Advancing the Human Condition: How Clinical Research Inspired and Prepared Me for Medical School

The Science of Medicine: My Journey Through the Infinite World of Research

My interest in medicine was born from my most involved hobby as a boy: one that was common to several individuals my age. Throughout my childhood my world revolved around club soccer; my family and my teammates traveled throughout the nation to participate in tournaments that gave me immense exposure to the intensely competitive athletic world around me. I relished such an environment and one of the things that fascinated me most was the hardship and ensuing recovery caused by sports injuries. Soon, this fascination developed into an interest in the medical field, as I was so intrigued by its unimaginable ability to restore star athletes to their original prowess on the soccer field. In order to pursue this curiosity, I sought out the most immediate and relevant channel, Columbus Children's Hospital (now called Nationwide Children’s Hospital).

Conveniently, this inquiry coincided with my honors science fair project, and Dr. William Shiels II, Chief of the Radiology Department, graciously offered to assist me with the task of weaving my recent attraction to medicine throughout the project's focus. In a collaborative effort, we planned a project that would simulate the sports injuries in which I had taken such an interest. How would one simulate such a traumatic event without harming an innocent individual? The answer was chicken legs! Interestingly enough, the knee joint in the chicken leg is strikingly similar to that in a human. Needless to say, it was an incredibly exciting and educational experience that incited my formal interest in a career in medicine, especially the aspect of clinical research: an interest that has blossomed into a deeply held dream and lifelong
goal. Additionally, this novel idea was a part of the creation of a set of medical simulators that are now used to train medical students, residents, and the occasional research aide.

The success of my middle school science fair project was the perfect introduction to what would become the extracurricular activity that has had a paramount influence on my personal development. It began with a volunteer position at the Nationwide Children’s Hospital Occupational Therapy, Physical Therapy, and Urgent Care Office in my hometown of Dublin, OH. Considering my aforementioned interest in sports injuries and their management, taking part in some of that treatment and witnessing the small, consistent improvements that each child underwent was an absolute joy.

Soon I was spending my days volunteering at the main Nationwide Children’s Hospital Campus in the Radiology Department. I found myself immersed in an incredible world of cutting edge technology and technique. I could feel my appreciation for the true life of a physician mounting with each day of experience in both the routine clinical proceedings and the edge-of-your seat afternoons in the Interventional Suite. Whether spending time with a young child with Down Syndrome as he sang all of the words to “Surfin’ USA”, or watching one of the Interventional Radiologists as he carefully drained a cyst under sonographic guidance, I constantly felt that I was in my element.

As I continued to work and volunteer with physicians who were passionate about medicine and involved in various fields of health care, I entered full-time employment status at the Nationwide Children's Hospital Department of Radiology as a research aide during the summer prior to my first semester at Miami University: a role in which I continue to serve today during my breaks from my formal undergraduate curriculum. The tasks which my position affords began with the organization and analysis of data to outline the success of a unique
procedure in Interventional Radiology which Dr. Shiels has been developing since his days in the military; this process involves the removal of soft tissue foreign bodies in a timely and less invasive fashion by utilizing imaging modalities intraoperatively. It is just one of many procedures which are a part of the constant innovation to which I am exposed on a daily basis. Not only have I spent a significant amount of time observing many of these novel techniques such as the ultrasound-guided removal of soft tissue foreign bodies, I was actually assigned to an in-depth study researching and documenting every aspect of this unique idea.

The project began on an exciting note; I was able to investigate, in a retrospective fashion, the case of every patient who had ever undergone soft tissue foreign body removal by either fluoroscopic or sonographic guidance in our center. It was thoroughly exhilarating to organize and analyze all of the data obtained from the physicians’ reports, radiologic studies, and foreign body specimens. Several times my office was a peculiar sight, strewn with bloodstained glass, menacing splinters, and the occasional oddity such as a chain-link fence wire, fish bone, or plastic comb tooth.

Having the opportunity to fully examine every dimension of this unique procedure and gain a perspective on its importance for the health and welfare of the patient was enormously valuable: not to mention the fact that I was able to actually perform an ultrasound-guided removal on a turkey breast training model! Prior to this project, I had never considered the hazard that splinters and other common traumatic injuries of this nature presented; I had always just yanked them out with some tweezers accompanied by a wince of pain. In many cases, when these foreign bodies are introduced into the body several millimeters (or even centimeters) below the surface of the skin, they can be impossible to remove by superficial means and can result in chronic infection (or worse if located in critical areas of the body) if not dealt with properly.
Many such severe cases result in an emergency room visit and may prove exceedingly difficult on those occasions where the inflammatory intruder is only a millimeter or more in size (and, in the case of glass, nearly invisible to the naked eye). One option would be to send the child to a conventional operating room (OR), where they may have the area surgically explored, resulting in a significantly large incision and possible general anesthesia: a sizeable production for a process which will, again, not guarantee the object’s removal. The solution, in these cases and beyond, may lie with proper localization and intraoperative guidance provided by diagnostic and interventional radiology. A surgical exploration which may take hours and return unsuccessful results can be avoided by sending the child to the interventional radiology suite with the 97% chance of successful removal in a visit which most times lasts for less than thirty minutes. Not only is an expedient resolution more likely, due to the introduction of imaging localization and guidance, the necessary incision averages approximately 5 millimeters as opposed to what could be several centimeters in the OR: thus, much less trauma for the patient.

This endeavor culminated with my presentation at the annual meeting of the European Society of Pediatric Radiology in Dublin, Ireland\(^1\textsuperscript{,}2\). It was an unparalleled feeling of accomplishment and appreciation after having organized such a study; I felt like what I was presenting was actually going to affect a positive change in the quality of available care. I will say that it was an intimidating sensation to stand in front of nearly two hundred physicians who possessed knowledge of which I had not yet scratched the surface; at the same time, however, it was one of the most exciting experiences I can recall and I delivered my message with fervor.

I have been fortunate enough to continue this work during each summer break from Miami; I am so grateful for all of the opportunities that I have encountered and seized. Beyond the foreign body project, which I am constantly updating and improving in preparation for its
release into the literature, I have taken part in several other studies documenting unique cases and procedures in addition to producing a chapter for a pediatric radiology text.

During the summer of 2005, I was introduced to Dr. Larry Binkovitz who was kind enough to engage the assistance of a mere undergraduate with a project to develop a chapter for a Mongolian pediatric radiology text book with a focus in urogenital imaging. This undertaking turned out to be one of the most tremendous learning experiences during my time at Children’s and the work actually ended up in a premier American radiology text. First and foremost, it allowed me to step outside the interventional realm and spend significant personal time with Dr. Binkovitz to witness each of the procedures we would be fully documenting in the chapter. After these first-hand experiences, I was able to gain significant perspective so as to confidently evaluate the current literature related to our topic. It was an extraordinary exercise in research: specifically the task of accumulating a tremendous amount of knowledge and boiling it down to the most essential information to be included in our chapter. Not only was I learning invaluable research practices, I was absorbing vital medical knowledge that it was my job to procure and dispense.

