Pediatr Radiology (1988) 18: 344–346

Pediatric Radiology

Local cerebral blood flow as assessed by xenon stable computed tomography in child drowning

J. A. Hodak[1], S. J. Tilden[3], S. D. Johnsen[2], T. J. Tarby[2] and B. P. Drayer[1]

Sections of [1] Neuroradiology and [2] Child Neurology, Barrow Neurological Institute at St. Joseph's Hospital and [3] Section of Pediatric Intensive Care, Children's Health Center at St. Joseph's Hospital, Phoenix, Arizona, USA

Abstract. A comatose patient who nearly drowned was studied with xenon stable computed tomography (CT) to assess regional cerebral blood flow (rCBF) after a basic CT studied revealed bilateral lucencies in the basal ganglia. Xenon stable CT revealed increased rCBF in the lucent areas of the basal ganglia and previously unsuspected absence of flow in the posterior circulation. Xenon stable CT may be a more sensitive indicator of ischemic cerebral damage than basic CT.

Drowning is a leading cause of acute neurologic injury in children and results in both anoxic and stagnant hypoxia of the brain [1]. Neuropathologic changes in these instances include ischemic changes concentrated in the arterial boundary zones of the cerebral cortex and cerebellum and variable ischemic changes in the basal ganglia [2]. Experimental studies in dogs with anoxic injury resulted in ischemic damage to the neocortex, basal ganglia, thalamus, and cerebellum; these changes are thought to be due to a combination of decreased brain perfusion as well as lack of oxygen [2]. Little is known about regional cerebral blood flow (rCBF) alterations in patients suffering from anoxic or generalized ischemic hypoxia. Anatomically specific imaging techniques (e.g. CT, magnetic resonance imaging) provide a unique window to analyze neuropathologic alterations that occur in live patients and

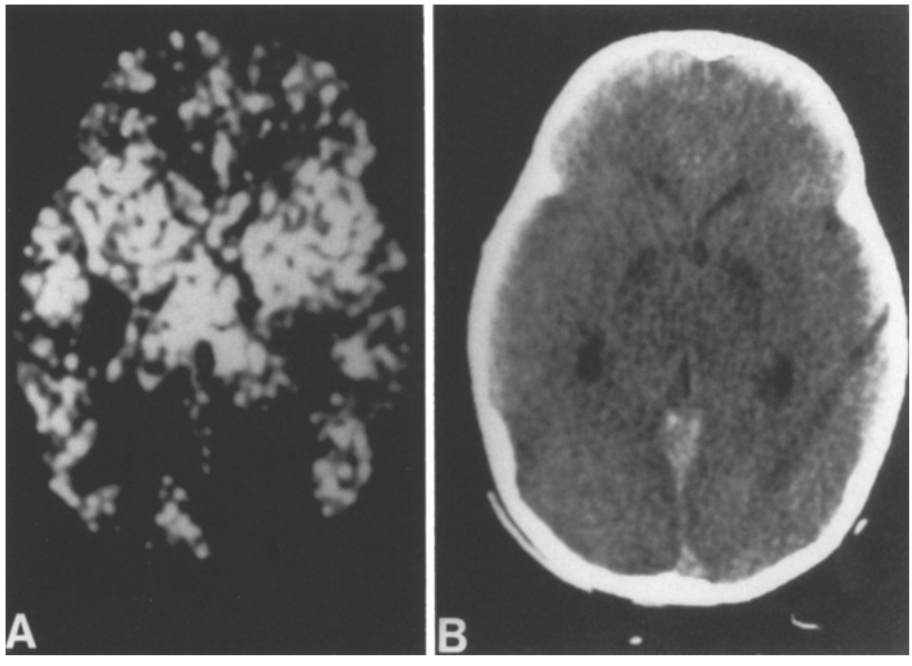

Fig. 1. **A** Xenon CT flow map showing bilaterally increased densities in the region of the globus pallidus and bilaterally decreased densities in the occipital region. These findings suggest hyperemia in the globus pallidus and decreased blood flow in the distribution of the posterior cerebral arteries. **B** CT scan at same level as flow map in Fig. 1 A showing decreased attenuation coefficients in the area of the globus pallidus bilaterally and no evidence of infarction in the regions of distribution of the posterior cerebral arteries

