大韓核醫學會誌：第29卷 第1號 1995

Assessment of Cerebral Collateral Circulation Using ^{99m}Tc-Hexamethyleneamine Oxime(HMPAO) SPECT During Internal Carotid Artery Balloon Test Occlusion

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=국문 초록=

내경동맥 풍선 시험 결찰술(BTO)시 ^{99m}Tc-HMPAO 뇌 SPECT를 이용한 대뇌 측부 순환의 평가

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저자들은 두개 기저나 경부종괴 또는 내경동맥의 동맥류등으로 인하여 내경동맥의 결찰이 필요한 환자에 있어서 객관적인 관점에서 수술전에 영구적인 내경동맥의 결찰의 안전성에 관하여 ^{99m}Tc-HMPAO 뇌 SPECT를 이용하여 보고자 하였다.

내경동맥의 결찰이 고려되는 24명의 두개기저나 경부종괴 환자를 대상으로 하였다.저자들은 풍선 시험 결찰술 시행전과 시행중의 양측 중대뇌동맥 영역의 섭취정도를 ^{99m}Tc-HMPAO 뇌 SPECT를 이용하여 비교해보았고 이러한 결과를 신경학적 검사, 경동맥 스텀프압 그리고 뇌전도검사등과 비교해 보았다.

대상환자중 19명의 환자에서는 풍선 시험 결찰술 동안 신경학적 이상등의 문제들을 경험하지 않았고 이들에 있어 중대뇌동맥영역의 섭취정도는 결찰술 시행전에 비교하여 95-101%에 해당하였다. 나머지 5명의 환자에서는 일과성 반신마비와 의식소실등의 심한 신경학적 증상을 보였고 이들에 있어 중대뇌동맥 영역의 섭취정도는 시행전에 비하여 77-85%에 해당하였으며 다른 검사결과와도 잘 부합되었다.

결론적으로 풍선시험결찰술 시행전과 시행중의 ^{99m}Tc-HMPAO 뇌 SPECT는 중대뇌동맥 영역의 섭취가 시행전에 비교하여 85%이하인 경우 영구적인 신경학적 결손을 예측할 수 있는 간단하고 객관적인 방법이 될 수 있을 것으로 생각한다.

Key Words: Catheters and catheterization, Ballon Cerebral blood vessels, Radionuclide studies Cerebral blood vessels, Therapeutic blockade Cerebral angiography Emission CT(SPECT) Radionuclide Tmaging

INTRODUCTION

In the treatment of extensive tumors inrolving the neck or skull base and inoperable internal carotid artery aneurysm may require occlusion of internal carotid artery. The circle of Willis provides collateral circulation for the territory of the

occluded internal carotid artery, however, it is completely intact in only 21 % of the population[1]. Therefore, permanent occlusion or surgical sacrifice of the internal carotid artery is associated with a significant risk of subsequent stroke[2]. Many of these stroke will involve large vascular territories and some will lead to death.

Balloon test occlusion(BTO) of the internal cerebral artery with monitoring of clinical neurologic status was used to identify those patients who might develop ischemia and infarction with permanent occlusion [3-5]. However, 5 to 20% of the patients who showed no clinical signs of ischemia during the BTO will develop an infarction with Permanent occlusion. A method that employs a cerebral perfusion imaging agent, ^{99m}Tc-HMPAO is described for identifying those patients who clinically pass an internal carotid artery BTO but who then may develop a cerebral infarction after permanent occlusion[2,6-8].

The purpose of our study was to assess the feasibility and preoperative predictability of neurologic deficits from the permanent occlusion of an internal carotid artery using ^{99m}Tc-HMPAO brain SPECT as an objective criterion.

MATERIALS AND METHODS

The study population comprised 24 patients with various of head and skull base; 6 patients with pituitary tumor, 5 thyroid carcinoma, 4 mucoepidermoid carcinoma, 3 angiofibroma, 3 meningioma, 2 massive jugulodigastric lymph node metastasis and one with osteogenic sarcoma of maxilla. All patients had the possibility of accidental ligation of the internal carotid artery during operation because of close contact with or encircling the internal carotid artery by the tumor mass.

