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Brain SPECT Used to Evaluate Vasospasm After Subarachnoid Hemorrhage

Correlation with Angiography and Transcranial Doppler

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Purpose: The primary objective of this study was to correlate Tc-99m HMPAO and ethyl cysteine dimer perfusion brain SPECT imaging with angiography and transcranial Doppler (TCD) to identify vasospasm after subarachnoid hemorrhage.

Methods: A retrospective analysis of consecutive patients who had cerebral blood flow SPECT imaging for subarachnoid hemorrhage and aneurysm clipping was made. Flow velocity measurements were correlated using TCD and cerebrovascular angiography.

Results: Of the 129 patients were included in this study, 84 were female and 45 were male, with a mean age of 51.9 years and a median age of 51 years (range, 9 to 84 years). Eighty-nine patients had brain SPECT evidence of hypoperfusion. Concordance was found between SPECT and TCD with vasospasm in 57 of 89 (64%) patients and nonconcordance was evident in 32 patients (36%). Eleven patients who had concordance between SPECT and TCD had nonconcordant results of angiography for vasospasm.

Conclusions: These findings suggest that all three methods are complementary to each other in the evaluation of patients with vasospasm after subarachnoid hemorrhage. Concordance of 64% between SPECT and TCD is acceptable and explicable by the differences in technique and measurement of cerebral blood flow compared with vascular narrowing, respectively.

Key Words: Brain SPECT, HMPAO, Subarachnoid Hemorrhage, Vasospasm.

Symptomatic cerebral hypoperfusion induced by vasospasm causes delayed ischemic neurologic deficits in approximately 30% of patients after subarachnoid hemorrhage (SAH) (1), and it is also a frequent complication in patients with SAH and aneurysm clipping. Breakdown in cerebral autoregulation and changes in cerebral hemodynamics after SAH are largely responsible for reduced regional brain blood flow. Any delay in prompt diagnosis increases the risk for irreversible ischemia, which can lead to infarction. Of the approximately 28,000 persons in North America in whom SAH develops as a result of a ruptured aneurysm, nearly 14% have severe complications or die (2). Early diagnosis of cerebral vasospasm can result in prompt intervention, such as angioplasty or vasodilator infusion–volume expansion, to correct the problem (3). When normal cerebral blood flow (CBF), which is approximately 55 ml·/100 $^{g-1}$·min^{-1}, decreases to less than 20 ml·/100 $^{g-1}$·min^{-1}, early neuronal dysfunction develops with the onset of ischemia. In extreme decreases of CBF (that is, less than 10 ml·/100 $^{g-1}$·min^{-1}), cerebral infarction develops. Symptomatic vasospasm typically occurs 48 to 72 hours after the SAH and might take as long as 6 to 10 days after the event to peak.

Although angiography has been the gold standard and can identify vasospasm of large and medium vessels, it is invasive, has associated complications, albeit of low incidence, and can itself induce vasospasm in some patients (4,5). Transcranial Doppler (TCD) estimates cerebral arterial erythrocyte velocity changes secondary to narrowing of medium vessels but is not sensitive enough to evaluate distal vessel changes, and it produces only indirect information concerning cerebral tissue perfusion (6–8). Information complementary to angiography and TCD is needed in the management of patients with SAH.

Technetium-99m perfusion SPECT imaging of the brain has been well established in the assessment of

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regional CBF (rCBF). The distribution of the radiotracer depends on the rCBF and has high first-pass extraction and long-term retention (9–11). Brain perfusion radiopharmaceuticals are readily available in clinical nuclear medicine departments, and their value in the detection of vasospasm has been established by various authors (2,11–16). After its uptake, HMPAO is converted intracellularly to a hydrophilic compound and remains fixed in the brain for a prolonged period, facilitating delayed imaging after injection. However, the brain SPECT imaging reflects blood flow, as existed during injection. The utility of brain SPECT that gives direct information on regional cerebral perfusion, in the early diagnosis of vasospasm, has been reported in the literature (2,12,15,17). One common feature of the earlier studies, however, is the relatively few patients examined.