Following the presentation and book chapter work in 2005, I spent the summer of 2006 working on two case reports documenting a unique occurrence of two diseases in concert, as well as the advent of a new procedure to determine the cellular composition of a particular type of cyst. Once again, the exercises involved with documenting these cases reinforced proper research practices as I reviewed previous literature on the topics as well as the radiologic methods demonstrated in the diagnosis and technique. Additionally, all of these experiences have given me the pleasure of observing and collaborating with several physicians across numerous disciplines within the hospital on a variety of endeavors both minor and
groundbreaking. Not only does my time spent at the hospital allow me to take part in the investigation of new and exciting ideas and cases, it also provides me with constant clinical exposure and patient encounters. I have come to appreciate that the true triumph comes upon witnessing the child who comes in with a health crisis (sometimes by cross-country air-lift) which no other physician has been able to reconcile, and then seeing that child relieved of his or her burden by one of many incredible and unique procedures which I have been fortunate enough to witness and study. The extraordinary thing about children is, once you treat them, like clockwork, they are up and bouncing around, happy to be healthy again; that is an unparalleled joy to behold.

My Motivation for Medicine and The Altruistic Physician

In addition to my research ventures at Children’s, a recent and unexpected development has done more in the way of inspiration than any other stimulus could have ever provided. Only months ago, one of my mentors and close friends was diagnosed with stage four colon cancer. To undergo a CT for bothersome stomach pain, and then four days later come out with a terminal disease is something that is difficult to comprehend. This tragedy has helped to open my eyes to the true purpose of medical care. It’s not the money, it’s not how many patients you turn over, it’s not the intellectual challenge and status. It is utter devotion to each and every individual who places the fate of their wellbeing into your hands. It is providing them with the utmost attention and care and never resting until you have done everything in your power for the proper treatment of their condition. It is committing yourself to the essential practice of lifelong learning so as to constantly seek out and develop new ideas for the betterment of the medical world and its ability to provide for those in need. The patient’s life and your integrity as a human being depend on it.
This man, who has modeled so many essential values and virtues – integrity, faith, love, trust, loyalty - has now helped to illustrate for me how paramount it is to seize the gift of life: not only in the sense of living one’s own to the fullest, but also incorporating the altruistic practice of improving the lives of others into our daily existence. Life is a fleeting blessing, and we must preserve it and take advantage of every moment. Living each day is a privilege, and the opportunity to care for others is at every turn. I have learned to grab hold of these opportunities and embrace their potential to mutually enrich the lives of those involved.

The remarkable thing about the medical world is that it is a realm of constant learning, discovery, and innovation all set in motion for one purpose: to take advantage of the altruistic opportunities to help those in need. These are the principles that drew me to health care: values that have been reinforced over the past four summers spent at Children’s. Altruism is, first and foremost, a life posture of sensing the needs of others and acting with their interests in mind; this virtue provides a sound ideological foundation on which to build a medical career.

My interpretation of the spirit of altruism is embodied in a simple pledge to improve people’s lives, and do so by personalizing health care to meet the needs of each individual. In order to improve the lives of others, altruism is of paramount importance. It is this empathetic sense to put first the needs of others that allows for the establishment of a collaborative environment where individuals work for the greater good. In the absence of compassion, one only acts for personal gain. What, then, of those who are not able to help themselves? The instinctive or learned concept of altruism, manifested in our personal and professional lives, makes it possible to tremendously improve the general wellbeing of these individuals. Some refer to this philosophy as humanistic medicine. There are so many vital dimensions of this way of life to appreciate and emulate which would immensely enrich my abilities to be an
outstanding physician. One of the most prominent elements of this posture is devotion to social justice: serving those in the community who are less fortunate. Care of the indigent is a staple of humanistic medicine and a core principle at Nationwide Children's Hospital. Universal Health Care is a touchy issue in our world today, but for those who are truly in need, it is my belief that they receive care regardless of their ability to pay. It is an urgent matter in our world today, and it is imperative that we find a practical, equitable way to facilitate the mending of a system that needs significant restoration. I hope to have the opportunity to grow and serve in this ambition with the guidance of The Ohio State University and all of my mentors at Children’s so that I may better understand and incorporate the practice of humanistic medicine in my life. For the rest of my life, I plan on making the most of every moment by giving and guiding as selflessly as my mentors.

**The Other Hand: The Business of Care-giving**

Not only has my experience at Children’s provided me with an up-close and personal exposure to and appreciation for a life in medicine, it has reinforced my aspiration to find a leadership niche within the complex and fascinating world of care-giving. This ambition began shortly before I was to start my undergraduate course of study at Miami; it was the day of my orientation and I was walking across campus to Laws Hall, where I would be undergoing my first College of Arts & Sciences information session regarding the pre-medical science majors. I knew that medicine was my calling, and I was incredibly anxious to get started. Despite the excitement of the moment, something did not seem right. Yes, I wanted to be a doctor. Yes, I wanted to prepare myself adequately for the rigors of medical school. So what was the matter? After some brief soul searching, I realized my dilemma; I did not want to be the traditional physician. Therefore, I did not want to be the traditional pre-medical student. I wanted to lead!
I wanted to break the mold! I knew what I had to do; I packed up my things and left the College of Arts & Sciences.

I made my way to The Richard T. Farmer School of Business; this was the first monumental step toward my becoming a physician leader. It was a risk, but I wanted to be a balanced, well-educated individual who could lead my colleagues in quality practice and fully informed decision making; with a business background I would have a much broader foundation of knowledge that would be applicable to a career in medicine considering today’s health care climate. Never in my life had I felt like I possessed such a purpose, direction, and mission; I have tried to experience the best of both worlds at Miami, both business and science, and I have never looked back.

In addition to this element of formal education, I have been fortunate to work with several mentors in leadership positions in the medical world. My position as a research aide at Nationwide Children’s Hospital over the past four summers has given me exposure to several levels of leadership in a health care environment. For instance, the physician with whom I have worked most closely on various projects, Dr. Shiels, serves as the Chief of the Nationwide Children’s Hospital Department of Radiology. Witnessing his devotion and drive to operate such a successful practice is a privilege. It is a stirring experience to be able to observe all that comes with such a leadership position, and what sorts of skills are required to meet the constant, enormous demands.

Moreover, to make my experience at Children’s comprehensive, I have taken part in several management tasks for the department in collaboration with the business manager of radiology as well as the treasurer of the hospital. These projects have involved in-depth financial analysis in order to determine the viability of a new Interventional Suite and PET Scanner, the
thorough restructuring and renewal of the service agreement for our electronic reading and records system, as well as the process of selecting a vendor to update the hospital's Radiology Information System. These experiences, in combination with my formal finance education, have provided me with a perspective on the dynamics of medicine and the role of the physician leader in the health care realm.

