radiographic diagnosis was compatible with the intraoperative findings (Fig. 2).

Case 2

A 53-year-old man was admitted to our neurosurgical service with sudden onset of a severe headache and vomiting. Neurologic examination revealed meningeal irritation, and CT revealed subarachnoid hemorrhage. IA-DSA demonstrated a left internal carotid artery aneurysm (Fig. 3). An emergency operation was performed in an attempt to clip the aneurysmal neck (day 0), but the operation was unsuccessful because of the aneurysm's small diameter and broad neck (1 mm and 1 mm, respectively). Trapping of the internal carotid artery and superficial temporal artery–middle cerebral artery anastomosis were performed. The intraoperative findings were in accord with the preoperative radiographic diagnosis.

Fig. 3.—Case 2: lateral angiogram shows left internal carotid artery aneurysm (*arrow*).

Case 3

A 63-year-old woman was transferred to our service with severe headache, vomiting, and drowsiness. CT revealed subarachnoid hemorrhage with a massive clot in the basal cisterns. IA-DSA revealed aneurysms of the left distal anterior cerebral artery and ipsilateral internal carotid artery (Fig. 4). An emergency operation (day 0) disclosed that the aneurysm of the distal anterior cerebral artery was unruptured and that the other aneurysm, which had a diameter of 1.5 mm, was ruptured. Although the ruptured aneurysm was small, neck clipping was successful (Fig. 5).

Case 4

A 35-year-old woman was transferred to our service with cardiorespiratory arrest and her pupils were mydriatic without response to light. She was resuscitated immediately but needed assistance in respiration and was given cardiac drugs. She was comatose with quadriplegia but her pupils gradually became small and responded to light (day 1). CT revealed subarachnoid hemorrhage with a massive clot in the prepontine cistern. IA-DSA showed a left ruptured internal carotid–posterior communicating artery (IC–PC) aneurysm and three unruptured aneurysms at bifurcation of the right middle cerebral artery, on the top of the right internal carotid artery and at the outlet of the right accessory middle cerebral artery (Fig. 6). She became drowsy on day 2 and underwent an operation in which the necks of the left IC–PC aneurysm and the right middle cerebral artery aneurysm were clipped and the muscles of the other small aneurysms were wrapped and coated. Figure 7 is an intraoperative photograph of the right small aneurysms. The patient became lucid with paraparesis on day 8.

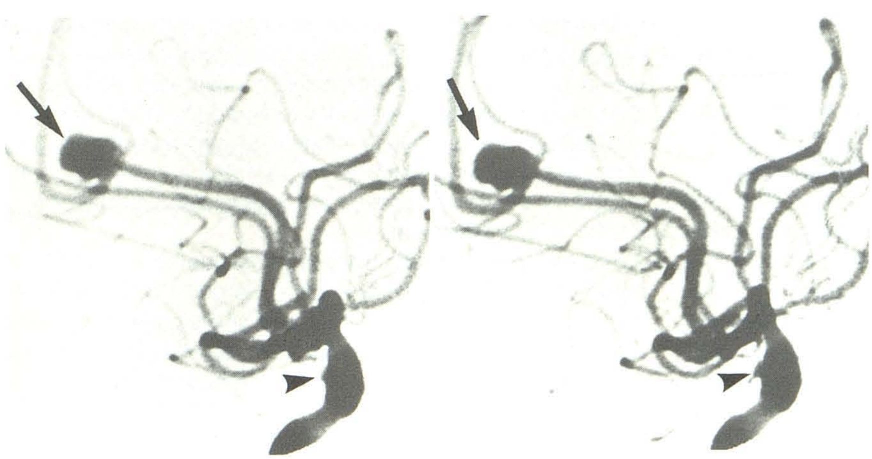

Fig. 4.—Case 3: left lateral carotid stereographic angiogram shows distal anterior cerebral artery aneurysm (*arrows*) and internal carotid artery aneurysm (*arrowheads*).

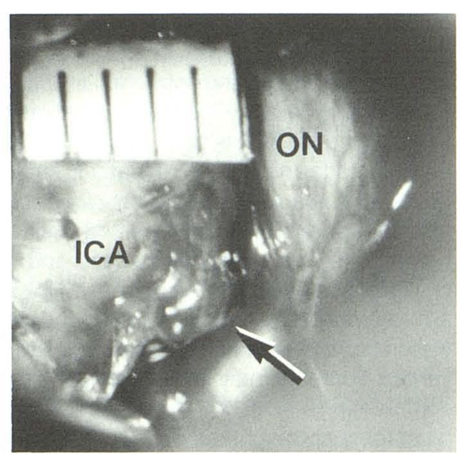

Fig. 5.—Intraoperative photograph of case 3 shows internal carotid artery aneurysm with diameter of about 1.8 mm (*arrow*). ICA = internal carotid artery; ON = optic nerve.

