Balloon Test Occlusion with Perfusion CT Imaging Utilizing Intraarterial Contrast Injection

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Summary

Balloon Test Occlusion (BTO) is performed to evaluate the collateral flow when a permanent therapeutic occlusion of unilateral carotid artery is planned. BTO with neurological evaluation alone, however, has a rather high false negative rate. In order to improve the sensitivity, several adjunctive procedures such as induced hypotension or cerebral blood flow (CBF) measurement with various modalities have been combined. Perfusion CT (PCT) is another imaging modality that is mainly used for the diagnosis of acute stroke. In this study, we evaluate the efficacy and the safety of BTO combined with PCT in the same procedure utilizing intraarterial contrast injection from the catheter.

Seven patients underwent BTO with PCT in our institution. All the procedures were performed in the angio/CT combination suite. BTO was performed in the usual fashion and when the patient passed the 30 minutes' BTO clinically, PCT was performed subsequently. Contrast material was injected from a Pig Tail catheter placed in the ascending aorta. The obtained data were transferred to a workstation and perfusion maps of CBF, cerebral blood volume (CBV), and time to peak (TTP) were generated using software. In three patients, single photon emission CT (SPECT) was also obtained with administering 99mTc -ethyl cysteinate dimer (99mTc -ECD) intravenously during BTO.

Although all the patients had passed the BTO clinically, the CBF maps of three patients revealed significant decrease in the occluded hemisphere. There was no procedure-related morbidity. PCT using intraarterial contrast injection during BTO was performed successfully and safely. Intraarterial injection allowed us to obtain excellent time-attenuation curves by utilizing less contrast material and less radiation dose.

Introduction

Therapeutic occlusion of a unilateral internal carotid artery (ICA) is sometimes inevitable in the treatment of large or giant cerebral aneurysms or skull base tumors. Balloon Test Occlusion (BTO) has been performed to evaluate the collateral flow when a permanent ICA occlusion is planned. BTO with neurological evaluation alone, however, has a rather high false negative rate¹. To improve the sensitivity, numerous adjunctive procedures such as induced hypotension, electroencephalogram, or cerebral blood flow (CBF) measurement with various modalities such as xenon-enhanced computed tomography (CT), single photon emission CT (SPECT) or positron emission tomography have been combined with BTO.

Perfusion CT (PCT) is another emerging modality that is mainly used for the diagnosis

Figure 1 The concept of an angio/CT comb suite.

of acute stroke. Intravenous injection of the contrast material is a current standard technique for PCT. Our institute has an angio suite equipped with a multi-detector CT. It enables us to do angiographic evaluation and BTO with PCT in one session without transferring the patient. This is a preliminary study to evaluate the efficacy and the safety of the BTO combined with PCT utilizing intraarterial contrast injection.

Figure 2 An aortic arch angiogram during the balloon test occlusion. Note the inflated balloon (arrowheads).

Methods

Patients

From July 2003 to October 2004, seven patients (six women, one man) underwent BTO with PCT. All patients were potential candidates for permanent occlusion of the parent artery. Six of them had wide-necked or giant aneurysms. The other patient had dissecting aneurysm in cervical carotid artery. Table 1 shows the patients characteristics.

Technique

All the procedures were performed in the angio/CT combination suite (Miyabi; Siemens, Erlangen, Germany, figure 1). This system consists of single plane C-arm DSA unit and multi-detector CT. Bilateral femoral arteries were punctured and femoral sheaths were placed. One sheath was placed for a diagnostic catheter with a temporally occlusion balloon (5-Fr Selecon Balloon Catheter; Clinical Supply, Gifu, Japan) and the other for a Pig Tail catheter. BTO was performed in the usual fashion, inflating the balloon in the cervical ICA for 30 minutes with neurological examination every five minutes. Angiographical evaluation during the balloon inflation was also performed. When the patient passed the 30 minutes' BTO clinically, PCT was performed subsequently. With keeping the balloon inflated, the C-arm was placed in the parking position, and the patient table was moved into the gantry of the multi-detector CT. Then the non-ionic iodinated contrast material (Omnipaque 300; Daiichi Pharmaceutical, Tokyo, Japan) was injected using a power injector from a Pig Tail catheter in the ascending aorta (figure 2). The scan started from five seconds before the contrast injection and continued until the contrast was washed out, with one scan in every second. The scan level was decided to cross the basal ganglia and two adjacent 10 mm slices were utilized for the evaluation in this study.

Data Analysis

The obtained data were transferred to a workstation and perfusion maps of CBF, cerebral blood volume (CBV), time to start (TTS), and time to peak (TTP) were generated using software (Perfusion CT software; Siemens). The calculation of CBF was based on the maximum slope method. The TTP was defined as the time lag between the first arrival of the

Figure 3 Asymmetric CBF maps of perfusion CT (Patient 4).

contrast material within major arteries included in the slice and the local bolus peak of the brain tissue.