In today’s health care environment, it seems that in some cases, physicians are being superseded by graduates of the business disciplines who are influencing the management of medicine without fully considering the paramount element of patient care. I have come to realize that today’s physician should be able to maintain the delicate balance of these two considerations and create an environment that is conscientious of both of these vital dimensions. I want to be one of these physician leaders who is born from the medical field. Doctors should lead doctors; they should be able to collaborate and work together to ensure the integrity and quality of their industry, while providing the best care for the right reasons. Physicians have the know-how and altruistic sense to help those in need and constantly seek out new ways to execute that mission, which is the most important thing to consider in the medical field; add some business knowledge to this foundation, and they are able to do their job in a more efficient manner to maximize the utility to the patient and the community.

It is my intention to further develop this business component of my skill set by obtaining a dual degree MD/MBA from The Ohio State University College of Medicine and Fisher School of Business. As a finance major with a combined MD/MBA degree in health management, I would be well equipped to tackle the increasingly complex task of balancing quality care with a viable business model. I believe that my being comfortable with the business dimension of health care would be tremendously valuable in a position that determines the direction of a
hospital, department, or private practice. During and after my formal education, I would work to combine the skills acquired from both realms so that I may lead and collaborate with others to ultimately provide optimal care for the mutual benefit of the patient and physician.

This combination of professional skills would be immensely valuable when facing the challenges of a career in medicine today. A physician must have a firm handle on the business of taking care of those in need so that he or she might ensure the ability to render their services in a fair manner for the benefit of their patients and the community. As a physician with a comprehensive background in both the clinical and business branches of learning, I would be confident in facing the day-to-day affairs that are present in modern medicine. In order to be competitive and improve a health care environment, I would be able to play an intimate role in strategic planning and daily operations of a medical practice. Such tasks would include capital budgeting, vendor selection, inventory and patient management, financial analysis, and all of the clinical skills implicit in such a position; these abilities would be honed and refined in the intensive curriculum of a dual MD/MBA degree.

**Conclusion: Invaluable Lessons for a Lifetime in Health Care**

There are so many individuals at Children’s who have been so helpful and so generous with their time and teachings. It has been a tremendous delight to be able to work with these intelligent, hospitable people who are able to impart so much knowledge and responsibility to an undergraduate, making my employment experience one that is both educational and enjoyable. In addition to lifelong learning, I now truly appreciate the element of teaching in the life of a great physician. It is because of their coaching that I have developed the aspirations that I now possess. Not only do I look forward to a successful future in the medical world, I also hope to have the opportunity to one day be a mentor who is as kind and generous to an aspiring physician
as so many individuals have been to me. I am also grateful that I have been able to be immersed in the daily lives of physicians of several specialties so that the constant demands and rewards of a life in medicine have become tangible to me.

Moreover, I look forward to continuing my connection to the world of clinical research that has been so rewarding. It is critical that the search for new ideas and improvements exist at some level in one’s medical career; it all comes back to that essential principle of lifelong learning. This practice and the conveyance of the newfound knowledge give hope to anyone who values the present and future health of themselves, their family, and their friends. I have tried to take advantage of every opportunity that has been presented to me in order to nurture this passion for research in the medical world; making sure that it is something that I truly want to pursue for the remainder of my life. I believe I now have a clear idea of exactly what I am getting myself into and why I am prepared to work so hard for it. Upon entering the doors to Children’s hospital only four short years ago, absolutely in awe, I would have never imagined that my initial curiosity would have matured into this deeply held appreciation for the science of medicine and how the study and mastery of this instrument can advance the human condition.
Bibliography


Aim: To report the MR imaging appearances of physeal bars resulting from meningococcal and other infection and compare them to those as a result of trauma.

Method: A retrospective blinded review of the positive MRI scans performed in patients with leg-length discrepancy and deformity due to physeal bar was performed. Differences in the results were sought between patients who had physeal bars as a result of infection (particularly meningococcaemia) and those due to trauma (reviewers were blinded to the information). Relevant features included: - number of physeal plates involved, location of the involved physis, site of the physeal bar within each physis, the size of the physeal bar as a percent of the physis and imaging characteristics of the bars on MRI.

Results: There were a total of 17 patients included in the study. Nine patients had MR imaging of 9 bars, which were the result of trauma. Six patients had MR imaging of 13 physeal bars, which were the result of infection (meningococcaemia in 4 of these). Two patients had MRI of 3 physeal bars due to other causes (one Ollier’s disease and one idiopathic). Our results show some significant differences between physeal bars caused by trauma and those caused by infection. Meningococcal / infective bars involve more physeal locations (up to 6 in 1 patient) and can be bilateral; may involve any segment of the epiphysis (proximally and distally); in addition to continuation of the ephysys and metaphysis and flame shaped protusions, they may cause irregularity of the physis and epiphyseal distortion; and they can involve a larger surface area of the physis (50% or greater) than physeal bars due to trauma.

Conclusion: Physeal bars caused by infection and in particular, meningococcaemia differ from those caused by trauma. The multiple locations involved and the extent of involvement of the surface area have direct bearing on prognosis and choice of management (including surgery). Features such as irregularity of the physis, distortion of the epiphysis and multiple locations should strongly suggest the etiology. Gradient Echo sequences are superior to all other sequences for diagnosis and computerised techniques for mapping will alleviate the effort and time taken creating manual maps.

O 96
Enchondromatous Cartilage Rests are not uncommon in Achondroplasia.

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Object: To show that enchondromatous metaphyseal rests, previously mentioned in only one case (Nizankowska-Blaz), are not uncommon on childhood achondroplasias radiographs.

Material and Methods: A review of recent achondroplasia childhood radiographs for regions extending from the metaphysis, less lucent than bone, and often containing cartilage-like dots or nodules within the area and more dense than background. Note was also made of enchondroma patterns in shafts regions that were not in continuity with metaphysis.

Results: Five achondroplastic children, the youngest 3 years old, showed such enchondromatous patterns extending from the metaphyses of long bones, especially about the knee and ankle. These cartilage rests generalized extended furthest into the shaft from the center of the metaphysis (the physis region oldest in the development of the child), as in Nizankowska-Blaz’s patient. Also encountered were a few enchondromas not in continuity with the metaphyses or the cartilage rest described above.

Conclusion: Although not previously emphasized, the pattern of enchondromatous metaphyseal rests is not uncommon in achondroplasia. Achondroplasia is known to be a condition of slowing of enchondral bone growth; disturbance of provisional calcification and primary spongiosan ossification may be an additional factor in the short stature of these individuals.

