

## Pediatric Nuclear Medicine

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The birth of pediatric nuclear medicine can be dated to 1968 following the marriage of short half-life radionuclides to the gamma camera. The gamma camera rapidly generates images while simultaneously encompassing a large field of view. These factors are ideal for children since radiation is minimized and rapidly completed images allow the examination of uncooperative infants and young children.

The radionuclide which exhibits ideal physical properties for children is technetium 99m ( $^{99m}\text{Tc}$ ). This radionuclide has a physical half-life of six hours and emits a monoenergetic gamma ray of 140 keV. The energy emission of  $^{99m}\text{Tc}$  is not marred by alpha or beta rays which contribute little to image production but much to patient radiation. The short half-life enables the administration of multimillicurie doses which enhances image resolution while decreasing the time needed to produce the image. Finally,  $^{99m}\text{Tc}$  can be bound to albumin macroparticles, colloidal particles, and chelates which effectively enable selective organ imaging. Commercial kits are now available which enable practically every organ in the body to be visualized with  $^{99m}\text{Tc}$  radiopharmaceuticals.

Brain imaging originally provided the most demand for radionuclide studies in children. During the last several years, the interests of pulmonary, cardiovascular, genitourinary, oncologic, and orthopedic practitioners have stimulated the development of new radionuclide techniques. These recent applications of nuclear medicine to patient care prompt this report in order to provide an awareness to the pediatrician of the current status of pediatric nuclear medicine.

### THE CENTRAL NERVOUS SYSTEM

$^{99m}\text{Tc}$  as sodium pertechnetate is considered to be the most ideal radiopharmaceutical for brain imaging. Immediate angiographic and early as well as delayed static images are recorded in various projections. Vascular lesions are best illustrated during the dynamic angiographic phases of the examination. Delayed static images, usually at two hours, are more desirable for the detection of tumor, brain abscess, cerebral infarction, and abnormal dural fluid collections.

#### Congenital Malformations

Congenital malformations of the brain often affect the placement of the major dural venous sinuses. Radionuclide angiography readily visualizes these channels before observable abnormalities in the configuration of the patient's head or abnormal skull films occur. Lesions such as the Dandy-Walker malformation, subarachnoid cysts, porencephaly, hemiatrophy, and unilateral hydrocephalus can be diagnosed even in the newborn period.

#### Neoplasm

Current techniques yield a detection rate of better than 90% for brain tumors. The greater incidence of posterior fossa lesions in childhood requires detailed attention to technique in order to visualize the posterior fossa adequately. One must remember that the nonspecificity of radionuclide studies prohibits a histologic diagnosis.

#### Inflammatory Lesions

The image patterns often characterize the nature of the inflammatory process, making

possible a differentiation between generalized encephalitis, localized cerebritis, ventricular and meningeal infections, and brain abscesses.

### **Trauma**

The innocuous manner with which radionuclide techniques evaluate brain trauma supports their routine use. Larger, and thus perhaps more significant, accumulations are more readily detected. One can expect a detectability rate between 70% and 90% for abnormal dural fluid collections.

### **Miscellaneous**

Brain imaging is of great value in localizing vascular abnormalities such as arteriovenous malformations. The extent of brain involvement in the Sturge-Weber syndrome can be determined long before any roentgenographic changes are noted. The definition of hypovascular abnormalities such as cerebral infarction, particularly in sickle cell patients or following anoxic episodes from birth trauma, assist in the management of these conditions.

## **CARDIOVASCULAR AND PULMONARY**

The principle of pulmonary perfusion imaging is capillary blockade by a labeled particulate radiopharmaceutical.  $^{99m}\text{Tc}$  albumin particles,  $20\mu$  to  $40\mu$  in size, lodge in the terminal arteriole supplying the first capillary bed encountered. Since pulmonary embolism is uncommon in childhood, these studies are more commonly utilized to measure pulmonary perfusion distribution in congenital heart disease. In addition to the alterations in pulmonary perfusion distribution which occur in entities such as transposition of the great arteries, tetralogy of Fallot, and pulmonary valvular stenosis, there is also disparate perfusion distribution which occurs following cardiovascular shunting procedures. These studies provide a means of evaluating the effect of various therapeutic endeavors, thus assisting in the management of these children.

$^{99m}\text{Tc}$  pertechnetate is most often used for radionuclide cardioangiography. Of value is the quantification of cardiac shunts. Considerable data manipulation is required; thus, a computer is almost mandatory for the performance of these studies. The major role for this innocuous procedure appears to be in the postoperative follow-up evaluation of patients when one is less desirous of repeat cardiac catheterization to evaluate the patient's status. The cardiac ejection fraction and stroke volume can also be calculated.

Radioactive gases such as xenon 133 ( $^{133}\text{Xe}$ ) quantitatively demonstrate airway patency. Combined perfusion and ventilation techniques demonstrate disparity of ventilation-to-perfusion ratios in diseased portions of the lung and also assist in the interpretation of nonspecific pulmonary perfusion defects. Although radioactive gases are more difficult to handle in children, the great advantage of minimal radiation because of rapid clearance support their use.

