Reversible Hypoperfusion of the Cerebral Cortex in Normal-Pressure Hydrocephalus on Technetium-99m-HMPAO Brain SPECT Images After Shunt Operation

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A man with dementia underwent radionuclide cisternography to establish the diagnosis of communicating hydrocephalus. Technetium-99m-HMPAO brain SPECT images showed marked hypoperfusion of both posterior cerebral cortices and three-dimensional displays that demonstrated perfusion defects at both of the posterior parietotemporal regions. A successful ventriculoperitoneal shunt operation was performed. Five and one-half months later, repeat three-dimensional display showed that the perfusion defects had resolved and a repeat brain SPECT image showed marked improvement of the hypoperfusion. This concurred with postoperative clinical improvement. Technetium-99m-HMPAO brain SPECT, which provides objective documentation of clinical recovery after surgery, could be routinely used to evaluate patients with normal-pressure hydrocephalus.

Key Words: SPECT; ventriculoperitoneal shunt; three-dimensional display

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The criteria for diagnosis of normal-pressure hydrocephalus (NPH) include: progressive gait abnormality, dementia, urinary incontinence or urgency and hydrocephalus demonstrated by CT. Normal-pressure hydrocephalus is treatable by permanent drainage of cerebrospinal fluid (CSF) (*1,2*). Intraventricular pressure (IVP) can be modified by implanting a shunt device through which CSF flows when IVP exceeds a certain pressure. In this study, we report a patient with a typical clinical syndrome of NPH who underwent ^{111}In-DTPA cisternogram and ^{99m}Tc-HMPAO brain SPECT scan before and after shunt operation. The reversible cortical hypoperfusion was demonstrated by SPECT images and three-dimensional display.

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CASE REPORT

A 64-yr-old-man presenting with imbalance, loss of bladder control and difficulty in walking over the past 6 mo was admitted to the neurosurgery service. His previous medical history was unremarkable, except for allergies to influenza vaccine and penicillin. Physical examination revealed increased deep tendon reflexes of both lower extremities, a positive Babinski response on the right side, severe ataxia and mild bilateral finger-to-nose test discoordination.

A CT scan of the head showed marked dilation of both the lateral and the third ventricles. CSF biochemistry was normal, and initial CSF pressure was 16 mm/H_2O. Indium-111-DTPA cisternography showed a rapid radiotracer penetration in both lateral ventricles and persistent radiotracer retention in the ventricles throughout the 48 hr study (Fig. 1). Technetium-99m-HMPAO brain SPECT images showed hypoperfusion of both cerebral hemispheres, which was more severe in the posterior cortices. The perfusion defects involving both the posterior temporal and the occipital lobes were well delineated by surface three-dimensional displays (Fig. 2). The activity ratio of the cerebral hemispheres to the cerebellar hemispheres was 1.3.

After medium-pressure ventriculoperitoneal (V-P) shunt placement, the patient's ataxic gait and bladder incontinence immediately improved. A shunt series showed continuity of the V-P shunt. The postoperative course was uneventful, and the patient was discharged with significant clinical improvement on the fourth postoperative day.

Five and one-half months later, a CT scan of the head showed increased thickness of the cerebral cortex and smaller lateral ventricles. A repeat SPECT scan of the brain showed marked improvement of perfusion at both cerebral cortices and although a repeat ^{111}In-DTPA cisternogram (Fig. 3) showed no significant changes from the preshunt images, the V-P shunt tube was visualized. Resolution of the perfusion defects was best demonstrated by surface three-dimensional images (Fig. 4). The activity ratio of the cerebral hemispheres to the cerebellar hemispheres was 1.6.

Brain SPECT scans were obtained before and after each shunt operation. Fifteen to 20 min after intravenous injection of 26 mCi of ^{99m}Tc-HMPAO, SPECT images were made with a triple-headed camera fitted with an ultra-resolution collimator for acquisition of SPECT data from 120 projections over 360°, with 30 sec of projection. The triple-headed camera was interfaced with a 64-bit supercomputer. SPECT images (transaxial, coronal and

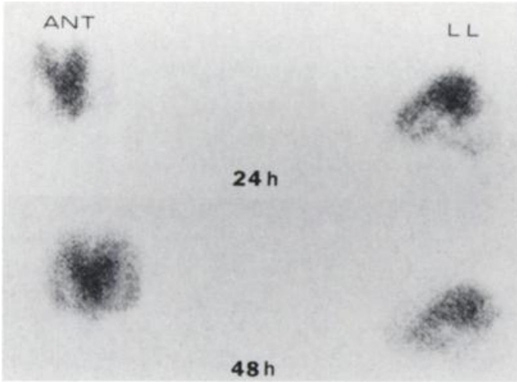

FIGURE 1. Indium-111-DTPA cisternograms at 24 and 48 hr show both lateral ventricles to be enlarged with persistent ventricular reflux consistent with normal-pressure hydrocephalus or communicating hydrocephalus.

sagittal sections) were reconstructed by using a Butterworth filter (order of 4, cut-off 0.3), backprojection and an attenuation correction. Surface and volume three-dimensional images were reconstructed from transaxial SPECT data; the processing time was 5–10 min. The surface threshold value was set at 50% and volume three-dimensional weighing factor was set at 0.1 (*3*).