Firstly, we performed cerebral angiography with contralateral carotid artery compression for the evaluation of circle of Willis. Evaluation of posterior communicating artery was done by compression of carotid artery during vertebral angiography. Balloon occlusion of the internal carotid artery with 5 French Swan-Ganz catheter through 7 French Hemaquet introducer sheath was applied and the balloon was filled with contrast material(Fig. 1). Occlusion was performed at the mid cervical internal carotid artery level to avoid carotid body stimulation and to avoid injury to petrosal segmment of ICA by the stiff balloon segment of catheter, and ballooning was continued until pulsatile motion of balloon from cardiac cycle is ceased. Neurologic examination of the patients was performed during the occlusion of the internal carotid artery. 15 minutes after BTO of the internal carotid artery, 20mCi (740MBq) of ^{99m}Tc-HMPAO (Ceretec, Amersham, Arlington Herghts, IL) were injected intra

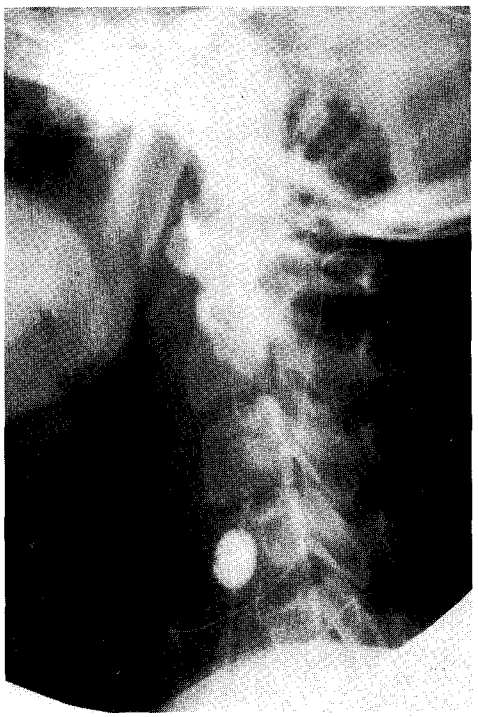

Fig. 1. Lateral view of the skull shows example of balloon occlusion of the internal carotid artery.

venously. The test occlusion was maintained for additional 15 minutes(a total of 30 minutes)as long as patients was without deficit on clinical neurologic examinations. At the conclusion of the procedure, the patient was transferred to the nuclear medicine department for cerebral SPECT images. SPECT images were obtained with the Siemens orbiter 7500 gamma camera. The examination was carried out by taking 64 views during 360 degree rotation about the long axis of the patients. A 64 X64 matrix(pixel size, 6.25 mm)was used, axial and coronal reconstuction were performed by Microdelta computer. Results of the occlusion study were compared to those of preocclusion study taken at least 3 days before balloon occlusion test using semiquantitative method. Semiquantitative analysis was performed using region of interests(ROIs)drawn on both middle cerebral artery(MCA)territories using mirror technique. Then relatve percent of redioactivity of ^{99m}Tc-HMPAO was calculated as follows:

$$\frac{\dfrac{\text{Count of redioactivity on ROIs of affected side MCA territory}}{\text{Count of radioactivity on ROIs of opposite side MCA territory}}\ \text{(occlusion test)}}{\dfrac{\text{Count of radioactiviy on ROIs of affected side MCA territory}}{\text{Count of radioactivity on ROIs of opposite side MCA territory}}\ \text{(preocclusion test)}} \times 100$$

We performed additional tests. Neurological examination which classified into clinically tolerated and clinically not tolerated groups, electroencephalography(EEG), monitoring of intracarotid stump pressure (Fig. 2) and cerebral angiography with contralateral artery compression were compared to the brain SPECT findings.

