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Clinical Benefits of Rotational 3D Angiography in Endovascular Treatment of Ruptured Cerebral Aneurysm

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BACKGROUND AND PURPOSE: **Recent neurointerventional and neurosurgical technologies require an understanding of lesions and adjacent structures in three dimensions. To clarify the clinical benefits of rotational 3D digital subtraction angiography (DSA), we retrospectively analyzed its advantages and disadvantages at the time of interventional procedures for ruptured cerebral aneurysms.**

METHODS: **From January 1998 through September 2000, 85 patients with a ruptured cerebral aneurysm were treated with Guglielmi detachable coils in the acute phase. Data for the patients treated before availability of 3D DSA (group A, 52 patients) were compared with data for patients treated after availability of 3D DSA (group B, 33 patients). Variables analyzed were age, sex, location of aneurysm, size of aneurysm, number of implanted coils, number of DSA exposures, and total amount of contrast medium used.**

RESULTS: **No statistically significant differences between the groups were noted when we compared the age, sex, aneurysm location, aneurysm size, and number of implanted coils. The number of DSA exposures was decreased in total by using 3D DSA ($P < .0001$), not only to determine the working projection ($P < .0001$) but also during the procedure ($P < .0002$). However, no statistically significant difference was noted in the comparison of total amount of contrast medium.**

CONCLUSION: **Three-dimensional DSA allows acquisition of high-quality 3D images of cerebral arteries and also allows observation and analysis from multiple directions to determine the appropriate working projection for embolization. Three-dimensional DSA is essential for optimal diagnosis and embolization of cerebral aneurysms and can reduce the number of exposures.**

Recent developments in neurointerventional technology and neurosurgical treatment demand a greater understanding of lesions and adjacent anatomic structures in three dimensions. Three-dimensional images reconstructed from CT, MR angiographic, and US data sets have been developed and evaluated clinically (1). The more recent, emerging technology of rotational angiography with 3D reformation has been used at several institutes, with reported clinical benefits (2–7). To our knowledge, however, no quantitative study has been conducted regarding the clinical advantages during interventional procedures for cerebral aneurysms.

We therefore sought to clarify the clinical benefits of rotational 3D digital subtraction angiography (DSA) by retrospectively analyzing its advantages and disadvantages at the time of interventional procedures for ruptured cerebral aneurysms.

Methods

We retrospective analyzed data from 85 patients (57 female and 28 male patients; mean age, 58.8 years; age range, 17–87 years) with ruptured cerebral aneurysms who were treated with Guglielmi detachable coils (GDCs; Target Therapeutics–Boston Scientific, Fremont, CA) from January 1998 through September 2000. Data for group A, those treated before the availability of 3D DSA (52 patients [35 female and 17 male patients; mean age, 59.3 years; age range, 17–81 years]), were compared with data for group B, those treated after the availability of this technique (33 patients [22 women and 11 men; mean age, 58.1

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years; age range, 34–87 years]) at our institution. The endovascular treatments were performed by the same operators (T.A., M.H., N.T.) and the same team of radiology technicians. All GDC systems were third generation. The 3D GDC and the stretch-resistant GDC systems were not available during the time these patients were treated. All aneurysms were treated with a conventional GDC procedure without balloon-assisted technique.

The 85 patients with subarachnoid hemorrhage due to ruptured cerebral aneurysms were successfully treated with GDCs in the acute phase. The procedure was explained to all patients and their families, and they gave informed consent. All procedures were performed with the patients under general anesthesia.

From September 1999, 3D DSA and conventional DSA were performed with an Advantx LCN plus DSA system (GE Medical Systems, Buc, France). Conventional DSA was performed with a 1024 × 1024 matrix, biplane DSA system with road-mapping function. Image-processing workstations, Advantage Windows 3.1 and Advantage 3D-XR 2.0 (GE Medical Systems), were used to obtain the 3D neuroangiographic images. Data were acquired in 512 × 512 matrix, with a rotation angle of 200° and rotation speed of 40° per second. Geometric distortions created by the image chain were automatically collected, and the 3D images were displayed within 3 minutes (1 minute for transfer and 2 minutes for reconstruction) after each exposure. Reconstructed images included maximum intensity projection images, shaded surface rendered displays that included a metal algorithm for displaying metal materials such as coils and clips, volume-rendered displays including transparent images that can change the degree of transparency of the vessels, and virtual endoscopic views. The fine adjustment of the automatically created 3D image was performed by two neuroradiologists. The injection rate of nonionic contrast medium (iopamidol, Iopamiron 300; Nippon Schering, Osaka, Japan) was 2.0–3.0 mL/s for a per run total of 10–15 mL. When the anterior circulation was evaluated, a total of 15 mL of the contrast medium was injected into the internal carotid artery at a rate of 3 mL/s. The contrast medium was administered with a power injector during the 5-second gantry rotation. With use of the 3D DSA images on the workstation, the working projection for GDC placement was decided, and the data and the position of x-ray tube and image intensifier were transferred to the C-arm automatically. Under the biplane road-mapping function, the operators performed the coil embolization by referring to the 3D reconstructed images.