This is a retrospective analysis of a series of consecutive patients after SAH and aneurysm clipping and correlates the role of brain SPECT with angiography and TCD.

Materials and Methods

We evaluated the records of 129 consecutive patients who had brain SPECT imaging from June 1993 to December 1995 for SAH and aneurysm clipping for this study. The mean age of the patients (84 female, 45 male) was 51.9 years, the median was 51 years, and the range was 9 to 84 years. Seventy-seven percent of patients were between 40 and 60 years old. Table 1 lists the frequency of brain SPECT scans.

TABLE 1. *Frequency of Brain SPECT*

Scans (n)	Patients (n)
1	97
2	17
3	7
4	5
5	3
Total	129

Each patient was injected with approximately 1,110 MBq (30 mCi) Tc-99m HMPAO (Nycomed/Amersham, Princeton, NJ) or Tc-99m ethyl cysteine dimer (DuPont Pharma, North Billerica, MA), and images were obtained approximately 35 minutes later. All images were acquired using a Prism 3000 triple-headed tomographic scanner (Marconi, Cleveland, OH) and a low-energy, high-resolution collimator. A 20% window was centered on the 140 keV photopeak of Tc-99m. SPECT images were acquired in a step-and-shoot manner with 64 steps, each lasting 25 seconds, acquired over 360° using clockwise rotation. Images were processed with a Wiener prefilter and RAMP

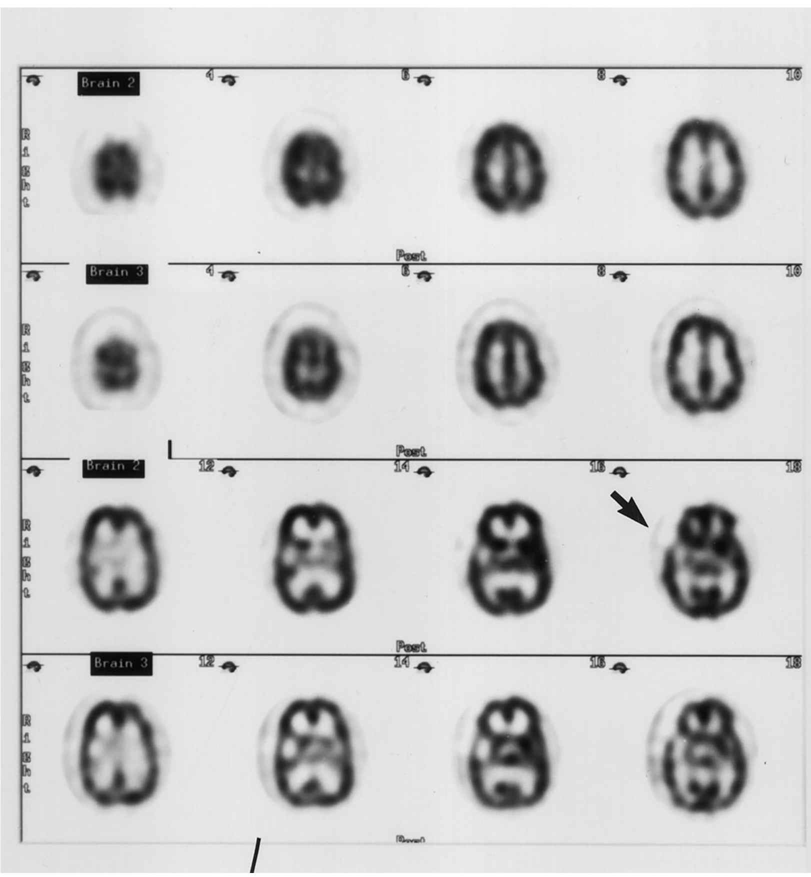

Fig. 1. A right middle cerebral artery aneurysm is shown after clipping. An operative site defect is evident in the right temporal lobe (solid arrow). There is no change in serial transaxial brain SPECT images (initial images are shown in rows 1 and 3, and follow-up images are shown in rows 2 and 4). No evidence of vasospasm-induced hypoperfusion is apparent.