RESULTS

19 patients showed no evidence of ischemia on clinical neurologic examination during the 30 minutes of BTO of internal (carofid artery) However, 5 Patiens showed abnormalities on clinical examination during 30 minutes of BTO of internal carotid artery. Our results divided into clinically tolerated and clinically not tolerated groups. Neurolog examinatim in clinically not tolerated group revealed thats 4 patient developed motor weakness, sudden loss of consciousness in 2 patients, sensory change in 3 patients and abnormal EEG

Clinically tolerated group showed postocclusion mean stump pressure ranging from 55 to 85mmHg, mean stump pressure decrease ranging

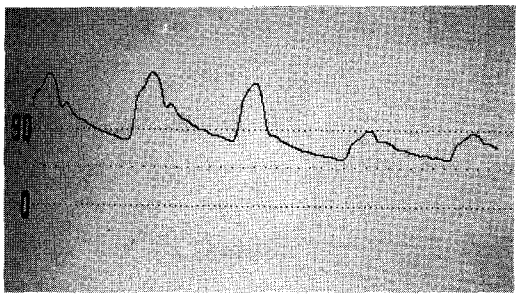

Fig. 2. Arterial pressure monitoring during the occlusion. Pressure differences before and after the occlusion is obvious.

Table 1. Stump Pressure Measurement and Relative Percent of MCA Territory on HMPAO SPECT

Ballon Occlusion Clinical	Postocclusion Mean Stump Pressure(mmHg)	Mean Stump Pressure Decrease(mmHg)	Relative percent of MCA Territory on HMPAO SPECT(%)
Tolerated(n=22)	55-85	10-45	95-101
Not tolerated(n=8)	30-60*	30-70*	77-85

*Couldn't be done on 2 cases because of sudden loss of consciousness.