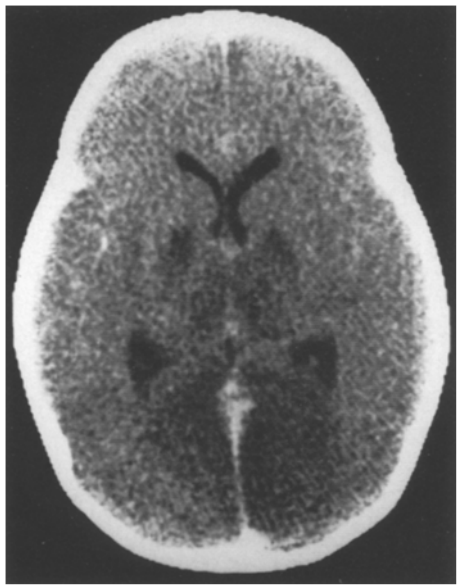

Fig. 2. CT scan 24 h after xenon study showing decreased densities, respresenting infarctions, in the regions of the globus pallidus and occipital cortex bilaterally

monitor these changes over time. We report here our findings in an 18-month-old near-drowning victim who had regional blood flow determinations using the nonradioactive xenon CT method for estimating rCBF [3].

Case report

An 18-month old boy was found after submersion in a bucket of water for approximately 10 min. This apneic and asystolic child was successfully resuscitated. On admission to the hospital, he was comatose and flaccid with a Glascow coma score of 3. His pupils were initially nonreactive, but became sluggishly reactive by six hours after admission. Twenty-four hours after admission, the child had a CT scan which was normal. A Richmond bolt was placed to monitor intracranial pressure. Initial intracranial pressure was 5 torr with an increase over the next 24 h to 14 to 17 torr. He remained comatose with sluggishly reactive pupils bilaterally and occasional spontaneous gasps while on a ventilator.

A rCBF determination was performed following the inhalation of 35% nonradioactive xenon in oxygen in the intubated child after informed parental consent. A General Electric 9800 CT scanner was used. The blood flow study showed normal to increased flow in the basal ganglia with markedly decreased rCBF in the occipital cortex bilaterally (Fig. 1 a). However, a nonenhanced CT study obtained just prior to the rCBF mapping, revealed bilateral lucencies in the globus pallidus and obliteration of the basilar cisterns (Fig. 1 b). The patient's condition remained stable during the study. An end-tidal CO_2 analyzer (Hewlett-Packard, Co., Waltham, Mass) was used to maintain the end-tidal pCO_2 at 33 torr. The patient's intracranial pressure during the study varied from 15 to 18 torr.

The patient's pupils became nonreactive and dilated with an elevation of intracranial pressure to 50 torr approximately 8 h after the rCBF study. The intracranial pressure remained elevated despite therapeutic intervention. A subsequent CT scan defined bilateral occipital infarction in the distribution on the posterior cerebral arteries (Fig. 2) as predicted by the regional blood flow study performed one day earlier. The patient was pronounced brain dead on the following day and life support was terminated.

Discussion

Determination of local cerebral blood flow in this patient with severe acute anoxic brain injury demonstrated that hypodense regions in the basal ganglia on computed tomography were not due to hypoperfusion, but rather post-ischemic edema [4]. Paradoxically, normal or increased perfusion was present in this region, presumably due to loss of vasoregulation and local lactic acidosis (Fig. 2). Conversely there was a marked decrease in blood flow to the occipital cortex bilaterally on the xenon enhanced CT study before changes were evident on the conventional CT study (Fig. 1).

In a study of CT abnormalities in children with profound hypoxic-ischemic events, Fitch et al. found abnormalities in the basal ganglia in five of fourteen patients; low density lesions occurred in two patients and hemorrhagic infarction in three [5].

The findings in this patient are consistent with the hypothesis that anoxic injury to the basal ganglia results in edema and "luxury perfusion" in this area. With extensive brain edema, expansion of brain volume occurs which may compress large cerebral arteries (e.g. posterior cerebral aa.), reduce their blood flow, and cause areas of zonal necrosis.

Because of the decline in the patient's clinical status following the study, a concern regarding the safety of xenon use arises. Although xenon at high concentrations is an anesthetic agent, at lower concentrations, such as used in this study, it is associated with a low incidence of adverse effects [6]. Arterial blood gas determinations before and after the study revealed no evidence of hypoxia, hypercapnia, or acidosis.

A functional study (xenon CT rCBF) may be more sensitive and an earlier indicator of ischemic damage than a morphologically based examination (nonenhanced CT). This should prove important for the early initiation of therapy to potentially prevent more catastrophic sequelae.

This case illustrates that comatose patients from near-drowning may have ischemia and hyperemia in the same anoxic brain regions. The determination of rCBF by the xenon enhanced CT method may be more sensitive than anatomic imaging for the early detection of herniation and occipital infarction. The xenon CT technique has the advantage of greater anatomic specificity as well as wide accessibility when compared to functional radionuclide studies using emission computed tomography.