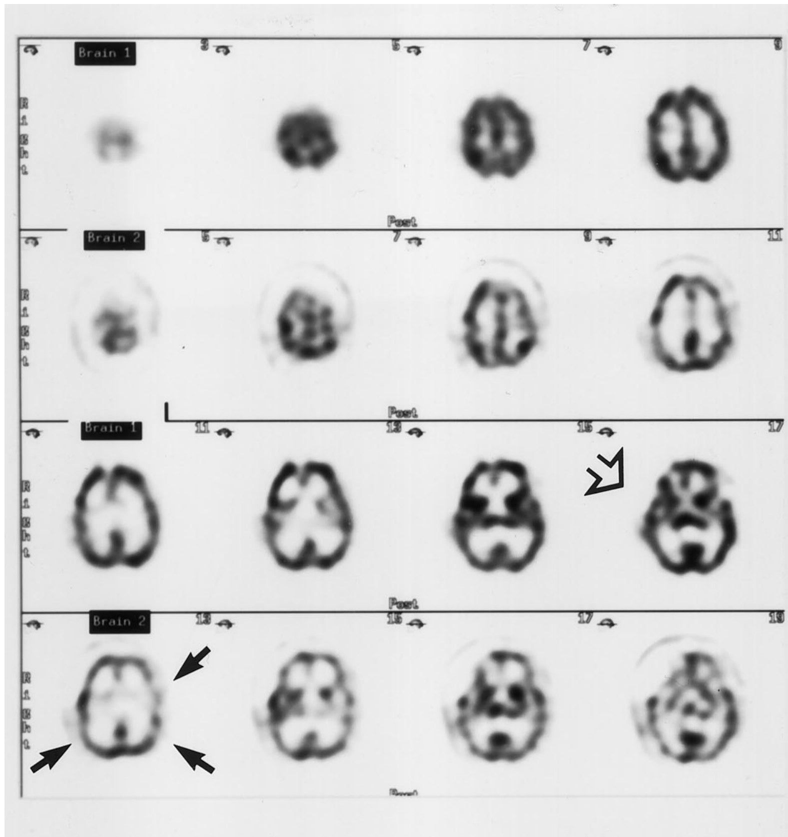

Fig. 2. An anterior communicating artery aneurysm is shown after clipping. An operative site abnormality is seen on the first set of transaxial SPECT images (rows 1 and 3; open arrow). Diffuse, multifocal moderate hypoperfusion is seen on subsequent images (rows 2 and 4), indicating progressive vasospasm (solid arrow).