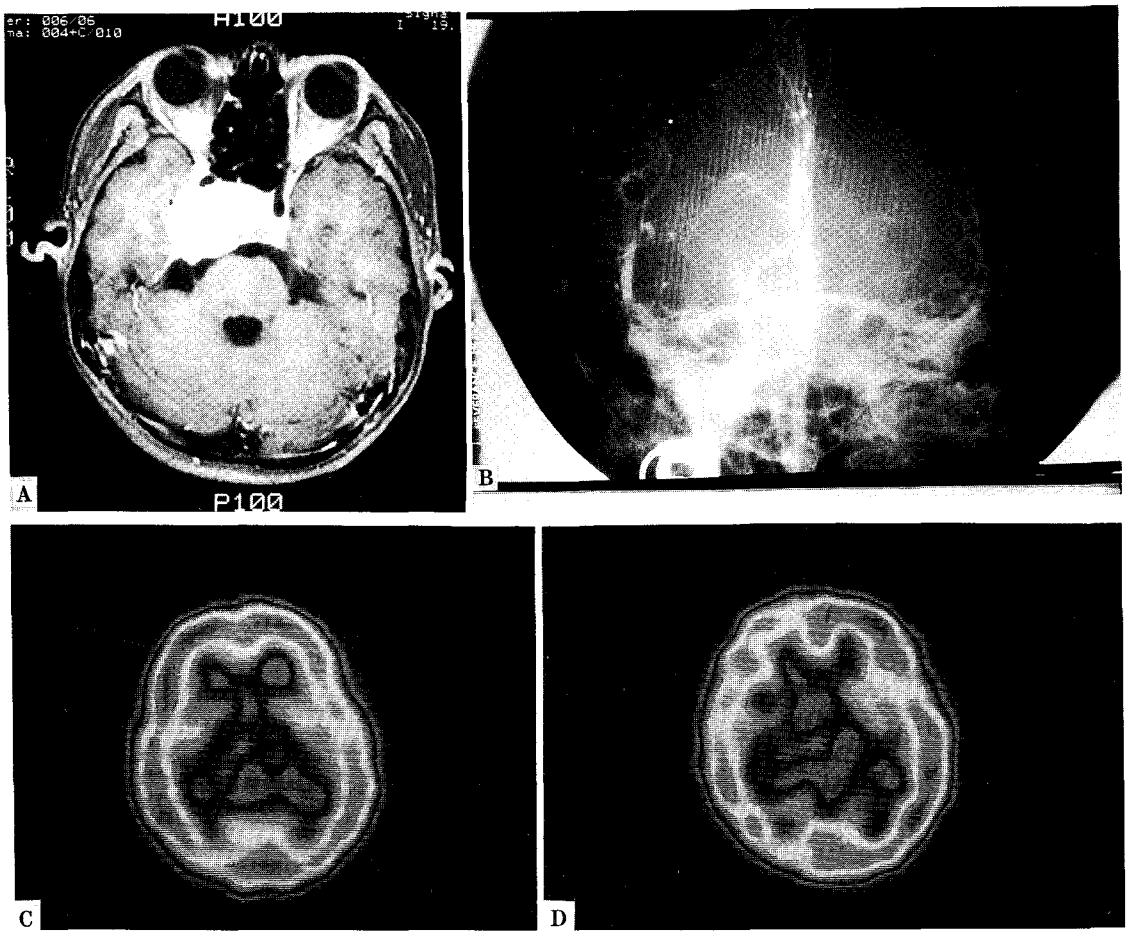

Fig. 3. 16 year-old male patient with pituitary adenoma.
a) Axial T1 weighted MR image shows pituitary tumor encircling the right internal carotid artery with extension to right parasellar area.
b) Carotid angiogram on AP projection shows good visualization of contralateral middle cerebral artery through the anterior communicating artery during left carotid compression.
c) Preocclusion brain SPECT shows no significant difference of radioactivity between the cerebral hemispheres.
d) Postocclusion brain SPECT shows markedly decreased perfusion on the right cerebral hemisphere. Semiquantitative study shows more than 15% perfusion deficits.

from 10 to 45mmHg, semiguantitaive analysis of relative percentage of MCA territory on the semiquantitative analysis of ^{99m}Tc-HMPAO SPECT ranging from 95 to 101% Whereas, clinically not tolerated group showed postocclusion mean stump pressure ranging from 30 to 60mmHg, mean stump pressure decrease ranging from 30 to 70mmHg, relative percentage of MCA territory on the semiquantitative analysis of ^{99m}Tc-HMPAO SPECT ranging from 77 to 85% (Table 1). ^{99m}Tc-HMPAO brain SPECT showed more perfusion deficits in clinically not tolerated group than in clinically tolerated group(Fig. 3, 4).

Asymmetrical cerebral hypoperfusion on the ^{99m}Tc-HMPAO SPECT with angiographic evidence of good cross-filling from the nonoccluded