Four symmetric pairs of regions of interest (ROIs), which diameter was 2.5 cm each, were placed manually on both sides to cover the anterior cerebral artery (ACA) area, the middle cerebral artery (MCA) area, the posterior cerebral artery (PCA) area, and the perforating artery area. The asymmetry index (AI: $(\text{Value occl} - \text{Value contra}) / \text{Value avg} \times 100$, where Valueoccl means the value on the occluded side,

and Valuecontra means the value on the non-occluded side) of CBF in each pair of ROIs were also calculated.

Comparison with SPECT

In three patients (Patient 4, 6, 7), CBF measurement with SPECT was also performed to compare the results with PCT. During the BTO, 99mTc-ethyl cysteinate dimer (99mTc-ECD) was administered intravenously. Data acquisition with gamma camera was performed after the BTO. Four pairs of ROIs corresponding to

Figure 4 Symmetric CBF maps of perfusion CT (Patient 3).

Figure 5 A SPECT image of Patient 6.

those of PCT were placed, and the ratio and the AI of radioactivity count were calculated.

Results

Although every patient had passed the BTO clinically, the CBF color maps of three patients (Patient 2, 4, 6, 7) revealed a significant decrease in the occluded hemisphere (figure 3), whereas the CBF of the others seemed to be symmetrical (figure 4). With comparing the AIs, the most affected areas with occlusion were the MCA and the perforating artery areas. Table 2 summarizes the average of AIs in the two adjacent PCT slices in the MCA and perforating artery areas.

The SPECT images also revealed reduced CBF in the occluded hemisphere (figure 5); however, the degree of the reduction was not as prominent as PCT.

Fortunately, all the aneurysms were treated without sacrificing the ipsilateral ICA. In the dissecting aneurysm patient (Patient 6), intensive anticoagulation therapy was chosen with considering the patient's young age and the unusual angiographic findings of the contralateral ICA.

In the first three patients, total of 30 ml contrast material was injected at a rate of 8 ml/s. As we found that less contrast was sufficient to obtain a sharp arterial input function, we injected only total of 10 ml contrast at 5 ml/s for the last

Table 1 Characteristics of seven patients.

Patient No.	Sex	Age	Diagnosis	Occluded Side	Presentation
1	F	52	Cavernous giant aneurysm	R	Mass effect (oculomotor palsy)
2	F	69	Paraclinoid large aneurysm	R	Incidental
3	F	51	Carotid-ophthalmic aneurysm	L	Incidental (with previously operated right carotid-oph. an.)
4	F	56	Paraclinoid aneurysm	L	Incidental
5	F	48	Paraclinoid aneurysm	R	Incidental
6	M	41	Cervical ICA dissecting aneurysm	R	Cerebral infarction (right basal ganglia)
7	F	60	Paraclinoid large aneurysm	L	Incidental

Table 2

Patient No.	AI of CBF in MCA (%)	AI of CBF in perforating artery (%)
1	-1.7	17.5
2	-29.4	-33.7
3	15.8	-6.7
4	-62.3	-49.7
5	-14.5	6.4
6	-9.0	-17.1
7	-63.4	-52.3
AI: asymmetry index		

three patients. We also changed the PCT acquisition protocol with reducing the mAs from 250 to 200 in the last three patients, although the data acquisition did not seem to be affected with that. The total scan time was less than 30 seconds in all the patients. There was no procedure-related permanent morbidity.

Discussion

Safe, Secure Procedure

The current study manifested the safety and the efficacy of the PCT with intraarterial contrast material injection during the BTO. There is no necessity to transfer the patient from an angio suite to the other modality with the balloon catheter placed in the carotid artery of the patient. The secure balloon occlusion could be achieved under fluoroscopy.

Threshold and Validation

At this moment no patient underwent a permanent therapeutic carotid occlusion. The threshold that assures the permanent IC occlusion without ischemic complication has not yet detected. We focused on the asymmetry index of CBF in ACA, MCA, PCA, and perforating artery area. The AI of CBF in MCA and perforating artery area seems to be promising to predict the outcome after the permanent occlusion. SPECT is another modality that is often utilized to evaluate the CBF during the BTO. In this study, SPECT imaging was acquired in three patients and the AI of the radioactivity count was calculated. Qualitative CBF reduction was detected on both of the PCT map and

the SPECT imaging, however, the asymmetry was more prominent in the PCT. As a next step, the validation with other modalities and finding out the threshold would be the main issue.

Reduction of the Radiation Doze and the Contrast Material

So far, we have never combined an additional challenge test such as acetazolamide administration with this technique. Jain et Al. reported PCT with BOT and acetazolamide challenge². Repeated study may occur the radiation dose problem. The protocol in the last three patients (200 mAs, 30 seconds, total of 10 ml contrast material injection at 5 ml/s) allows 40% reduction of the radiation dose and 80% reduction of the contrast material comparing to the standard stroke protocol of PCT with intravenous contrast injection (250 mAs, 40 seconds, total of 50 ml contrast material at 8 ml/s). These reductions would be great advantages in performing a challenge test or a repeat study.

Conclusions

PCT using intraarterial contrast injection during BTO was performed successfully and safely. Intraarterial injection allowed us to obtain excellent time-attenuation curves by utilizing less contrast material and less radiation dose. This technique seems promising, however, further studies are necessary as the number of patients was limited and quantitative results should be validated against those of other modalities.

References

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