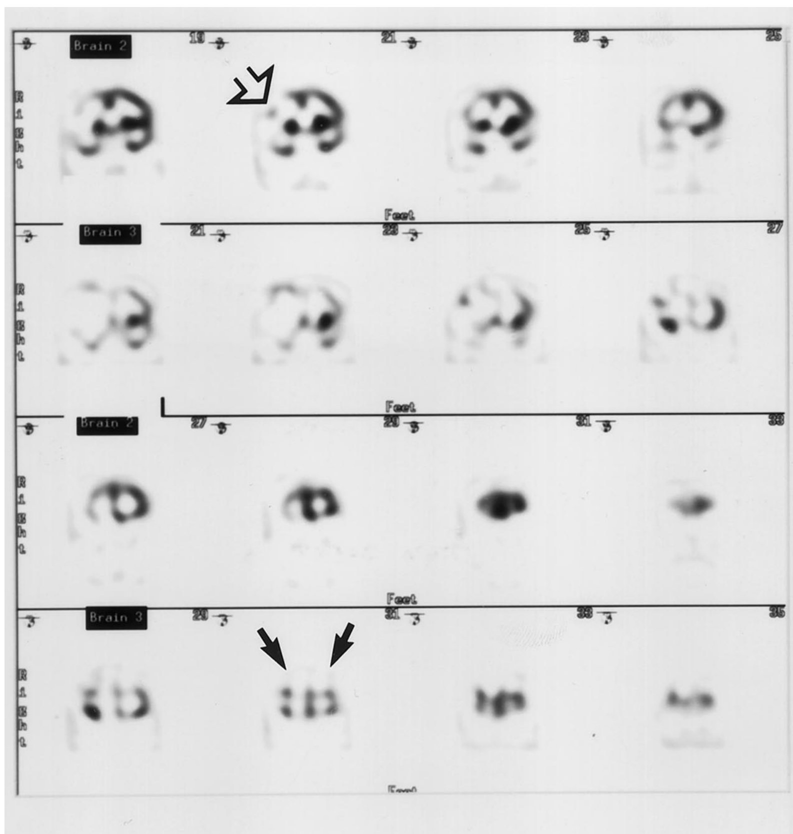

Fig. 3. The right ICA aneurysm is shown after clipping. The right middle cerebral artery infarct is seen on coronal SPECT images in rows 1 and 3 (open arrow). Extension of known infarct and new zones of severely decreased to absent perfusion caused by worsening vasospasm are seen in anterior cerebral artery territories bilaterally on subsequent coronal images (rows 2 and 4; solid arrows). These represented multiple zones of infarction in this patient, who subsequently died.

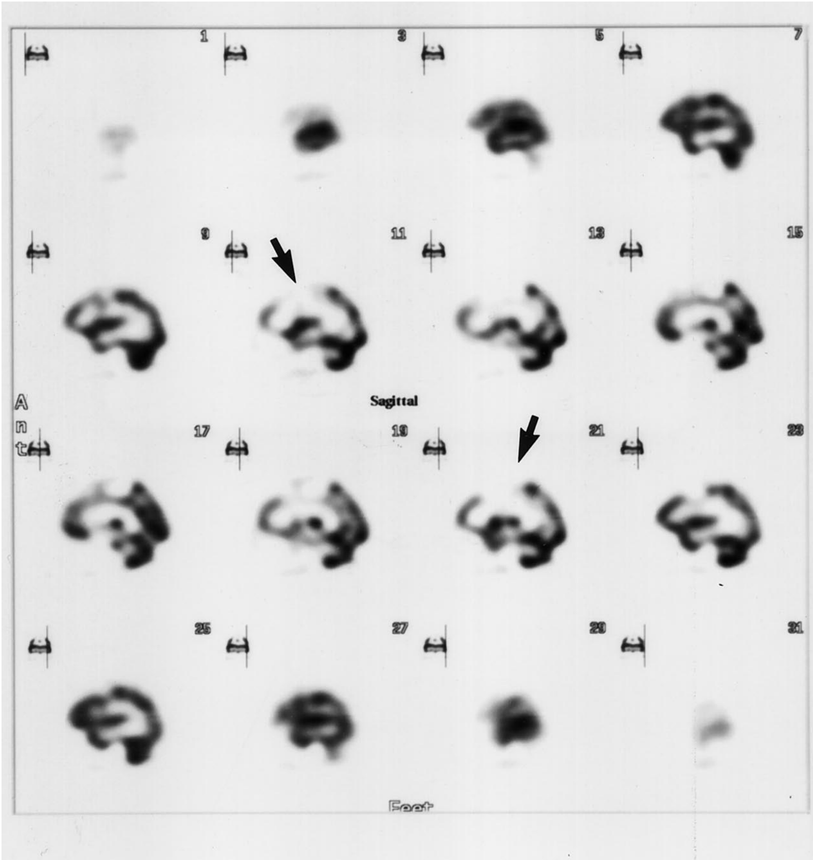

Fig. 4. This patient was examined some days after experiencing an unrecognized subarachnoid hemorrhage. Extensive infarction caused by vasospasm is evident in the anterior cerebral artery territories bilaterally on the sagittal SPECT images (solid arrows).

filter for resolution recovery. Software attenuation correction with a coefficient of 0.11 cm^{-1} was used in all patients with intact cranial bones. All images were reconstructed in transaxial, coronal, and sagittal planes that were approximately 6 mm thick (Figs. 1 to 4). The imaging room contains medical gases and suction and basic monitoring and resuscitation equipment. All patients underwent their first brain SPECT scans by the second postoperative day (that is, approximately 48 to 72 hours after the original event). Additional brain SPECT images were obtained later if the patient's clinical condition warranted.