Before the introduction of 3D DSA (January 1998 to August 1999), the interventional procedures were performed on a biplane DSA system with high-spatial-resolution (1024 × 1024 matrix) and road-mapping function (Digitex 2400; Shimadzu, Kyoto, Japan). The working projection was determined by the interventionalist using stereo views of angiograms and multi-projected DSA studies.

Data compared between groups A and B were age, sex, location of aneurysms, size of aneurysms, number of implanted coils, number of DSA exposures, and total amount of contrast medium used. Location of the aneurysms was divided into four categories as follows: arising from the internal carotid artery, the anterior cerebral artery and anterior communicating artery, the middle cerebral artery, and the vertebrobasilar system and posterior cerebral artery. The number of exposures needed to acquire the DSA images was evaluated with four classifications as follows: total number for the interventional procedure, number needed to decide the working projection, number obtained during coil embolization, and number acquired with 3D DSA. The total amount of contrast medium used per procedure was taken from the nursing records. Unfortunately, in some after-hours and holiday cases (30 cases), records of contrast medium were not kept. Therefore, comparison of total amount of contrast medium was performed for 32 patients in group A and 23 patients in group B. Two neuroradiologists (Y.U., K.K.) who were blinded to the clinical cases performed all data acquisition and analysis.

Differences between the two groups were analyzed by using the Student *t* test for unpaired values on patient age, size of aneurysms, number of implanted coils, number of DSA exposures, and total amount of contrast medium used; a significance level of .05 was used. For comparisons of patients' sex and location of aneurysms, statistical analysis was performed with the χ^2 test; statistical significance was set with a *P* value of less than .05.

TABLE 1: Patient and aneurysm characteristics

Variable	Group A (n = 52)	Group B (n = 33)
Mean (± SD) age (y)	59.3 ± 12.4	58.1 ± 14.0
Sex		
Female	35	22
Male	17	11
Location of aneurysm		
Internal carotid artery	24	14
Anterior cerebral artery	15	12
Middle cerebral artery	5	1
Vertebrobasilar system	8	6
Mean (± SD) aneurysm size (mm)	5.0 ± 3.0	5.0 ± 2.8
Mean (± SD) no. of coils	5.3 ± 4.5	4.8 ± 2.4

Note.—Differences between the groups for all variables were not significant ($P > .05$).

TABLE 2: Comparison of clinical data

Variable	Group A (n = 52)	Group B (n = 33)	*P* Value
No. of exposures			
Total procedure	23.1 ± 7.5	15.3 ± 4.8	<.0001
Working projection	7.5 ± 4.8	1.9 ± 1.4	<.0001
During embolization	11.6 ± 5.2	7.8 ± 2.8	.0002
3D DSA	–	2.0 ± 0.4	–
Total contrast medium (mL)*	211.3 ± 55.5	215.2 ± 62.9	>.05

Note.—Data are mean ± SD.

* For this variable, n = 32 for group A and n = 23 for group B.

Results

No significant differences were noted between the two groups for patient age, sex, location of aneurysms, size of aneurysms, and number of implanted coils (Table 1).

The clinical differences during the procedure in the DSA suite between the two groups are listed in Table 2. The total number of exposures during the interventional procedure were fewer in group B than group A ($P <$ .0001). This included exposures used to define the working projection, confirmatory angiography after each coil placement, road mapping, intraaneurysmal angiography, and so on. The number of exposures needed to decide on the working projection was reduced from 7.5 in group A to 1.9 in group B ($P < .0001$). Also, the number of exposures for embolization was reduced from 11.6 in group A to 7.8 in group B ($P = .0002$). For 3D DSA, data acquisitions were performed before and after embolization. The mean number of 3D DSA exposures used was 2.0. However, the total amount of contrast medium used did not show a significant difference between the two groups.

Discussion

Since Guglielmi et al (8, 9) introduced electrolytically detachable platinum coils in 1991 for the endovascular treatment of cerebral aneurysms, these coils have become an important treatment choice for cerebral aneurysms. As expected, the technology has spread rapidly worldwide. This treatment method requires high-spatial-resolution and spatially directed DSA to evaluate the vascular anatomic structures adjoining the cerebral aneurysm and the parent and daughter arteries. Three-dimensional images, reconstructed with the data from MR angiography or CT, can provide clinically useful information to the operator (1). To assist in therapy, however, this information must be received before the therapeutic procedure. More recently, 3D reconstructed angiography systems, which are based on rotational digital angiography with or without a subtraction technique, have been developed (10–13). Rotational 3D angiography not only enables the operator to understand the 3D anatomic relationships described above, but also provides the information necessary in the DSA suite at the time of the procedure.