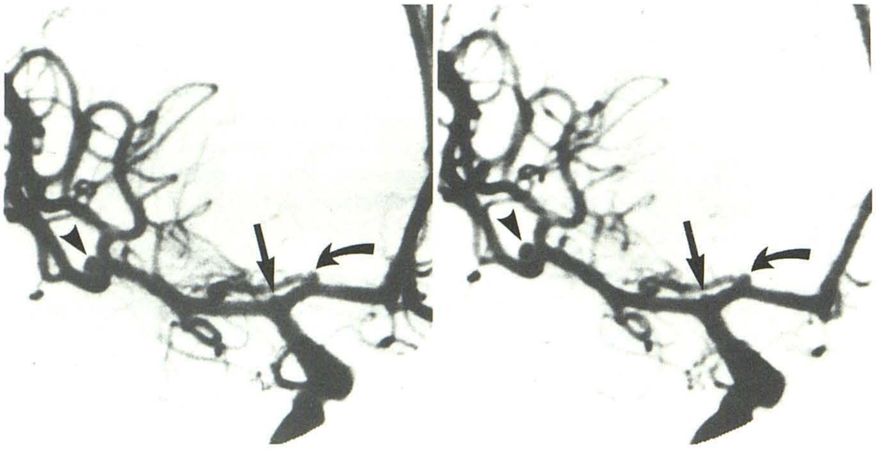

Fig. 6.—Case 4: right internal carotid stereographic angiogram done after cardiorespiratory resuscitation shows internal carotid artery bifurcation (*straight arrows*), anterior cerebral artery (*curved arrows*), and middle cerebral artery aneurysms (*arrowheads*).

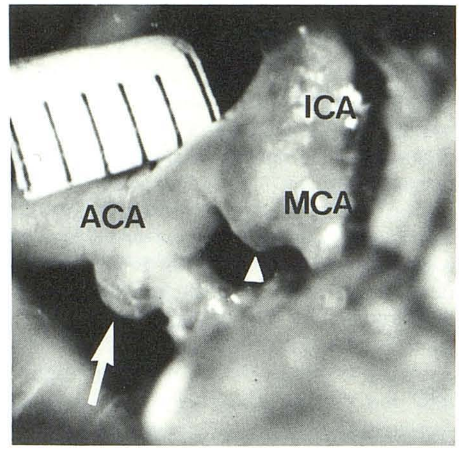

Fig. 7.—Intraoperative photograph of case 4 shows right internal carotid bifurcation aneurysm (*arrowhead*) and anterior cerebral artery aneurysm (*arrow*). ACA = anterior cerebral artery; ICA = internal carotid artery; MCA = middle cerebral artery.

Case 5

A 60-year-old man was transferred to our service with severe headache. CT revealed subarachnoid hemorrhage. Conventional, anteroposterior, and lateral views could not demonstrate any aneurysms. However, a right internal carotid angiogram, 25° off lateral, using IA-DSA disclosed an anterior communicating aneurysm (Fig. 8). The emergency operation (day 0) demonstrated an anterior communicating aneurysm (Fig. 9).

Discussion

IA-DSA was introduced in January 1985 for diagnosis of intracranial aneurysms in patients with subarachnoid hemorrhage. In cases in which IA-DSA revealed no aneurysm, conventional angiography also could not detect any aneurysms. From March 1985, IA-DSA was introduced as the only method for diagnosing intracranial aneurysms. Digital subtraction angiography permits visualization of the vascular structures after IV injection of contrast material (IV-DSA), and its advantages have been repeatedly stressed in the literature [3, 6–9]. It is a noninvasive technique, causing little discomfort, and therefore can be repeated easily. The procedure can be performed on an outpatient basis and is less time-consuming than conventional angiography. However, there may be adverse reactions during IV-DSA, brought about by the contrast material itself or by the method of its administration. The venous approach may induce local, systemic, and neurologic complications such as extravasation at the injection site, hematoma at the catheter site, chest pain, itching, shortness of breath, nausea, emesis, pulmonary embolism, faintness, headache, syncope, transient vision loss, progression of hemiparesis to a completed stroke, and seizure [10, 11]. Seyferth [12] also reported possible ischemic cardiac complications.

The well-known limitations of the IV-DSA technique are the limited spatial resolution as well as the limited number of runs possible because of contrast volume limitations [4, 13].