References

1. Rogers MD (1985) Near drowning: cold water on a hot topic? J Pediatr 106: 603
2. Brierley JB, Graham DI (1979) Hypoxia and vascular disorders of the central nervous system. In: Adams JH, Corsellis JAM, Duchen LW, Greenfield's neuropathology. John Wiley, New York, 125
3. Drayer BP (1981) Functional applications of CT of the central nervous system. AJNR 2: 495
4. Kjos BO, Brant-Zawadzki M, Young RG (1983) Early CT findings of global central nervous system hypoperfusion. AJNR 4: 1043
5. Fitch SJ, Gerald B, Magill HL, Tonkin ILD (1985) Central nervous system hypoxia in children due to near drowning. Radiology 1156: 647–650
6. Latchaw RE, Yonas H, Pentheny SL, and Gur, D (1987) Adverse reactions to xenon-enhanced CT cerebral blood flow determination. Radiology 163: 251–254

Received: 17 November 1986; accepted: 10 June 1987

Dr. S. J. Tilden
Section of Pediatric Intensive Care
Children's Health Center
St. Joseph's Hospital
Phoenix, AZ 85013
USA

Literature in pediatric radiology (continued from p. 343)

Common use of diagnostic imaging for childhood wetting (enuresis): A survey of practicing paediatricians in the Federal Republic of Germany and West Berlin. Fendel, H. et al. (Dr. von Haunersches Kinderspital der Univ., Lindwurmstr. 4, D-8000 München 2, FRG) **30,** 473 (1987)

Evaluation of sub-ureteric Teflon injection as an antireflux procedure. Sweeney, L. E., Thomas, P. S. (Royal Belfast Hosp. for Sick Children, Belfast BT12 6BE, Northern Ireland) **30,** 478 (1987)

Symptomatic patient urachus in children: The contribution of ultrasound. Avni, E. F. et al. (Dept. of Rad., Univ. clinics, Hôpital Erasme, route de Lennik 808, 1070 Brussels, Belgium) **30,** 482 (1987)

Ectopic ureterocele in the male. Eklöf, O. et al. (Dept. of Rad., St. Göran's Children's Hosp., Stockholm, Sweden) **30,** 486 (1987)

Local evaluation of abdominal neuroblastoma stage III and IV: Use of US, CT, and 123 I-meta-iodobenzylguanidine (MIBG) scintigraphy. Neuenschwander, S. et al. (Serv. de Radiodiagn., Inst. Curie, 26, rue d'Ulm, F-75005 Paris, France) **30,** 491 (1987)

Diagnosis of ovarian cysts in the perinatal period and therapeutic implications (20 cases). Grapin, C. et al. (Montagne, J. P., Serv. de Rad. Péd., Hôpital Trousseau, 26, ave. du Dr A. Netter, F-75012 Paris, France) **30,** 497 (1987)

Sonography of the neonatal hip: a dynamic approach. Gomes, H. et al. (Dept. of Ped. Rad., American Memorial Hosp., rue Cognacq-Jay, F-51100 Reims, France) **30,** 503 (1987)

Bone marrow diseases in children. Significance of MRI in comparison to other imaging modalities. Reither, M. et al. (Dept. of Diagn. Rad., Community Hosp., Flurstr. 17, D-8500 Nürnberg, FRG) **30,** 511 (1987)

Budd-Chiari syndrome in children: Radiologic investigation. Pariente, D. et al. (Serv. de Radio-Péd., Hôpital Bicêtre, 78, ave. du Général Leclerc, F-94270 Le Kremlin Bicêtre, France) **30,** 518 (1987)

Acute intestinal intussusception in children. Contribution of ultrasonography (145 cases). Pracros, J. P. et al. (Serv. de Radiopéd., Univ. Claude Bernard, UFR Lyon Nord, Hôpital Debrousse, 29, rue Soeur Bouvier, F-69322 Lyon Cedex 05, France) **30,** 525 (1987)

Archives Françaises de Pédiatrie (Paris)

Neurofibromatose diffuse, médiastinale, rétropéritonéale et hépatique chez une enfant de quatre ans. Delacourt, C. et al. (Scheinmann, P., Hôpital Necker-Enfants-Malades, 149, rue de Sévres, F-75730 Paris Cedex, France) **44,** 601 (1987)

Hépatite virale à forme cholestatique et épaississement des parois des voies biliaires intrahépatiques. Hermier, M. et al. (Unité d'Hépatogastroentérologie pédiatrique, Hôpital E.-Herriot, place d'Arsonval, F-69374 Lyon Cedex 08, France) **44,** 605 (1987)

Vertèbre lombaire en rostre d'étiologie traumatique (cas radiologique du mois). Sirinelli, D., Serv. de Rad., Hôpital Trousseau, 26, av. du Dr A.-Netter, F-75012 Paris, France) **44,** 609 (1987)