The accuracy of 3D DSA regarding the size of the aneurysm neck, the shape of the aneurysm body, and the relationship of the aneurysm to major branches has been proved (2, 3). In addition, the clinical usefulness of evaluation with 3D DSA has been reported (2–7). Although our approach regarding the evaluation of 3D images in this series was not based on randomization, our study presents the clinical advantages at the time of the interventional procedures for treating the acutely ruptured cerebral aneurysm, by employing comparisons between windows of time before and after the introduction of 3D DSA in our department.

Our 3D DSA system allowed us to acquire high-quality 3D images of cerebral arteries in a short time and also allowed us to observe the critical region of therapeutic anatomy from multiple directions without unfavorable influences from intervening and overlying bones and veins. Three-dimensional DSA was very useful for diagnosing cerebral aneurysms and for choosing therapeutic procedures, especially with regard to determining the appropriate working projection angle for the task of embolization (2). We can determine the optimal position for embolization with much greater operator confidence in a shorter period of time than would be otherwise expected. If the limitation of the movement of C-arm disturbs the optimal anatomic positioning, the biplane system still allows an approximate, or second-best, position according to the information provided by 3D DSA. These combined features contributed to the decrease in total number of DSA exposures from 23.1 to 15.3 on average, in the decision step to arrive at the ideal working projection from 7.5 to 1.9, and in the number of DSA exposures necessary during embolization from 11.6 to 7.8 on average. The reduction in the number of exposures is expected to limit the side effects of radiation.

Usually, 3D DSA studies were performed before and after embolization, and the mean number of 3D DSA exposures was 2.0. Since the two acquisitions required approximately 30 mL of contrast medium, the total amount of contrast medium administered for the diagnostic and interventional procedures did not show a significant difference between the two groups.

In conclusion, because the 3D DSA system is extremely helpful for diagnosis and endovascular treatment of cerebral aneurysms, this system can reduce the number of exposures.

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References

1. White PM, Wardlaw JM, Easton V. **Can noninvasive imaging accurately depict intracranial aneurysms? A systemic review.** *Radiology* 2000;217:361–370
2. Anxionnat R, Bracard S, Ducrocq X, et al. **Intracranial aneurysms: clinical value of 3D digital subtraction angiography in the therapeutic decision and endovacular treatment.** *Radiology* 2001;3:799–808
3. Tanoue S, Kiyosue H, Kenai H, Nakamura T, Yamashita M, Mori H. **Three-dimensional reconstructed images after rotational angiography in the evaluation of intracranial aneurysm: surgical correlation.** *Neurosurgery* 2000;47:866–871
4. Ishihara S, Ross IB, Piotin M, Well A, Aerts H, Moret J. **3D rotational angiography: recent experience in the evaluation of cerebral aneurysms for treatment.** *Intervent Neuroradiol* 2000;6:85–94
5. Missler U, Hundt C, Wiesmann M, Mayer T, Bruckmann H. **Three-dimensional reconstructed rotational digital subtraction angiography in planning treatment of intracranial aneurysm.** *Eur Radiol* 2000;10:564–568
6. Turjman F, Bendib K, Girerd C, Froment JC, Amiel M. **Pretherapeutic evaluation of intracranial aneurysms using three-dimensional angiography (3D morphometer): preliminary results.** In: Taki W, Picard L, Kikuchi H, eds. *Advances in Interventional Neuroradiology and Intravascular Neurosurgery.* Amsterdam, the Netherlands: Elsevier Science B.V., 1996;75–79
7. Anxionnat R, Bracard S, Macho J, et al. **3D angiography: clinical interest and first applications in interventional neuroradiology.** *J Neuroradiol* 1998;25:251–262
8. Guglielmi G, Venuela F, Sepetka I, Macellara V. **Electrothrombosis of saccular aneurysms via endovascular approach, I: electrochemical basis, technique, and experimental results.** *J Neurosurg* 1991;75:1–7
9. Guglielmi G, Venuela F, Dion J, Duckwiler G. **Electrothrombosis of saccular aneurysms via endovascular approach, II: preliminary clinical experiences.** *J Neurosurg* 1991;75:8–14
10. Kumazaki T. **Development of rotational digital angiography and new cone-beam 3D image clinical value in vascular lesions.** *Comput Methods Programs Biomed* 1998;57:139–142
11. Fahrig R, Fox AJ, Lownie S, Holdsworth W. **Use of C-arm system to generate true three-dimensional computed rotational angiograms: preliminary in vitro and in vivo results.** *AJNR Am J Neuroradiol* 1997;18:1507–1514
12. Bidaut LM, Laurent C, Piotin M, et al. **Second-generation three-dimensional reconstruction for rotational three-dimensional angiography.** *Acad Radiol* 1998;5:836–849
13. Heautot JF, Chabert E, Gandon Y, et al. **Analysis of cerebrovascular diseases by a new 3-dimensional computerized x-ray angiography system.** *Neuroradiology* 1998;40:203–209