Quantitative data were obtained by activity ratio of cerebral hemispheres to cerebellar hemispheres. A coronal section that concomitantly included cerebral and cerebellar hemispheres was chosen. Regions of interest of both cerebral hemispheres to both cerebellar hemispheres were counted before and after the shunt.

RESULTS

Technetium-99m-HMPAO brain SPECT images made before the shunt procedure showed hypoperfusion of both cerebral hemispheres, more severe in the posterior cortices. The perfusion defects involving both the posterior temporal and occipital lobes were well delineated by three-dimensional displays (Fig. 2). Five and one-half months later, a repeat brain SPECT scan showed marked improve-

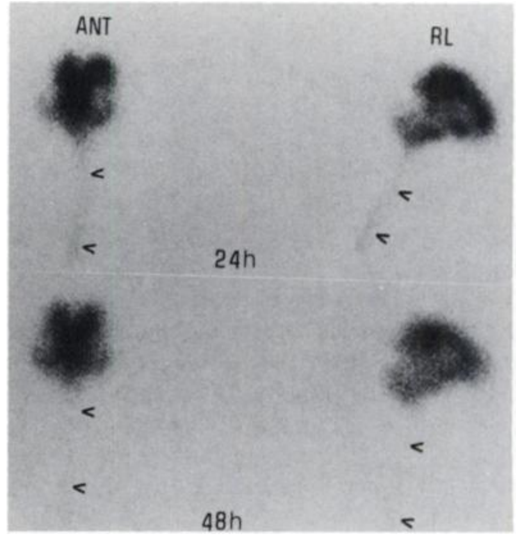

FIGURE 3. Repeat ^{111}In-DTPA cisternograms at 24 and 48 hr performed 5.5 mo after the first study show persistent radiotracer retention in the enlarged lateral ventricles and visualization of the ventriculoperitoneal shunt tube (open arrowheads).

ment of perfusion at both cerebral cortices. Resolution of perfusion defects was best demonstrated by three-dimensional images (Fig. 4). The cerebral-to-cerebellar ratios before and after the shunt operation were 1.3 and 1.6, respectively.

DISCUSSION

Normal-pressure hydrocephalus is a treatable dementia. Our patient's ataxia and urinary incontinence were improved after the shunt operation. Although ataxic gait and urinary incontinence are objective clinical findings that indicate NPH, brain SPECT provides better objective documentation of the condition. Radionuclide studies for eval-

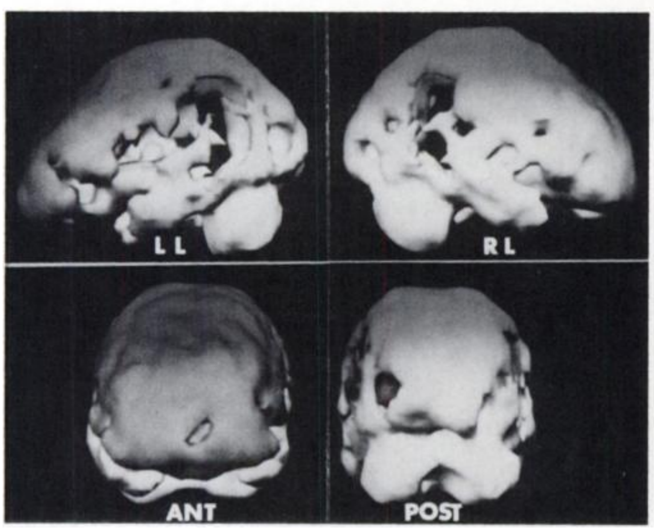

FIGURE 2. Surface three-dimensional displays showed perfusion defects in the posterior temporoparietal and occipital areas.

