Pediatric Nuclear Medicine: Special Issues, Unique Clinical Studies

They hold hands and read their patients' favorite books aloud. They decorate imaging rooms in an outer-space motif. They investigate signs of child abuse and testify in criminal lawsuits. They are, in fact, nuclear physicians, but they belong to a tiny subspecialty dedicated to pediatrics.

Only a few dozen nuclear physicians in the U.S. consider themselves pediatric nuclear physicians, and virtually all work at children's hospitals. "We're a small group, and we all know each other," said Barry Shulkin, MD, an associate professor of nuclear medicine and director of the pediatric nuclear medicine satellite unit at Mott Children's Hospital at the University of Michigan Medical Center in Ann Arbor. As a result, there is a strong sense of camaraderie among these nuclear physicians who share a niche in the highly specialized field of nuclear medicine and who have withstood the efforts of managed care to pull them toward broader-based practices.

Diagnosing Elusive Orthopedic Problems

The real need for pediatric nuclear physicians lies in their ability to distinguish normal growth changes in children from serious anomalies. In evaluating bone scans, for instance, nuclear physicians must be familiar with normal bone tracer distribution over five different age categories from infancy through adolescence. "We also need to understand which types of bone problems afflict particular age groups," said Gerald Mandell, MD, chief of nuclear medicine at the Alfred I. DuPont Hospital for Children in Wilmington, DE. Adolescents are more likely to develop a growth plate fracture in the hip area called slipped capital femoral epiphysis, whereas elementary school children are more likely to develop an abnormal growth fusion in the hindfoot known as a tarsal coalition.

Bone scans are particularly useful in evaluating occult fractures, those that take several weeks to manifest themselves on standard x-rays. For example, a toddler who jumps off a bed and injures a foot or lower leg may develop an occult fracture. "The only way to recognize this injury in a limping toddler is on a bone scan," said Mandell. Bone scans are typically used in orthopedics to evaluate back pain, bone infections, foot pain, hip pain and suspected fractures, all of which may not be diagnosed immediately on an x-ray.

Besides understanding the distinct patterns in children's bones, pediatric nuclear physicians must also obtain high-count images to achieve high-resolution bone scans. John Miller, MD, head of the division of nuclear radiology at Children's Hospital in Los Angeles, uses a high-resolution collimator to obtain a 500,000 count on a planar bone scan in children. Nuclear physicians typically use a LEAP or GAP collimator on adult bone scans, which yield a count of about 250,000. "A higher count density for a child is absolutely mandated since we need exquisite detail to see the smallest bone changes," said Miller. With the high-resolution collimator, the typical bone scan in a child takes 20 to 30 minutes, nearly twice as long as an adult's. For this reason, Miller estimates that about 5% to 10% of pediatric patients require sedation during a bone scan.

Photo courtesy of Siemens Medical Systems, Inc., Hoffman Estates, IL.

Nuclear medicine personnel help a child prepare for a nuclear medicine scan.

Putting Kids at Ease

The very challenges that confront pediatric nuclear physicians also have their rewards. "Each study must be tailored to the individual patient, and we have to work hard to make the test palatable and comfortable for a child who may not have the patience to sit perfectly still for up to an hour," said Helen Nadel, MD, head of the division of nuclear medicine at British Columbia Children's Hospital in Vancouver, Canada. "On the up side, we have more contact and interaction with our patients than most nuclear physicians have with adult patients."

Recognizing children's special needs, Nadel has gone to great lengths to make her patients feel at ease. The walls in one examination room are painted with space ships and astronauts, and Day-Glo® stars shine softly when the lights are dimmed. For those patients not interested in outer space, nuclear medicine technologists will blow soap bubbles, read a book, put on a video or simply hold a hand. These distractions have a major payoff: Nadel finds that she rarely needs to use sedation, even on toddlers under the age of 4. "Sedation is the exception, not the rule," she said.

As the need for nuclear medicine procedures in children has grown in recent years, Nadel's insti-

> **"It is imperative for nuclear physicians—even those who deal mostly with adult patients—to familiarize themselves with the types of fractures caused by battered-baby syndrome and other abuse."**

tution has experienced a dramatic increase in nuclear medicine volume. "In 1984, we obtained the first SPECT camera in British Columbia and were performing 800 nuclear medicine studies a year," she said. "Now we do only SPECT studies using two cameras—one with a dual head—and perform 3300 studies a year." (Nadel is one of only three pediatric nuclear physicians in all of Canada, so her institution handles a large volume of nuclear medicine studies for pediatric patients throughout the province.)