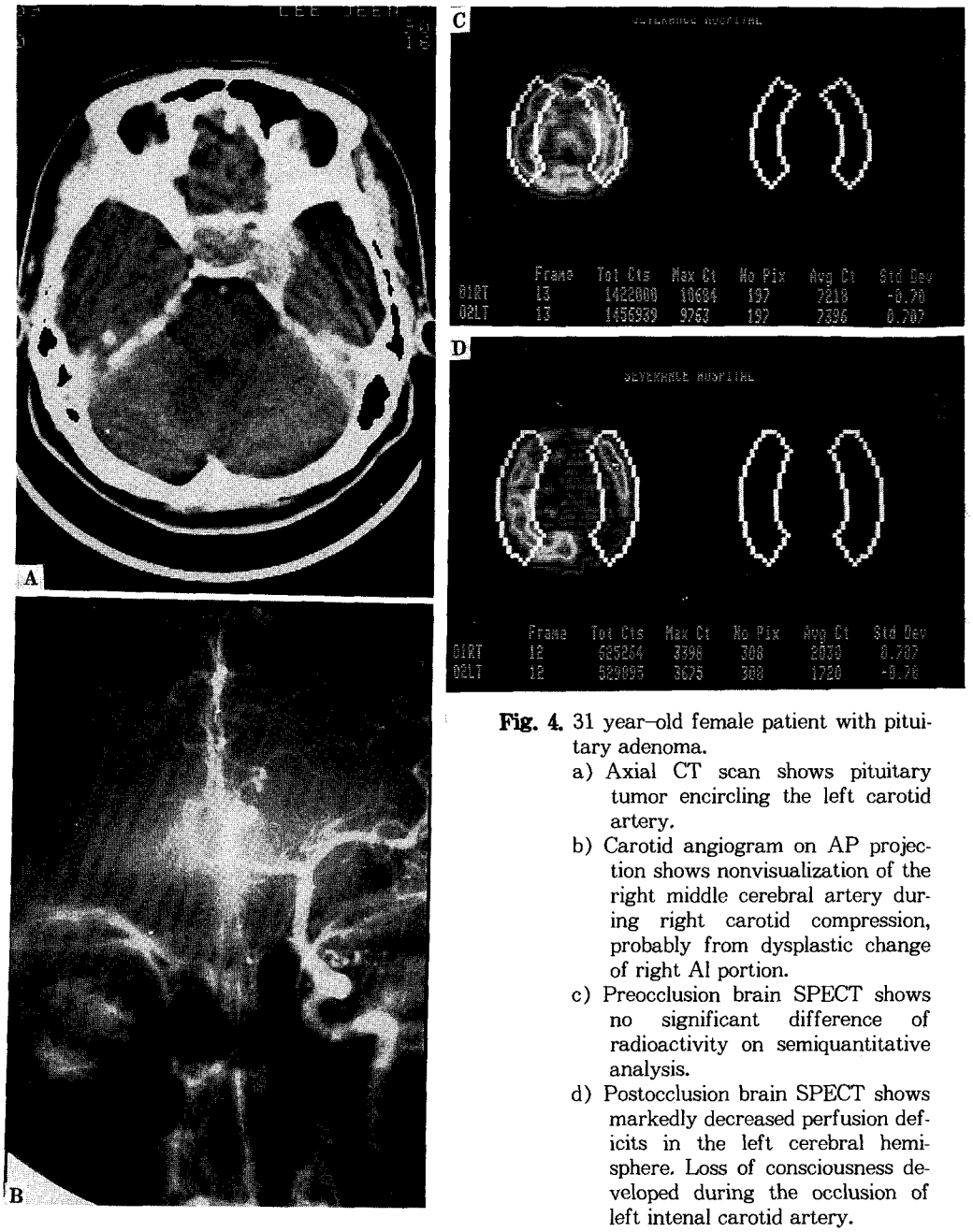

Fig. 4. 31 year-old female patient with pituitary adenoma.
a) Axial CT scan shows pituitary tumor encircling the left carotid artery.
b) Carotid angiogram on AP projection shows nonvisualization of the right middle cerebral artery during right carotid compression, probably from dysplastic change of right Al portion.
c) Preocclusion brain SPECT shows no significant difference of radioactivity on semiquantitative analysis.
d) Postocclusion brain SPECT shows markedly decreased perfusion deficits in the left cerebral hemisphere. Loss of consciousness developed during the occlusion of left intenal carotid artery.

side to the ocluded side was demonstrated in 2 patients(Fig. 5).