O 97
Preossification Centers of the Developing Elbow: MRI-Radiographic Correlation.

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The preossification center constitutes an early structural change in the developing ossification center, and can easily be identified by MR signal characteristics. The radiologic appearance of the pediatric elbow has been described; however, MR changes of the ossification center have not been reviewed in detail.

Purpose: To determine the MR changes of the cartilage and bone marrow related to the six elbow ossification centers and patient’s age, and to correlate the findings with the radiologic appearance.

Material and Methods: For 3 years, 100 consecutive MR elbow studies performed in Siemens I 5 T magnet, and plain films from the Children’s Hospital of Philadelphia were reviewed. We included patients from 0 to 11 years. The site and appearance of the six ossification centers of the elbow were identified on radiographs and correlated to the signal characteristics on T1, T2, and GE images. The bone marrow signal in the epiphyses was also noted.

Results: We observed sequential MR development of the six elbow ossification centers. The ossification centers were preceded by the appearance of the preossification center. The statistical analysis showed that the age of appearance of the preossification center was definitely earlier than the ossification center (p value 0.03). The average age of the appearance of the preossification center was 5 years, and 7.3 years for the ossified center.

Conclusions: The preossification center appears at a statistically significant earlier age than the ossification center. The time interval between the appearance of the preossification center and the evident ossification is 24 months. The preossification center represents an important tool in the evaluation of the pediatric elbow and can be used as the MR precursor of the ossification center.

O 98
Sonography of Soft Tissue Foreign Bodies: Diagnostic and Operative Correlation of the Hypoechoic Halo

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Purpose: To correlate the clinical, diagnostic, and operative significance of the hypoechoic halo surrounding soft tissue foreign bodies undergoing sonographically guided removal.

Materials and methods: Two hundred and twenty cases of sonographically guided foreign body removal were evaluated, in which 111 cases of documented hypoechoic halo presence were analyzed. Mean age 104 Mo; median length of foreign body presence 14 days (D) (range 1095 D, SD 192 D).

Results: On diagnostic sonography hypoechoic haloes ranged between 0-6 mm in single radius thickness, mean size 2mm; associated foreign body type, wood 60, glass 21, metal 26, plastic 2, bone 1. Norplant 1. No consistent correlation between length of presence and thickness of halo; earliest halo seen at 2 D. Haloes are most prominent with wood foreign bodies, and less with inert materials
of glass and metal. Of documented operative correlates, 24 haloes were granulization tissue and 23 pus. Pus haloes were managed with US guided irrigation following FB removal. Granulization tissue was not excised. No longterm complications or recurrent infections.

**Conclusions:** The hypoechic halo surrounding foreign bodies represents either a purulent collection or granulization tissue, most frequently seen with porous materials such as wood. US guided management of the hypoechic halo is successful following FB removal

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**R 6**

**Radiological Evaluation of the Patients with Pituitary Langerhans Cell Histiocytosis at Diagnosis and Follow-Up.**

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**Objective:** To evaluate the pituitary imaging findings of the patients with Langerhans cell histiocytosis (LCH) who had diabetes insipidus and to detect the changes during the follow-up.

**Patients and Methods:** Ninety-eight patients with LCH diagnosed between 1993 and 2004 were evaluated retrospectively. Twenty (20.4%) of them had diabetes insipidus. Thirteen patients had been evaluated with cranial imaging methods. Pituitary magnetic resonance imaging (MRI) was done in 9 patients, cranial MRI in one and cranial computed tomography had been done in three patients. Follow-up MRI was present only in 9 patients. Radiological changes of anterior and posterior pituitary, infundibulum, sella and hypothalamus were recorded. Chemotherapy (CT) and/or radiotherapy (RT) were used as treatment regimen.

**Results:** Eight out of thirteen patients had disease involvement of both pituitary gland and bone. Three patients had multisystem involvement besides pituitary disease. There are only two patients who had isolated pituitary disease. RT alone was used only in patients with isolated pituitary disease. Ten patients have been treated with CT and one has been treated with both CT and RT.

**Pretreatment imaging findings:** Infundibulum was thickened in 11 (84.6%) patients, very thin in one (7.7%) and normal in one (7.7%) patient. Posterior pituitary hyperintensity was absent in 10 patients (76.9%). The pituitary gland was atrophic in 6 cases. Sellar mass was detected in one patient.

**Posttreatment imaging findings:** In two patients radiological findings were normal, 3 patients had stable radiological findings and other three had developed pituitary atrophy. All patients had diabetes insipidus and needed desmopressin acetate treatment for lifetime.

**Conclusion:** Infundibular thickening and absence of posterior pituitary intensity were the most common radiological findings. One third of patients returned to have normal imaging findings, while one third progressed to pituitary atrophy. The patients with LCH who had diabetes insipidus should be followed for the pituitary atrophy.

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**SESSION 7: Fetal Imaging/Miscellaneous**

**O 101**

**In Vivo Investigation of Fetal Lung Maturation with Magnetic Resonance Imaging.**

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Sonography of Soft Tissue Foreign Bodies: Diagnostic and Operative Correlation of the Hypoechogenic Halo

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INTRODUCTION

• Soft tissue foreign bodies-common
• Sonography for diagnosis and pre-operative plan
• Hypoechoic halo
• Inflammatory reaction
  – Purulent microabscess
  – Reactive granulation tissue /fibrous tissue
• Lack of understanding of significance
HYPOTHESES

1. Correlation between foreign body duration and halo thickness

2. Wood
   a. Most frequent halos
   b. Most prominent halos
PURPOSE

- Investigate associations of halos and foreign bodies
- Determine statistical correlations
  - Between halos and foreign body type
- Relevance:
  - Pre-operative planning
  - US guided foreign body removal
MATERIALS AND METHODS

• 264 cases US guided soft tissue foreign body removal
• Age: 5D – 468 months (Mean=109 months)
• FB duration: 1 – 720 days (Mean=69 days)
• FB types
  – Wood
  – Glass
  – Metal
  – Plastic
  – Norplant
  – Stone
  – Bone
• Halo type reported at removal-Interventional Radiology
  – Purulent collection, granulation tissue/scar
Foreign Bodies Removed

- Wood: 99
- Metal: 86
- Glass: 68
- Plastic: 8
- Stone: 4
- Bone: 1
- Catheter: 1
- Lead: 1
- Norplant: 1

# Removed
Metal needle-No halo
Wood-
Mild halo
Wood-Moderate halo
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## FB Duration v. Halo Thickness Correlation

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<td><strong>Wood with Granulation</strong></td>
<td><strong>0.411</strong></td>
<td><strong>P&lt;.05</strong></td>
<td><strong>Positive</strong></td>
</tr>
</tbody>
</table>
Wood-Purulent halo
Wood-Purulent halo
Wood-Purulent halo
Three year needle
Wood-Granulation
Wood-Granulation
4 Months
Wood-3 Months
CONCLUSION