## **LIVER AND SPLEEN**

The liver and spleen are visualized by labeling radionuclides to colloidal particles which are phagocytized by the reticuloendothelial system.  $^{99m}\text{Tc}$  sulfide colloid is the radiopharmaceutical of choice at present.

### **Congenital**

Splenic abnormalities such as asplenia, polysplenia, and heterotaxia are readily determined. Herniation of the liver or spleen through a hemidiaphragm is easily demonstrated.

### **Neoplasm**

The major use of liver/spleen imaging is for the oncologic management of neoplasia. Although findings such as organomegaly or defects within the liver or spleen are nonspecific, the innocuous manner in which the information is derived makes this procedure a useful adjunct study as a baseline in mass lesions of these organs. The effect of chemotherapy can be followed with minimum trauma to the child.

### **Trauma**

The most simple and rapid method available for the accurate assessment of trauma to the liver and spleen is radionuclide imaging. Rupture, subcapsular hematoma, and even contusion can be detected within minutes after admission to the hospital.

### **Abscess**

Combined liver/lung imaging readily delineates the extent of subdiaphragmatic abscesses. Recent reports indicate that gallium 67 citrate ( $^{67}\text{Ga}$ ) is of value for localizing abscesses within the abdomen.

## **GENITOURINARY**

The chelate labeled technetium compound diethylenetriamine-pentaacetic acid ( $^{99m}\text{Tc}$ -DTPA) has become the agent of choice for

imaging the kidneys.  $^{131}\text{I}$  orthoiodohippurate remains the most suitable for renography.

### **Congenital**

Absence of a kidney, ectopic location, horse-shoe configuration, and duplication with minimal function in the duplicated segment are easily recognized and characterized with radionuclide renal imaging. The location, size, and degree of renal function can be quantitated even in those instances which prohibit visualization with roentgenographic techniques. Allergic reactions are not a problem with radionuclide techniques.

### **Renal Transplants**

Radionuclides have provided a simple mechanism for the management and follow-up of renal transplant patients. Subtle changes occur in the renogram prior to clinical or, often, laboratory evidence of transplant rejection. These studies have replaced contrast angiography and in most instances intravenous pyelography as the method of choice for determination of transplant dysfunction.

### **Radionuclide Cystography**

Short half-life radionuclides instilled into the bladder detect vesicoureteral reflux when it occurs. Radiation is markedly reduced when compared with roentgenographic techniques. In addition, various functional parameters can be determined, *i.e.*, an accurate calculation of residual urine volume, the bladder volume at which time reflux occurs, and the drainage time of refluxed urine following voiding. Presently, radionuclide cystography is advocated for the long-term management of patients with known vesicoureteral reflux.

### **SKELETAL**

With the advent of  $^{99\text{m}}\text{Tc}$ -labeled phosphate compounds such as  $^{99\text{m}}\text{Tc}$  diphosphonate, bone imaging in children has become a clinical practicality. Bone images are much more effective for detecting metastasis than bone survey roentgenographic examinations. Primary bone neoplasms such as osteogenic sarcoma, Ewing's sarcoma, and neuroblastoma are effectively detected by radionuclide bone imaging. The minimum radiation from these radiopharmaceuticals permits the evaluation even of benign lesions. Osteoid osteoma is easily localized even in those areas such as the spine which are difficult to assess roentgenographically. Radionuclide techniques are already playing an important role in the

management of patients with avascular necrosis and other abnormal bone conditions.

### **CONCLUSION**

The subspecialty of pediatric nuclear medicine has rapidly developed since the last discussion<sup>1</sup> of the indications for and value of radionuclide imaging in children. New imaging techniques, equipment, and radiopharmaceuticals have stimulated this rapid growth. Bone imaging with the  $^{99\text{m}}\text{Tc}$  phosphate compounds has been applied to evaluate benign as well as malignant processes. Tumor detection and staging have been accomplished with various  $^{99\text{m}}\text{Tc}$  radiopharmaceuticals. Vesicoureteral reflux is more effectively detected with direct radionuclide cystography. A major role in the detection and evaluation of cardiac abnormalities and shunts has been achieved with nuclear techniques.

Recognition of this remarkable growth and development is found in the publication of several books on pediatric nuclear medicine, the presentation of pediatric nuclear medicine seminars, and formal sessions at the Society of Nuclear Medicine annual meeting.<sup>2-6</sup> This brief discussion will hopefully keep the pediatrician aware of the expanding role that radionuclide techniques have in the management of pediatric patients.

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## **Pediatric Nuclear Medicine**

Herman Grossman, Alvin Felman, John Kirkpatrick, Charles E. Shopfner, Leonard E. Swischuk, Paddy Taber and James J. Conway  
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