DISCUSSION

Permanent occlusion of the internal carotid

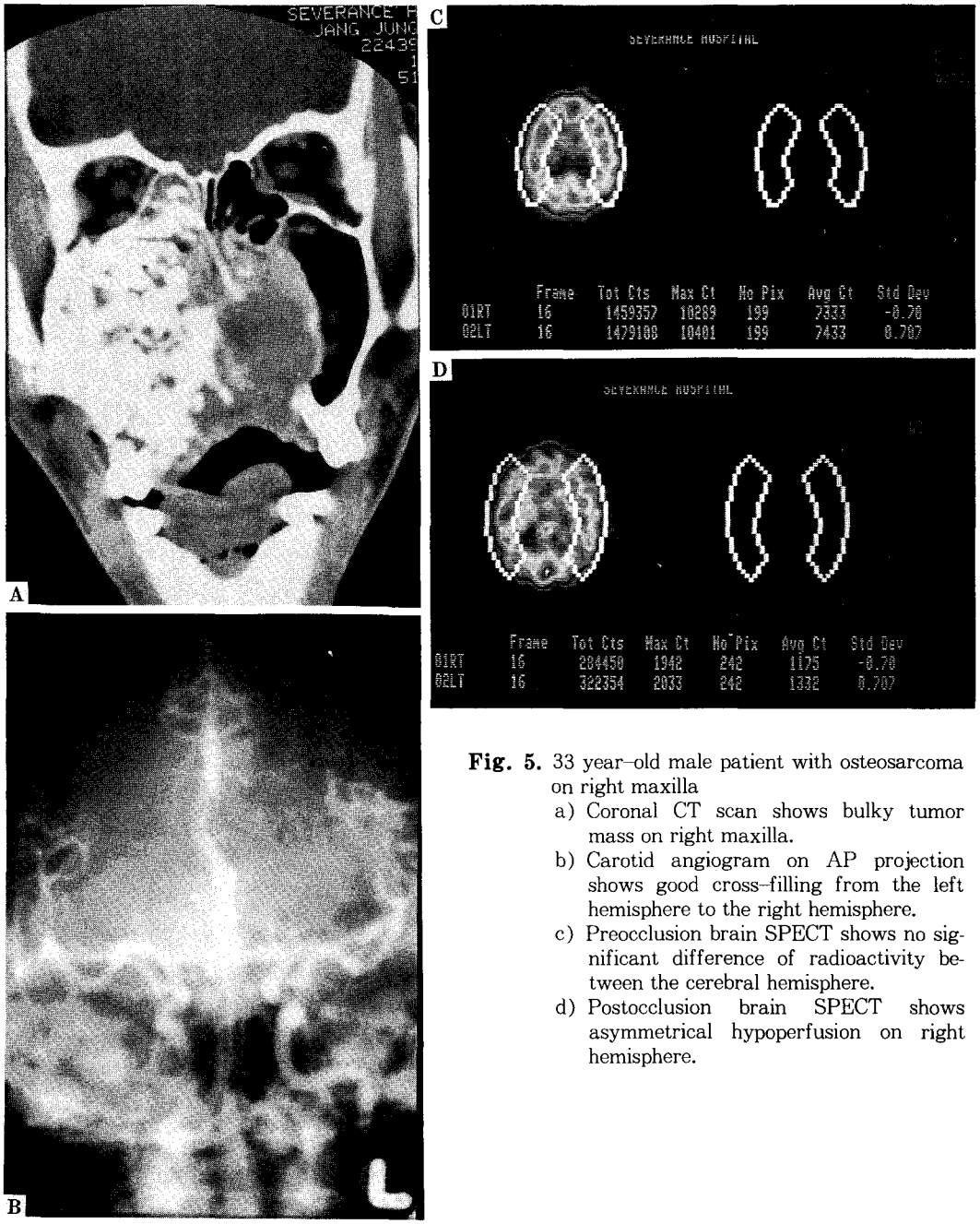

Fig. 5. 33 year-old male patient with osteosarcoma on right maxilla
a) Coronal CT scan shows bulky tumor mass on right maxilla.
b) Carotid angiogram on AP projection shows good cross-filling from the left hemisphere to the right hemisphere.
c) Preocclusion brain SPECT shows no significant difference of radioactivity between the cerebral hemisphere.
d) Postocclusion brain SPECT shows asymmetrical hypoperfusion on right hemisphere.

arterg is a recognized treatment for certain in tracranial aneurysm and extensive tumor involving neck and skull base when there is adequate collateral cerebral circulation[9,10]. However, previous report demonstrated that occlusion of the common carotid artery or internal carotid artery carries about 30% risk of ischemia of the ipsilateral cerebral hemisphere[9]. In 21% of those case,

onset of deficits is delayed for more than 48 hours after occlusion. It is thought that infarction after successful temoporany and permanent carotid occlusion has two basic causes. One is hypoperfusion and ischemia due to inadequate collaterals around the circle of Willis and the cardiovascular status of the patient[6,8]. This problem of hypoperfusion is definitely more serious in the elderly, whose blood pressure and cardiac output are less stable than in younger persons[6]. The other major cause is embolism, due to clot developing in the stump of the occluded supraclinoid carotid artery and then dislodging and entering the middle cerebral artery circulation[6-8,11].