• Hypoechoic halo
  – Purulent collection
  – Granulation tissue

• Wood – most common halo

• Wood – most prominent halo
  – Reactive plant matter
  – Porous – indulent infection

• Useful for interventional planning
Imaging investigations of the genitourinary tract are common in pediatric practice. In past years, the choices were rather limited, but advances in all modalities have increased the number of techniques available. The ability to delineate anatomy with current imaging methods is impressive, and the functional information obtainable is becoming more sophisticated through nuclear medicine and magnetic resonance imaging (MRI) techniques. Acquiring the necessary information for proper patient treatment must be tempered with patient safety and minimization of radiation exposure. Advances in ultrasonography (US), nuclear medicine, and MRI have helped in this regard. Although there are generally accepted approaches to many genitourinary diseases, the tests performed vary among institutions, countries, and individual radiologists. Our practices change as we learn and understand more about the conditions we investigate, but the goal of obtaining clinically relevant, high-quality diagnostic data in the safest manner possible remains constant.

FETAL UROLOGIC IMAGING

Prenatal US examination of the fetus is performed with increasing frequency in cases of suspected fetal abnormalities (see Chapter 12). More than one third of the anomalies detected in the fetus are urogenital. Fetal kidneys and bladder can be visualized by US as early as 13 weeks of gestation. The pelviocalyceal systems and ureters are not seen unless dilated. Urinary anomalies are discovered incidentally during routine screening or in cases of oligohydramnios, abnormal serum 

CONTRAST MEDIA

Radiographic and Computed Tomographic Contrast Media

Contrast media are pharmaceuticals that alter tissue characteristics to enhance information obtained on diagnostic images. The contrast media used in radiography are based on the interruption of x-ray beam transmission by iodine; they are categorized as high-osmolality contrast media (HOCM) and low-osmolality contrast media (LOCM). When choosing a contrast agent, considerations include the concentration of iodine needed, economic factors, and safety issues. HOCM are rarely used as intravascular agents in current pediatric practice, but low-osmol-too-concentration formulations are freqeently used for nonvascular fluoroscopic studies. LOCM have an iodine content ranging from 128 to 320 mg/ml and an osmolality ranging from 290 to 792 mOsm/kg.
serum osmolality is 285 mosm/kg. Those with an iodine content of 240 to 300 mg/mg are called “intermediate” cases, and those with less than 240 mg/mg are called “low” cases. LOC in the case of a high iodine content (250 to 370 mg/mg) occur for CT and angiography.

The intravenous (IV) dosage of contrast material is based on grams of iodine in relation to body mass. It is approved for use in adults of 150 kg weight. The most commonly used forms of LOC. However, with newer CT scanners and rapid scanning techniques, adequate contrast enhancement can often be achieved with smaller doses. Intravenous urography (IVU), though rarely required in current practice, may require higher doses of contrast agent (especially in infants) for adequate opacification of the collecting system.

Atropine, a potent contrast amort, a peak plasma level occurs within the first minute. This peak is followed by a rapid decline resulting from renal excretion, and calcium-magnesium phosphate precipitation in the renal tubules, and rapid diffusion into the extracellular and intracellular spaces. Contrast material is filtered by the glomerulus and concentrated in the proximal tubules. Contrast excretion begins immediately on initial circulation through the kidney and peaks at 10 to 20 minutes. At least 50% of injected contrast material is excreted within 2 to 5 hours of injection, and 100% is cleared within 24 hours. In patients with renal failure, contrast material remains in the circulation for much longer periods. Absorption from mucosal surfaces, including the small bowel and gallbladder, is the quality of radiographic renal visualization is related to the initial plasma level of contrast material. Adequate renal perfusion is necessary. Only low-osmolality contrast agents are being used as the primary contrast medium of choice. Since the use of high-osmolality contrast agents is associated with a higher incidence of nephrotoxicity, the use of low-osmolality contrast agents is preferred.

Contrast reactions are the most common complications of intravascular contrast administration. Reaction rates vary with the type and preparation of contrast media used. The most common complications are reactions that occur within minutes of injection, namely allergic reactions, and the diuretic effect of the contrast medium used.

Evidence suggests that there are definite advantages to the use of LOC. Current indications for the use of LOC are as follows:

1. Patients with a history of a previous allergic reaction to contrast material.
2. Patients with a history of asthma or allergy.
3. Patients with known cardiac dysfunction.
4. Patients with severe renal impairment.
5. Patients with a history of cardiac collapse, severe arrhythmias, unstable angina, or myocardial infarction.

In infants and children, considerations include very small size, prematurity, significant cardiac disease, congestive heart failure, and previous reaction to contrast material, renal insufficiency, and sickle cell anemia. In general, only LOC should be used for intravascular administration in pediatric practice. Only low-osmolality contrast media should be used for intravascular administration in children.
be used for intravascular administration in clinical practice.

Only low-osmolality contrast media should be used for intravascular administration in children.

**ADVERSE REACTIONS**

Factors affecting the chemotoxicity of contrast media include concentration, site of injection, specific chemical action, and osmolality. The effects related to osmolality include hyperosmolar diuresis, urinary diuresis, altered vascular endothelial permeability, decreased resistance and blood pressure, blood flow, pain, and sinus bradycardia and conduction delays.

Contrast with HOCM, LOCM have little or no effect on serum osmolality, serum sodium, vasodilatation, reduced red blood cell viscosity, or vasoactivity. There is little or no effect on the base of blood pressure. There are fewer electrocardiographic and fewer alterations in myocardial contractility output, and left ventricular pulmonary artery pressure. LOCM cause less endothelial damage and less activation of vasoactive substances than HOCM. There is a higher risk of contrast-induced nephropathy (CIN) in patients with a history of previous contrast administration, and nearly 20% of such patients develop identified severe renal reactions. There is a higher frequency of reactions when the total iodine dose is too high.

Several disease processes may be aggravated by the administration of intravascular contrast material. Hypertensive crisis, related to catecholamine release, may occur in patients with pheochromocytoma. Contrast-induced crisis can occur in patients with sickle cell anemia, and patients with hyperthyroidism may develop thyroid storm. Contrast nephropathy may occur following intravascular contrast administration; patients at risk for this complication are those with azotemia, diabetes mellitus, heart failure, contrast allergy, studies, or renal tubules filled with uric acid precipitates (e.g., patients undergoing rapid tumor biopsy). It is advisable to administer contrast media for as few patients as possible. Hyperglycemic agents containing metformin who continue the medication after IV contrast media administration may develop fatal diabetic acidosis. Some medications are not commonly prescribed to patients, however.