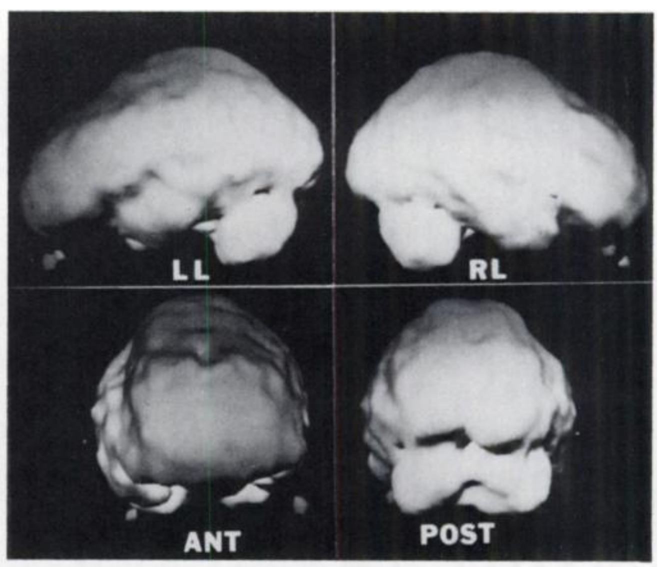

FIGURE 4. Surface three-dimensional displays show resolution of perfusion defects.

uation of NPH before and after shunt operation have been reported using ^{133}Xe inhalation with SPECT imaging (*4–6*) and, recently, ^{18}F-FDG with PET (*7–9*) and SPECT with ^{99m}Tc-HMPAO (*10,11*). Previous reports found decreases in cerebral blood flow both globally and regionally in patients with NPH. Decreased flow in the frontal lobe has been reported in studies using ^{133}Xe (*4,5*). Graff-Radford et al. reported global decreases in flow, but the decreases were more severe in the frontal lobe (*6*). Brain SPECT using ^{99m}Tc-HMPAO showed decreased blood flow in the bifrontal region and in the inferior and midtemporal cortex (*11*). Our patient's decreased flow involved the posterior temporoparietal and occipital regions but the perfusion to the frontal lobes appeared to be normal.

PET scan with ^{18}F-FDG shows postoperative recovery of cerebral glucose metabolism after shunt placement (*7–9*). Lipophilic radiopharmaceuticals such as ^{99m}Tc-HMPAO and ^{123}I-IMP cross the intact blood-brain barrier and are localized in neurons. The information about regional blood flow or perfusion obtained from ^{99m}Tc-HMPAO or ^{123}I-IMP is concordant with metabolic data obtained by PET using ^{18}F-FDG. Thus, regional blood flow detected by ^{99m}Tc-HMPAO could be an indirect measurement of cerebral metabolism. In our case, the ^{99m}Tc-HMPAO brain SPECT image demonstrated an improvement of cerebral blood flow after the shunt operation, as compared with the amount of cerebral blood flow demonstrated by the baseline SPECT scan. Since a PET scan is more expensive than ^{99m}Tc-HMPAO brain SPECT, the latter could be used as a routine procedure for evaluating the cerebral blood flow of patients with communicating hydrocephalus before and after the shunt operation.

To demonstrate improvement of cortical perfusion after shunt surgery, we quantitated the cortical-to-cerebellar ratio. The cerebral cortex is vulnerable because of lateral ventricle dilation caused by NPH. The cerebellum has been chosen as the reference region in NPH (*10,11*) because it is not known to be associated with structural abnormalities in the cerebellum. Coronal sections were selected for determining the cortical-to-cerebellar ratio because the posterior part of the coronal sections included the cerebral cortex and the cerebellum. This method was especially suited to our patient because his cortical involvement was more severe in the posterior temporoparietal and occipital lobes.

With a patient in the initial stages of NPH, evolution of the cerebral cortex in response to the dilation or enlargement of lateral ventricles may manifest itself as relative increases in perfusion or blood flow. As the ventricle is further enlarged, compromised white matter cerebral flow and persistent brain dysfunction are caused by continued tension against the brain tissue across the ependymal surface of the ventricles (*11*). After some time, cortical blood flow decreases markedly (Fig. 2), and CT scans show thinning of the cerebral cortex. At this point, cortical hypoperfusion is still reversible after shunt operation (Fig. 4).

Marked hypoperfusion, as shown in the ^{99m}Tc-HMPAO brain SPECT images (Fig. 4), reflects cerebral cortical atrophy, and cortical thinning is demonstrated by CT scan of the head before the shunt procedure. Five and one-half months after the shunt operation, reversible hypoperfusion of the cerebral cortex was evidenced by a follow-up CT scan showing that the thickness of the cerebral cortex had increased. Technetium-99m-HMPAO provides functional perfusion information of the cerebral cortex in concordance with anatomic information obtained from CT scans.