In terms of the differences between imaging adults versus children, Nadel emphasizes that children are not little adults. The growth process and radiopharmaceutical distribution are different in children. Moreover, high-resolution images are necessary because an organ in a child may be just one-fourth the size of an adult's yet have the same number of receptors attaching to the radiopharmaceutical. Children also suffer from different types of cancers with different disease patterns and are more likely to have more aggressive tumors. For this reason, most nuclear physicians have replaced localized bone scanning with whole-body images in children. "Once we inject a child with a radioactive tracer, it behooves us to do a whole-body scan rather than just a localized scan," said Nadel.

Evaluating Child Abuse

One of the more harrowing aspects of pediatric nuclear medicine is the use of bone scans to evaluate cases of suspected child abuse. Bone scintigraphy is extremely sensitive in the detection of trauma to the pediatric skeleton and detects 25% to 50% more areas of involvement than x-rays, according to John Sty, MD, a pediatric nuclear physician and chief of radiology at Children's Hospital of Wisconsin in Milwaukee. Evaluating about 100 bone scans a year on babies suspected of being abused, Sty spends many hours a week consulting with social services counselors and emergency room physicians. He even serves as an expert witness in criminal trials against abusive parents or caregivers. "I testify about 10 times a year, and it's definitely one of the hardest parts of the job," Sty said.

In children under 2 years of age, abuse tends to be linked to fairly distinctive patterns of injuries. For instance, infants and toddlers rarely break ribs or have metaphyseal fractures caused by hyperextension or rotation on their own. "These young children are not strong enough to cause these kinds of injuries to themselves," said Sty. "The fractures are usually caused by an adult shaking, swinging or throwing the child." Often, a referring physician will rely solely on the results of the bone scan and accompanying x-rays since babies cannot speak for themselves.

Sty emphasized that all nuclear physicians should take on the responsibility of learning to recognize the signs of child abuse on a bone scan. According to the National Center for Child Abuse and Neglect in Washington, DC, an estimated 3 million children are abused in the U.S. each year. "About 5% to 8% of pediatric emergency room visits are related to child abuse or neglect, so it is imperative for nuclear physicians—even those who deal mostly with adult patients—to familiarize themselves with the types of fractures caused by battered-baby syndrome and other abuse," Sty said. Nuclear physicians can learn more about child abuse patterns on bone scans through continuing medical education courses such as those offered at the Society of Nuclear Medicine (SNM) Annual Meetings.

Researching Childhood Diseases

Although PET research has been mainly reserved for adults, Shulkin and his colleagues at Mott Children's Hospital in Ann Arbor have been doing PET studies on children for the past 7 years for the evaluation of pediatric cancers. "Recent advances in hardware and imaging techniques have made PET more pediatric friendly," Shulkin said. The new hardware allows for larger fields of view, which is important for evaluating systemic spread, which is more common in pediatric tumors. In addition, correction imaging can now be done after injection of the radiopharmaceutical, which has cut the scanning time in half. "For most studies, children now need to lie still for 30 minutes to 1 hour instead of 90 minutes to 2 hours using the traditional correction imaging methods," he said.

Shulkin performs about 10 to 12 PET studies per year, usually as part of a research protocol. The short-term goals of most of the studies involve assessing the prognosis and response to therapy, whereas long-term goals may be to derive new therapies from research findings. He is currently investigating neuroendocrine tumors using ^{11}C-hydroxyephedrine and ^{11}C-epinephrine to learn about the catecholamine uptake system of these tumors. PET has shown some clinical use in some specialized situations where it is used to evaluate the effectiveness of therapy or determine whether residual disease is left after therapy in such cancers as Wilm's tumor, Ewing's sarcoma and lymphomas. "We're still collecting data, but PET appears to be a valuable, noninvasive tool in assessing a patient's response to therapy," said Shulkin.

Occasionally, PET is used in conventional care to answer a clinically relevant question, but a lack of reimbursement from insurance companies and managed care has discouraged the use of the modality. Shulkin described a recent case in which he was trying to find an occult tumor in a child who had already undergone CT, MRI, laparatomy

(Continued on page 26N)

Pediatric Nuclear Medicine

(Continued from page 14N)

and SPECT imaging. "It took 4 months of phone calls to the managed care company to receive reimbursement," he said.

Other researchers are performing SPECT studies on pediatric patients in an effort to learn more about a common psychological problem called attention deficit hyperactivity disorder (ADHD). Researchers from Stanford University in Stanford, CA, performed brain SPECT imaging using ^{99m}Tc-ethyl cysteinate dimer on eight children who were diagnosed with having ADHD, both before they started taking the medication Ritalin and while they were on a course of the stimulant. The study found that administration of Ritalin caused an increase in cerebral blood flow to the prefrontal and anterior temporal regions of the brain, which are thought to be involved in ADHD. The researchers are now performing the same study on control subjects who have not been diagnosed with ADHD to see whether they have similar cerebral blood flow changes after taking Ritalin. "We don't know if the blood flow changes are caused by Ritalin improving ADHD or by Ritalin itself," said study researcher H. William Strauss, MD, director of nuclear medicine at Stanford and SNM president. "We want to see if SPECT can assist in providing a standard for diagnosing ADHD, since right now it is a very difficult diagnosis to make."