Furthermore, diagnosis is not always precise with regard to intracranial studies. Wilms et al. [5] reported that the low-contrast-dose and low-pressure intraarterial subtraction technique is equivalent to conventional angiography with less risk and discomfort to the patient and results in considerable saving in cost. Several advantages of IA-DSA over the conventional film-screen technique have been mentioned. It is a safe and expedient procedure, producing precise diagnostic results. In our study we found that the IA-DSA technique minimizes examination time for several reasons: exposures can be visualized fluoroscopically, subtraction is almost instantaneous, and the excellent ability of IA-DSA to detect contrast material allows a decrease in the volume or concentration of the contrast agent compared with that used in conventional angiography. It has been reported that the volume and rate of contrast agent injection were 50–80% of that in a conventional arteriographic study; and Wilms et al. [5], in his IA-DSA study, used a dilution of one-half of the 76% contrast medium with an injection rate of 4 ml/sec and a total of 6 ml for the carotid artery, and 3 ml/sec and a total of 4 ml for the vertebral arteries.

The majority of intracranial aneurysms detected by IA-DSA reported in the past were relatively large [14]; however, in our study, the five patients illustrated in the case reports had aneurysms smaller than 1.5 mm as revealed by IA-DSA, and when they were compared with their intraoperative views, the results agreed.

There was a small unruptured internal carotid aneurysm undetected by preoperative IA-DSA. In most series, the incidence of intracranial aneurysm found in a general autopsy series is 0.2–9.0% [15]. In a cooperative study of 3321 aneurysm cases reported by Sahs et al. [16] the rate of

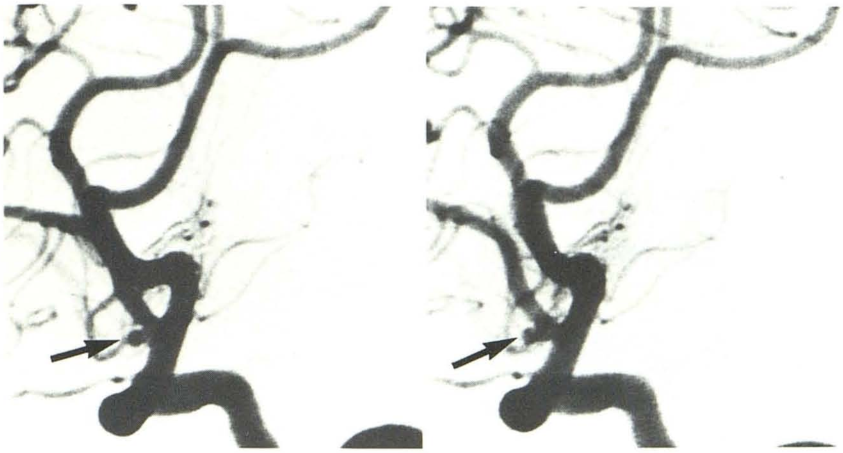

Fig. 8.—Case 5: right internal carotid angiogram, 25° off lateral, shows anterior communicating aneurysm (*arrows*).

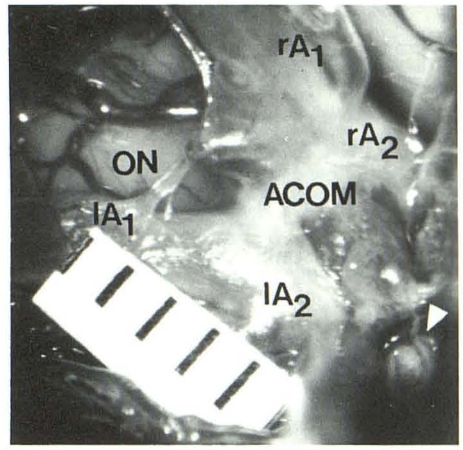

Fig. 9.—Intraoperative photograph of case 5 shows anterior communicating artery aneurysm with diameter of about 2.0 mm (*arrowhead*). A_1 = first segment of anterior cerebral artery; A_2 = second segment of anterior cerebral artery; ACOM = anterior communicating artery; ON = optic nerve; r = right; l = left.

multiple aneurysms at autopsy was 22% as compared with the angiographically demonstrated rate of 18.5%. Suzuki et al. [17] reviewed 10,795 cases of intracranial aneurysm in which the incidence of multiple aneurysms was 14.1% overall with a range of 7.7–29.8% based on clinical and angiographic findings, and 1404 cases of intracranial aneurysm in which the incidence of multiple aneurysms was 23.5% with a range of 18.9–50% based on necropsy findings. Those figures suggest that the incidence of multiple aneurysms detected at autopsy is much higher than that detected by conventional angiography. For that reason, it is not surprising that a small unruptured aneurysm was accidentally found at surgery, and it does not deny the clinical usefulness of IA-DSA. The overall quality of the images in our study was equivalent to that obtained by conventional angiography, with technically better subtractions and visualization of the intracranial aneurysms, and very little decrease in spatial resolution. The use of equipment of comparable quality to ours and magnification and stereography with IA-DSA should allow replacement of conventional angiography for detection and definitive diagnosis of intracranial aneurysms, considering the decrease in time, risk, patient discomfort, and cost while preserving the quality of the acquired image.

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