**Magnetic Resonance Imaging Contrast Media**

In urography, MRI contrast media are used to improve the inherent contrast differences between magnetically similar tissues, to directly evaluate organ function, and to estimate perfusion of renal and other MRI contrast agents are used in this technique. Newer contrast agents may offer higher doses of contrast agent (especially in infants) for adequate visualization of the collecting system.

After the injection of contrast material, a peak plasma level occurs within the first minute. The peak is followed by a rapid decline resulting from renal excretion, dilution of the material from mixing within the vascular space, and rapid diffusion into the extravascular and extracellular compartments. Contrast material is filtered by the glomerulus and concentrated in the proximal tubules. Contrast excretion begins immediately on initial circulation through the kidneys and is complete within 20 minutes. At least 75% of injected contrast material is excreted within 1 hour of injection, and 100% is cleared within 24 hours. In patients with renal failure, contrast material remains in the circulation for a longer time, but it may be excreted via the urinary tract and further dilution with the small bowel and gallbladder.

The quality of radiographic renal visualization is affected by the circulating level of contrast material. The contrast material is used and is voided by the speed of contrast transit. Immediate treatment of the agent's effects is possible when the patient's VTC is related to the concentration of contrast material in the plasma, the volume of pre-contrast plasma, and the dose of contrast material used.

Evidence suggests that there are definite advantages to the use of LOCM. Contrast agents as recommended by the American College of Radiology (ACR) include:

1. Patients with a history of previous allergic reaction to contrast material.
2. Patients with a history of asthma or allergy, including immediate or delayed allergic reactions.
3. Patients with a history of cardiovascular disease, including acute coronary syndrome, aortic valves, pulmonary hypertension.
4. Patients with severe or chronic circulatory insufficiency.

A specific indication for the use of LOCM is the presence of aortic and renal stenosis. Common side effects and children's reactions include nausea, vomiting, diarrhea, and skin reactions to contrast material. Eosinophilic reactions are common and treatable with antihistamines. In severe cases, anaphylaxis, or allergy-like, severe anaphylaxis. Contrast material may produce histamine release from basophils and mast cells and may affect both the complement and coagulation systems. Nonionic, nonosmotic reactions result from direct toxic effects of contrast material and contrast hyperosmolality and include nausea, vomiting, cardiac arrhythmias, pulmonary edema, and cardiac arrest. Cardiovascular collapse. Although some contrast agents are used in greater concentration in children, global contrast agents are not the result of warm or cold compresses, and some have advocated the subcutaneous injection of saline or hydrocortisone for larger extravasations. If the local reaction is severe, or if there are any questions, surgical consultation should be sought.

**Contrast Extravasation**

If, during IV contrast administration, there is any indication of extravasation, such as swelling or pain, the injection must be halted. Extravasation produces an inflammatory response causing pain, edema, and necrosis of subcutaneous tissues. Such reactions are less severe with LOCM than with HOCM. Unfortunately, extravasation is a rare event with any contrast material, and treatment regimens include elevation and warm compresses, and some have advocated the subcutaneous injection of saline or hydrocortisone for larger extravasations. If the local reaction is severe, or if there are any questions, surgical consultation should be sought.

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to having gadolinium administered. If renal insufficiency is discovered or suspected, noncontrast, nonenhanced, or delayed imaging modality should be considered, depending on clinical conditions.

Ultrasonography Contrast Media

US contrast media promise to be an exciting addition to the diagnostic capabilities of this modality. Although they have existed for many years, these agents have only recently become widely available and approved for use. The specific compositions of these agents vary by manufacturer, but all are microbubbles of air or perfluoropropane gas contained within a lipid or perfluorocarbon shell. When insonated, these bubbles resonate, increasing both gray scale and color Doppler signal. Specific US pulse strategies have been developed to optimize signal from these contrast agents, further improving their usefulness.

Used intravenously, US contrast media can help evaluate tissue perfusion and assess normal structures as well as masses. Used intravenously, these agents provide a method to evaluate vesicoureteral reflux (VUR) without the use of ionizing radiation.

**RADIODGRAPHIC PROCEDURES**

**Intravenous Urography**

IVU uses the physiologic excretion of injected iodinated contrast media for visualization of the renal cortex, medulla, and collecting system. Anatomic details of the renal parenchyma and collecting system and general intrarenal perfusion and function are obtained. The study requires good bowel preparation. Excretion of contrast media is generally obtained by placement of a urethral catheter, followed by injection of filtered contrast material. The urethral catheter is placed with the patient supine, and the contrast material is injected over a period of 10 to 15 seconds.

**Vesicoureteral Reflux**

Vesicoureteral reflux (VUR) is a condition in which urine from the bladder flows retrograde up the ureters and into the kidneys. The diagnosis of VUR is usually made using radioisotope renography, a test that measures the rate of urine flow from the kidneys to the bladder. The test is performed by injecting a radioactive tracer into a vein and monitoring the rate of excretion of the tracer into the bladder. The test is usually performed on children, who are often referred for evaluation due to symptoms of urinary tract infection or renal scarring.

**Renal Function Tests**

Renal function tests are used to evaluate the ability of the kidneys to filter and excrete waste products. Common tests include blood urea nitrogen (BUN), creatinine, and glomerular filtration rate (GFR). These tests can help diagnose and monitor conditions such as diabetes, hypertension, and kidney disease. Other tests, such as urine analysis, urine culture, and imaging studies, may also be used to evaluate renal function.
CHAPTER 107 — GENTOURINARY DIAGNOSTIC PROCEDURES

Ultrasonography Contrast Media

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Used intravenously, US contrast media can help evaluate tissue perfusion and assess normal structures as well as masses. Used intravesically, these agents provide a method to evaluate vesicourethral reflux (VUR) without the use of ionizing radiation.

**Radiographic Procedures**

**Intravenous Urography**

IVU uses the physiologic excretion of injected iodinated contrast media for visualization of the renal cortex, medulla, and collecting system. Anatomic and functional details of the collecting system are visible. The information concerning renal function is obtained. IVU is a contrast nephrography phase and extension of contrast material into the pelvicalyceal collecting system. IVU was and continues to be a valuable tool for the radiologist, but it has been supplanted by US, CT, and MR in recent practice. Baseline information is important and preparation is unnecessary in infants and Dehydration should be avoided. A light meal or clear liquids are allowed for 2-4 hours before the study. The patient is instructed to void before the study, and then instructed to avoid voiding during the study. Plain abdominal X-ray is taken after the IVU, and the patient is instructed to void within 2 hours and bring the specimen to the radiologist. The desired images are obtained and the patient is instructed to empty the bladder by voiding or suprapubic catheterization. If necessary, the patient is given fluid. A total of 2-3 mL/kg is obtained intravenously to obtain adequate concentration in the renal tubules and collecting system. The imaging sequence is tailored to the individual patient, and the injection is timed to ensure that the renal collecting system is filled. The renal collecting system is filled with contrast material, and the kidneys and their collecting systems are observed. The images are taken at the appropriate times to visualize the renal collecting system and renal tubules.