Surface three-dimensional displays, shown in Figures 2 and 4, easily delineated the extent of posterior cortical involvement in our patient. After the shunt operation, these defects disappeared. Thus, three-dimensional display is the best technique for assessing shunt response. Volume and surface three-dimensional images view the brain from all angles, and not only simplify but increase the quality of SPECT images. Surface three-dimensional displays have been applied in the evaluation of cerebral perfusion (*3,12–14*) for patients who have suffered a stroke (*3,15,16*), seizure (*16*), depression (*17*) and slow progressive apraxia (*18*). Compared with baseline brain SPECT scan, surface three-dimensional images display an expanded perfusion defect with Diamox (*16,18*). The expanded defect represents the areas of failed vasodilation reserve (*18*).

We propose the use of volume and surface three-dimensional displays to evaluate cerebral cortical perfusion in normal-pressure hydrocephalus patients who are routinely evaluated by brain SPECT scan before and after shunt surgery.

REFERENCES

1. Adams RD, Fischer CM, Hakim S, Ojemann RG, Sweet WH. Symptomatic occult hydrocephalus with normal cerebrospinal fluid pressure. A treatable syndrome. *N Engl J Med* 1965;273:117–126.
2. Hakim S, Adams RD. The special clinical problem of symptomatic hydrocephalus with normal cerebrospinal fluid pressure. Observations on cerebrospinal fluid hydrodynamics. *J Neurol Sci* 1965;2:307–377.
3. Shih WJ, Schleenbaker RE, Stipp V, Magoun S, Slevin JT. Surface and volume three dimensional displays of ^{99m}Tc-HMPAO brain SPECT in stroke patients by a three-headed camera. *Clin Nucl Med* 1993;18:945–949.
4. Mathew NT, Meyer JS, Hartmann A, Ott EO. Abnormal cerebrospinal fluid-blood flow dynamics. Implications in diagnosis, treatment and prognosis in normal pressure hydrocephalus. *Arch Neurol* 1975;32:657–664.
5. Ingvar DH, Schwartz MS. The cerebral blood flow in low pressure hydrocephalus. In: Lundberg N, Pontén U, Brock M, eds. *Intracranial pressure II*. New York: Springer-Verlag; 1975:153–159.
6. Graff-Radford NR, Rezai K, Godersky JC, Eslinger P, Damasio H, Kirchner PT. Regional cerebral blood flow in normal pressure hydrocephalus. *J Neurol Neurosurg Psychiatry* 1987;50:1589–1596.
7. Friedland RP. Normal-pressure hydrocephalus and the saga of the treatable dementias. *JAMA* 1989;262:2577–2581.
8. Jagust WJ, Friedland RP, Budinger TF. Positron emission tomography with ^{18}F-fluorodeoxyglucose differentiates normal pressure hydrocephalus from Alzheimer-type dementia. *J Neurol Neurosurg Psychiatry* 1985;48:1091–1096.
9. Brooks DJ, Beaney RP, Powell M, et al. Studies on cerebral oxygen metabolism, blood flow and blood volume in patients with hydrocephalus before and after surgical decompression, using positron emission tomography. *Brain* 1986;109:613–628.
10. Waldemar G, Hasselbalch SG, Andersen AR, Delecluse F, Petersen P, Johnsen A, Paulson OB. Technetium-99m-d,l-HMPAO and SPECT of the brain in normal aging. *J Cereb Blood Flow Metab* 1991;11:508–521.
11. Waldemar G, Schmidt JF, Delecluse F, Andersen AR, Gjerris F, Paulson OB. High-resolution SPECT with ^{99m}Tc-d,l-HMPAO in normal pressure

hydrocephalus before and after shunt operation. *J Neurol Neurosurg Psychiatry* 1993;56:655–664.
12. Keyes JW Jr. Three-dimensional display of SPECT images: advantages and problems [Editorial]. *J Nucl Med* 1990;31:1428–1430.
13. Wallis JW, Miller TR. Volume rendering in three-dimensional display of SPECT images. *J Nucl Med* 1990;31:1421–1428.
14. Wallis JW, Miller TR. Three-dimensional display in nuclear medicine and radiology. *J Nucl Med* 1991;33:534–546.
15. Ishimura J, Fukuchi M. Clinical application of three-dimensional surface display in brain imaging with ^{99m}Tc-HMPAO. *Clin Nucl Med* 1991;16:343–351.
16. Devous MD Sr. Comparison of SPECT applications in neurology and psychiatry. *J Clin Psychiatry* 1992;53:13–19.
17. Okuda B, Tachibana H, Kawabata K, Sugita M, Fukuchi M. Three-dimensional surface display with ^{123}I IMP of slowly progressive apraxia. *Clin Nucl Med* 1993;18:85–87.
18. Holman BL, Devous MD Sr. Functional brain SPECT: the emergence of a powerful clinical method. *J Nucl Med* 1992;33:1888–1904.