In the assessment of the adequacy of the collateral circulation during the test occlusion of the internal carotid artery, vanious techniques have been recommended including angiography[12], EEG[13,14], somatosensory evoked potentials (SEPs)[15], stump pressure[16,17], transcranial doppler[18], ^{131}Xenon with external probes[13,17], stable Xenon with CT[3,19,20] and positron emission tomographg(PET)[21]. Measurement of stump pressure has been shown to be correlated with intracranial blood flow, but the wide range of normal values precluded its use as an absolute predictor of adequate cerebral blood flow and this technique is available only at a few institutions[4,6]. A PET scan during the test occlusion period would be technically difticult[21]. External probe measurement with ^{131}Xenon is easy to perform in the angiography suite and offer reproducible quantitative measurements but do not provide information about regional perfusion. Stable Xenon CT cerebral blood flow imaging may show focal area of ischemia with BTO that are clinically inaparent but it requires special features to be added to the CT scanner[6].

Matsuda et al have used ^{99m}Tc-HMPAO SPECT to assess cerebral perfusion during test occlusion of the carotid artery[22]. ^{99m}Tc-HMPAO is a lipophilic radiotracer with an extraction across the blood-brain barrier of about 0.75. Once inside the brain, it is rapidly converted into a hydrophilic form that is retained for hours. The contrast between normal and abnormal brain remains constant between 10 minutes and 2 hours. ^{99m}Tc has a half life of 6 hours, therefore, ^{99m}Tc-HMPAO SPECT studies may be repeated the next day to determine if a perfusion defect is reversible and related to the BTO[23,24].

We use semiquantitative method for measurement of relative percentage of middle cerebral artery territory to evaluate relative hypoperfusion according to BTO. Our result demonstrated that relative percentage of middle cerebral artery territory on ^{99m}Tc-HMPAO SPECT in clinically tolerated group ranging from 95 to 101%, whereas 77 to 85% in clinically non-tolerated group. 2 patients demonstrated good angiographic evidence of cross-filling from the nonoccluded side of the internal carotid artery to the occluded side of the internal carotid artery through anterior communicating artery showed asymmetric cerebral hypoperfusion on ^{99m}Tc-HMPAO SPECT during BTO. Therefore, angiographic evidence of cross-filling is a poor predictor of whether the patient will tolerate permanent occlusion. As previously mentioned, there are several ways of predicting which patients will not tolerate occlusion because of inadequate collateral circulation. However, until recently, no studies are available that can objectively predict which patients will not tolerate internal carotid occlusion because of the thromboembolic complications.

In conclusion, although the number of patients suggest we studied is small and postoperative follow-up is scanty, our results suggest that ^{99m}Tc-HMPAO brain SPECT before and during BTO seems to be a simple and objective method for prediction of permanent neurologic deficits when

the comparative uptake of middle cerebral artery territories during BTO is lower than 85% of that before BTO.

SUMMARY

To predict preoperatively the safety of permanent occlusion of an internal carotid artery with ^{99m}Tc-HMPAO brain single photon emission computed tomography(SPECT) from an objective point of view.

Twenty-four patients underwent balloon test occlusion(BTO) of the internal carotid arteries because of neck and skull base tumors. The authors assessed the uptake of both middle cerebral artery territories before and during BTO with ^{99m}Tc-HMPAO brain SPECT using semiquantitative analysis method and compared the results with other factors(neurologic examination, arterial stump pressure and electroencephalogram).

Nineteen patients had not experienced neurological deteriorating or any problem during BTO. Their comparative uptakes of the middle cerebral artery territories were 95 to 101% of the pre-BTO state. The remaining five patients showed severe neurologic symptoms such as transient hemiplegia and unconsciousness. Their comparative uptake of the middle cerebral artery territories were 77 to 85% of the pre-BTO state, and were well matched with other factors.

^{99m}Tc-HMPAO brain SPECT before and during BTO seems to be a simple and objective method for prediction of permanent neurologic deficits when the comparative uptake of middle cerebral artery territories during BTO is lower than 85% of that before BTO.

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