**Cystourethrography**

Antegrade voiding cystourethrography (VCUG) is an examination of choice for detailed anatomic evaluation of the bladder, for study of the anatomy of the male urethra, and for identification of VUR. VCUG preparation, a well-lubricated small catheter is advanced through the urethra into the bladder. The urethra is visualized with an anesthetic gel to relax the sphincter. The bladder is filled by gravity pressure (fluid at a height of approximately 1 m) using dilute sterile contrast material with an iohexol concentration of 390 to 100 mg/mL. Sufficient contrast is injected into the bladder to produce an opacification of the bladder wall visible fluoroscopically. The bladder is emptied by suprapubic catheterization, and the catheter is removed. The VUR is noted when the kidneys and ureters are evaluated for reflux. The bladder is then emptied through the catheter.

**Vesicostomy Study**

In patients with a simple vesicostomy, a small Foley catheter is inserted into the bladder through the stoma, and the balloon is inflated and used to occlude the vesicostomy site. A cystogram is then performed, filling the bladder by gravity introduction of indigo carmine. Bladder size and morphology, VUR, and bladder outlet can be evaluated.

**Retrograde Urethrogram**

Retrograde urethrogram is obtained infrequently in children but are performed in boys to evaluate possible urethral injury or retraumatization due to straddle injury or pelvic trauma. A small catheter is introduced into the anterior urethra to or slightly past the fossa navicularis, and the meatus is occluded. In the patient in a steep oblique position, a small amount of contrast material is injected through a syringe to allow evaluation of the urethra to the level of the external spincter. Spasm of the external spincter is often noted on imaging of the most proximal portion of the posterior urethra. Though urethrograms are rarely performed for girls, the tip of a small Foley catheter with the balloon distended can be placed into the urethra and then taped to the perineum to allow retrograde evaluation of the urethra.

**Vaginography**

A vaginogram is used to evaluate vaginal size, a common urogenital orifice, the presence of a cervix, or a vaginal mass. The technique is used in older cases of ambiguous genitilia or common urogenital sinus. A small catheter is introduced into the vagina and taped. If possible, another catheter is introduced anteriorly into the urethra and bladder, particularly when evaluating a common urogenital sinus. Contrast material is injected under fluoroscopic control with the patient in a steep oblique or lateral position to establish the interrelationships of the urogenital structures.
CHAPTER 107 — GENITOURINARY DIAGNOSTIC PROCEDURES

Genitography

Genitography is most useful in children with suspected intersex or whose sexual differentiation is indeterminable by external genitalia. Most of these children are masculinized females. US or MRI can establish the presence of a uterus and gonads, but genitography is used to detail the anatomy of the urethra, vagina, and bladder. Genitography is carried out by catheterization of the urethra and urinary bladder; a second catheter may then be placed just dorsally and enter a vagina that communicates with the proximal urethra. Some examiners also prefer to place a catheter within the rectum, possibly with a small amount of contrast material. A standard cystourethrogram is performed to evaluate the bladder and urethra. During this procedure, there may be reflux of contrast material into the vagina that enters a masculinized urethra. If this does not occur, use of a second posterior catheter passed by hand into the urethra, with the tip of the catheter placed in the posterior urethra, often delineates a vagina and its associated cervix. These studies have been performed in the patient in the true lateral position and are discussed in Chapter 153.

Retrogade Pyelography

This procedure is usually done as an adjunct to cystoscopy, with the urologist placing retrograde catheters within the ureters. The examination is performed most frequently in children with a blind-ending ureter (eclabour bladder) who, before uroterestopic ureteralcoplasty, were thought to have ureteral atresia to ensure that no ureteral anomalies existed. Following the placement of the ureteral catheters by the urologist, sterile contrast medium is injected, and images are obtained to identify the anatomic relationships.

Nephrostomy and Ureterostomy Studies

These examinations are performed by gravity introduction or low-pressure manual injection of indinated contrast material into an indwelling catheter, or through a ureteral catheter inserted into the renal pelvis and advanced to the desired location. Both procedures are performed with fluoroscopic guidance.

ULTRASONOGRAPHY

Real-Time Gray Scale Ultrasonography

US is the most widely used general examination of the urinary tract in children and infants. The widespread use of obstetric US has resulted in the early detection of many congenital urinary tract abnormalities, allowing subsequent treatment and the prevention of adverse sequelae.

Ultrasound is a safe and easily accessible technique for screening, identifying, and characterizing urinary tract abnormalities and for postoperative and post-treatment follow-up. Common indications for US of the urinary tract include the following:

- Fetal evaluation (in utero screening)
- Palpable abdominal mass
- Renal enlargement
- Nephrosclerosis, fever, proteinuria, failure to thrive
- Urinary tract infection

- Hematuria
- Abnormal pattern of urination
- Presence of anomalies that may be associated with urinary anomalies: limb, vertebral, cardiac, anal
- Physical characteristics associated with renal neoplasia: hemihypertrophy, viscerohypertrophy, spina bifida
- Hydropsphrosis
- Renal and orthostatic findings of diminished renal function or impending renal failure
- Positive family history of urinary abnormalities

Owing to the small physical habits of infants and children and their lack of abdominal fat, along with the lack of ionizing radiation, US is an ideal method for examining the kidneys and bladder. There is no specific preparation for an ultrasound examination; patients are generally not asked to fast, and patients are hydrated. During the examination, patients are encouraged to drink fluids so as to have a full bladder at the start of the examination. Priopriate use of new frequencies and transducer design (sector, phased, convoluted, and linear) allow for optimal visualization approaches. Children are scanned in the supine, decubitus, or prone position. The liver provides an excellent acoustic window for the right kidney, and the spleen may be used as an acoustic window for the left kidney. Occasionally, bowel gas may obscure part of the kidney on supine views, but a posteroanterior approach can be used to improve visualization.

In young children, it is advisable to initiate the ureteral ultrasound examination with an examination of the bladder. The full bladder of an infant usually causes the transducer to be placed in the suprapubic region. The kidneys are imaged in the longitudinal and transverse planes. The highest frequency transducer that allows adequate penetration should be used to provide the best spatial resolution possible. Examination with high-frequency linear transducers can provide information about the renal cortex and medulla (eg, pyramids, corticomedullary, and intrarenal cysts) more directly from hyperechoic masses.

The kidneys are complex organs with many medium-level echoes arising from the cortex; a well-delineated corticomedullary junction with high-echoic acuate arteries; and perinephric fat, relatively large medullary rays that are hyperechoic. Cortical echogenicity in neonates and young infants is higher and the renal central pyramids are more hyperechoic than in older children (Fig. 107-2).