Two nuclear medicine physicians interpreted the images via consensus reading. Hypoperfusion was defined as mild, moderate, or severely decreased uptake compared with cerebellar and contralateral hemispheric uptake. Angiography and transcranial Doppler information was obtained from patients' charts or computer reports.

Results

SPECT evidence of cerebral hypoperfusion was found in 89 (69%) patients. Anterior circulation aneurysms were noted in 82 patients and posterior aneurysms in 45, whereas two patients had post-traumatic SAH. There was concordance between SPECT and TCD, with vasospasm in 57 of 89 (64%) patients and nonconcordance in 32 patients (36%). Among the latter patients, SPECT revealed abnormalities in the basal ganglia, thalami, or brain stem in 11. Eleven patients who had concordance between SPECT and TCD had nonconcordant angiography for vasospasm. Five of 32 (16%) patients who had nonconcordant results between TCD and SPECT had angiographic support of SPECT findings. Eight of 11 patients with abnormalities in the basal ganglia, thalami, or both on SPECT had normal results of TCD and no vasospasm on angiography.

Discussion

The primary objective of this study was to evaluate the complementary roles of cerebral angiography, TCD, and brain SPECT in evaluating vasospasm in patients with SAH and aneurysm clipping. Several diagnostic methods such as computed tomography (CT) (18), TCD, magnetic resonance imaging (19), and rCBF evaluation with xenon CT (20) or positron emission tomography (21) have all been used to identify vasospasm. Magnetic resonance imaging, despite its sensitivity in locating the site of the bleeding and evaluating postoperative edema, is not superior to CT in diagnosing hypoperfusion. Both magnetic resonance imaging and CT have inherent difficulties in the presence of metallic artifacts such as surgical clips. Tranquart et al. (12) in a series of 26 patients studied found that CT was positive only in 42% of patients with modest (less than 10%) hypoperfusion.

A 64% concordance rate between TCD and SPECT seen in our study correlates favorably with other studies and is explicable by the differences in the techniques involved and the location of the vasospasm in the artery. Among the 32 patients who showed nonconcordance, 11 (34%) were found to have abnormalities in basal ganglia, thalami, or brain stem on SPECT. Of these, 5 (16%) patients had angiographic support of SPECT findings. Although TCD effectively identifies proximal vasospasm, it is limited in the evaluation of distal vasospasm (7,8,22). Furthermore, in the early phases of vasospasm, CBF may be maintained by increased cerebral blood volume by dilatation of small blood vessels secondary to autoregulation; reduced CBF also may be associated with normal arterial flow velocities, at least in some patients (11). Eleven patients who had concordance between SPECT and TCD, but had nonconcordant angiography for vasospasm. Angiography depends more on the dimensions of the narrowed arterial lumen in establishing the diagnosis than the other two methods.

Eight of the 11 patients with reduced rCBF in basal ganglia or thalami on SPECT did not have abnormal results of TCD and angiography. This is likely a result of the greater sensitivity of SPECT to minimal CBF changes caused by vasospasm or occlusion in distal vessels, and thus it is useful in the evaluation of subcortical and white matter ischemia resulting from small perforator artery occlusions, before other imaging methods manifest these changes (23).

Thirty-two (25%) patients in our study were scanned more than one time during a single admission, emphasizing its ease and the noninvasiveness of brain SPECT and its utility in the routine clinical management of patients with SAH (12).

Uptake is greatest in the cerebellum, with the white matter showing considerably less uptake (16). Commercial introduction of a more stable agent, ethyl cysteine dimer, gives the flexibility of either immediate (because of more rapid background clearance) or delayed imaging. Knowledge of the surgical site is critical for the interpretation of the studies, because operative sites show reduced perfusion (24) resulting from edema and sometimes retraction injury from surgery.

Brain SPECT is not absolutely quantitative and thus has limited use in the presence of symmetric, globally decreased perfusion. However, in our series, we did not see any patient with such findings. A semiquantitative estimation of rCBF, through manual regions of interest or automated image analysis, should complement visual evaluation of rCBF and its role in identifying patients with vasospasm who would benefit from early intervention (16) and in predicting clinical outcome (2,12).

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