Devenir des hémorragies péri-intraventriculaires majeures à court, moyen et long terme. Monset-Couchard, M. et al. (Unité de Soins Intensifs Néonatals, CHU Cochin Port-Royal, 123, Bd de Port-Royal, F-75014 Paris, France) **44,** 779 (1987)

Syndrome de Mondini (cas radiologique du mois). Keita, M. M. et al. (Ernest, C., Serv. de Rad. Infantile, Hôpital Necker-Enfants Malades, 149, rue de Sèvres, F-75015 Paris, France) **44,** 811 (1987)

Apport de l'échographie au diagnostic étiologique des hypothyroidies congénitales. Ythier, H. et al. (Serv. de Péd., Hôpital Claude Huriez, CHR de Lille, F-59037 Lille, Cedex, France) **44,** Suppl., 691 (1987)

Abcès cérébraux à Proteus mirabilis de la période néonatale. Carre, M. et al. (Demarquez, J. L., Serv. de Néonatologie, Hôpital des Enfants, 168, cours de l'Argonne, F-33077 Bordeaux Cedex, France) **44,** 871 (1987)

Pseudo-diverticule traumatique du pharynx chez un nouveau-né. Saïed, H. (Serv. de Péd., Hôpital d'Enfants, Tunis, Tunisia) **44,** 883 (1987)

Chirurgie Pédiatrique (Paris)

La dilatation congénitale de la voie biliaire principale. Reding, R. et al. (Cliniques Univ. St.-Luc, ave. Hippocrate 10, 1200 Bruxelles, Belgique) **28,** 145 (1987)

Résultat du traitement des invaginations intestinales aiguës par lavement opaque. Gaudin, J. et al. (CHU Morvan, F-29279 Brest Cedex, France) **28,** 151 (1987)

Pancréatite et kyste du cholédoque. Rémy, P. et al. (Hopital de Jolimont, B-7161 Haine Saint-Paul, Belgique) **28,** 179 (1987)

Une form rare d'invagination intestinale du nourrisson: l'invagination iléo-caeco-colique totale. Chazelet, C. et al. (Serv. de Chirurgie Digestive, Hôpital Carémeau, CHR, rue Pr Robert-Debré, F-30006 Nimes, France) **28,** 185 (1987)

Journal de Radiologie (Paris)

Fiabilité du "couple" échographie-cystographie dans l'exploration de l'infection urinaire de l'enfant. Deflandre, D. et al. (Legmann, P., Serv. de Rad., Hôpital Louis-Mourier, 178, rue des Renouillers, F-92700 Colombes, France) **68,** 625 (1987)

Les formes cartilagineuses de la dysplasie fibreuse de Jaffé-Lichtenstein. Fauré, C. et al. (Serv. de Rad., Hôpital Trousseau, 26, ave. du Docteur A. Netter, F-75012 Paris, France) **68,** 657 (1987)

Chondrolyse aiguë sur coxopathie protrusive primitive de l'enfant. Le Bastard, E. et al. (Serv. de Rad., Hôpital des Enfants, Cours de l'Argonne, F-33077 Bordeaux Cedex, France) **68,** 671 (1987)

Thrombus calcifié de la veine cave inférieure. Du Lac, P. et al. (Padovani, J., Serv. de Rad. Ped., C. H. U. Timone, bd Jean-Moulin, F-13385 Marseille Cedex 5, France) **68,** 719 (1987)

Pédiatrie (Paris)

Apport de l'imagerie par résonance magnétique dans les maladies dégénératives spino-cérébelleuses. (A propos de 8 cas). Nicolau, A. et al. (Daird, F., Serv. de Rad., Hôpital des Enfants, Cours de l'Argonne, F-33077 Bordeaux Cedex, France) **42,** 359 (1987)

Etude scintigraphique de la vidange gastrique chez des enfants avec obésité commune. Magazzu, G. et al. (Ist. di Clinica Ped., Policlinico Univ., I-98100 Messina, Italy) **42,** 383 (1987)

Duplications kystiques digestives: apport de l'échographie en période néonatale. Le Luyer, B. et al. (Unité de Gastro-entérologie pédiatrique, Centre Hosp. du Havre, 55 bis, rue Gustave-Flaubert, F-76083 Le Havre Cedex, France) **42,** 451 (1987)

Les mastoïdites: toujours d'actualité. Sevin, F., Disant, F. (Pavillon, U., Hôpital Edouard-Herriot, F-69437 Lyon Cedex 03, France) **42,** 467 (1987)

Reflux gastro-oesophagien et atrésie de l'oesophage. Louis, D. et al. (Serv. de néonatologie, Hôpital Debrousse, 29, rue Soeur-Bouvier, F-69322 Lyon Cedex 05, France) **42,** 479 (1987)

(continued on p. 350)