Adjusting to Managed Care

While most nuclear physicians have been affected by cutbacks due to managed care, pediatric nuclear physicians have been particularly affected. Most find themselves doing more pediatric radiology procedures or more nuclear medicine studies in adults. In the past year, Shulkin began doing a 1- to 2-month annual rotation through the Michigan VA Hospital in Ann Arbor. He also occasionally sees adult patients at the University of Michigan Medical Center. He doesn't, however, view this as a negative. "I think it's beneficial to do adult studies to keep my skills honed," he said. "There are certain procedures, such as OncoScint imaging or prostate studies, that are almost never performed in children."

Miller has found that the nuclear medicine department at Children's Hospital in Los Angeles closely mirrors cutbacks in other departments. "We took some hits a few years ago when managed care executives first took over the hospital," he said. "But now that we've shown that nuclear imaging is cost-effective, we've experienced a resurgence in business." At its peak in the late 1980s, the nuclear medicine department was performing 2400 scans a year, according to Miller. This dropped to about 1500 scans a year during the early 1990s and has now risen to about 1800 scans a year. Regardless of managed care pressures, most pediatric nuclear physicians are content in their career choice. In a sense, they are pioneers who must adapt a high-tech specialty to meet the needs of the smallest patients.

—Deborah Kotz

Nuclear Medicine Pioneer: Hal O. Anger

(Continued from page 19N)

tors to scan the whole body, was introduced in 1953. Anger cites as pioneering Myron Pollycove, MD's, research using the first whole-body scanner and ^{59}Fe to study iron kinetics and hemoglobin synthesis in humans.

In 1959, Anger developed the first positron camera and the principle of coincidence detection. Donald van Dyke, MD, a research physiologist, did pioneering work using the positron camera by demonstrating that blood flow and marrow distribution in various disease states could be imaged using ^{52}Fe and ^{18}F made by LBL chemist Yukio Yano in the Berkeley cyclotron, said Anger. According to Pollycove, now a Visiting Medical Fellow with the Nuclear Regulatory Commission, Anger's development of the positron camera helped facilitate the study of blood disorders with ^{52}Fe. "With the positron camera and ^{52}Fe," said Pollycove, "you could get better distribution and visualization of the iron kinetics." Additionally, use of the positron camera made it possible to use oral or intravenous administration of ^{52}Fe, said Pollycove.

In 1966, Anger developed the first multiplane tomographic scanner, a camera that images multiple planes in the body simultaneously. Nuclear-Chicago Corp. manufactured the camera, which in time was superseded by SPECT instrumentation.

Professional Commendations

The holder of 15 U.S. patents as well as the author of numerous journal articles and book chapters, Anger is the recipient of many major awards and honors, including the John Scott Award in 1964 for development of the positron camera; Guggenheim Fellowship, 1966; Gesellschaft fur Medizin, 1971; honorary doctorate in science, Ohio State University, 1972; Nuclear Medicine Pioneer Citation, SNM, 1974; Modern Medicine Award for Distinguished Achievement, 1975; SNM First Western Regional award for distinguished contributions to nuclear medicine, 1976; Centennial Year Medal, Institute of Electrical and Electronics Engineers (IEEE), 1984; Societe Francaise de Biophysique Medal, 1988; George de Hevesy Memorial Medal, Vienna, 1991; and Honorary Member and Fellow, American College of Nuclear Physicians, 1992.

In 1994, SNM paid tribute to Anger by awarding him the first Cassen Prize, a $25,000 award to a living scientist whose work has made a major advance in clinical nuclear medicine science, for his invention of the gamma camera and other related achievements in nuclear medicine science. According to Patton, who served as president of the seven-member Cassen Prize Committee when Anger was nominated, the selection of Anger was unanimous, and there was no discussion of other nominees.

Current Activities

Since his retirement in 1982, Anger has maintained professional memberships in both SNM and IEEE. Anger keeps abreast of instrumentation developments by reading the literature and attending occasional meetings and conferences. The latest instrumentation that Anger finds most intriguing is ADAC's Muehllehner dual PET scanner and Digirad's solid-state gamma camera, a notable advancement, given that the camera is about the size of a laptop computer because solid-state detectors are used instead of the crystals and PMTs used in larger traditional