The kidneys are more echogenic compared with the liver and spleen in preterm infants and are echogenic in newborns and young infants, and diminishes progressively in the first year of life. On a longitudinal view of the renal pyramids, the central echo pattern to that of the child typically occurs between 6 and 9 months (Fig. 107-3). The central, highly echogenic sinus results from vascular structures interfacing with fat around the renal pelvis. In infants and young children, the kidneys typically appear as a homogeneous mass, surrounded by renal peritoneal fat. With maturation, the highly echogenic hilar structures develop in the third trimester and are similar to those of adults by the time children reach adolescence. Separation of the hyperchoic renal sinus echo can be seen with collecting system obstruction; but it can also be seen with diuresis and prone positioning.

Abnormal echogenicity of the renal sinus may represent a cyst of renal sinus fat.

On a sagittal view, the posterior wall shows that the renal cortex is hypoechoic and the medulla is hyperechoic, while the middle echogenicity of the kidney represents a lack of renal sinus fat.

The normal adrenal glands of full-term neonates are one of the last organs to be visible at birth, but they decrease in echogenicity during the first 5 weeks of life. On a longitudinal view of the adrenal gland appears as an echogenic structure superior and slightly inferior to the kidneys. The central echo pattern is also echogenic and the central medulla is hypoechoic. These structures are discussed in Chapters 24 and 144.

Ultrasonography is used using the fluid-filled bladder. Structures are easily seen within the bladder, because of residual maternal urine, which may continue if the child is not able to void urine into the mid-pyelicycal. With pyelicycles, the urine flow begins to develop, and the end-plate bladder at the start of micturition may be seen. Several modalities can be discussed in Chapter 155. Although it is often avoided in pediatric imaging, endosonographic technology is a valuable technique in adolescents. Patients who have had prior ureteral reimplantation or who have undergone pyeloplasty and have undergone a pyelography, who use tamsulosin, or who are sexually active should be considered for an endosonographic examination if transabdominal scanning is unresolving.

The tests can be visualized within the scrotum or in the inguinal canal up to the internal inguinal ring. High-frequency linear transducers provide excellent resolution. The tests are ovoid, with the comma-shaped epididymis and appendix, identified superiorly. A medium-echo pattern is present throughout the tests, and a slightly hyperchoic central bulbus is identified. Fine subcortical echogenicities are occasionally seen. Chapter 154 discusses testicular examination in detail.

Doppler Ultrasonography

Although gray scale US provides excellent anatomic detail, it does not provide functional data. The use of color and pulsed-wave Doppler, however, can provide important information about renal perfusion and indirect information about the renal parenchyma. Doppler US is valuable for the detection of intrarenal vascular anatomy, such as an arterial perfusion, or to exclude venous thrombosis. Measurable blood flow parameters from spectrally Doppler analysis include peak systolic velocity, end-diastolic velocity, and acceleration times. Calculated values such as mean velocity, volume flow, and flow impedance, and the urine flow can also be obtained. The normal renal artery has a prompt systolic upstroke with an accelerating time to peak velocity greater than or equal to a visible early systolic peak (Fig. 107-4). The normal resistive index depends on patient age; it may be as high as 0.9 in a preterm infant and falls to around the adult value of 0.7 in the first few months of life. Elevated renal artery resistive velocities relative to the aorta, or a delayed systolic wave, may indicate renal artery stenosis (see Chapter 150). Diminished diastolic or reversed diastolic arterial flow indicates increased resistance and, in pediatric patients, may be seen in medical renal diseases, venous obstruction, and renal transplant dysfunction (see Chapter 149). Abnormally increased diastolic blood flow may indicate renal artery stenosis or abnormal arteriovenous communication.
Genitography

Genitography is most useful in children with suspected intersex or whose sexual differentiation is indeterminate by sexual genitalia. Most of these children are masculinized females. US or MRI can establish the presence of a uterus and gonads, but genitography is used to display the anatomy of the urethra, vagina, and bladder. Genitography is carried out by coloration of the urethra and urinary bladder; a second catheter may then be placed just distally and enter a vagina that communicates with the proximal urethra. Some examiners also prefer to place a catheter within the rectum, possibly with a small amount of contrast material. A standard cystourethrogram is performed to evaluate the bladder and urethra. During this procedure, patients are encouraged to drink fluids so that a full bladder at the start of the study. Various frequencies and transducer designs (curvilinear, and linear array) allow for improved approaches. Children are scanned in the supine position, or prone position. The liver provides an acoustic window for the upper pole of the right kidney and the spleen may be used as an acoustic for the left kidney. On occasion, bowel gas may obscure the kidney on supine views, but a prone approach can be used to improve visualization.

In young children, it is advisable to initiate initial ultrasound examination with an abdominal bladder. The full bladder of an infant may be imaged in the supine position, or prone position. Kidneys are imaged in the longitudinal and transverse planes. The highest frequency transducer is adequate for superficial resolution possible. Examination frequency linear transducers can provide improved visualization about the renal cortex and medulla (e.g., "thick scan") that may be missed during a previous examination. The use of harmonic imaging in large patients and may help distinguish cysts from hyperechoic masses.

The kidneys are ovoid solid organs with an echo level echogenicity from the cortex; a well-defined corticomedullary junction with bright echoes, arcades, and pyramid-shaped, relatively large echoes that are hyperechoic. Cortical echogenicity in young infants is higher and the medullary rays are more hyperechoic. Cortical echogenicity is increased compared to the spleen in preterm infants, isolette growth age, and young infants, and diminishes among older children. The transverse pattern of the transverse pattern to that of the child typically occurs between 6 and 9 months (Fig. 107-3). The central regions results from vascular structures near the renal pelvis. Structures are easily identified in newborns because of residual maternal hormonal stimulation, which may continue if the child is breastfed. During childhood, the ovaries become smaller and more difficult to visualize until puberty. With puberty, the uterus fundus begins to develop, and the endometrium becomes more visible. These appearances are discussed in Chapter 155. Although it is not available in pediatric imaging, endovaginal sonography is a valuable technique in adolescents. Patients who have had gynecologic examinations, who use tampons, or who are sexually active should be considered for an endovaginal examination as transvaginal scanning is unwarranted.

The testes can be visualized within the scrotum or in the inguinal canal up to the internal inguinal ring. High-frequency linear transducers provide excellent resolution. The testes are ovoid, with comma-shaped epididymis and appendix identified superiorly. A homogeneous medium-echo pattern is present throughout the testes, and a slightly hyperechoic central hilum is identified. Fine septations are occasionally seen. Chapter 154 discusses testicular evaluation in detail.

Doppler Ultrasound

Although gray scale US provides excellent anatomic detail, it does not provide functional data. The use of color and pulsed-wave Doppler, however, can provide important information about renal perfusion and indirect information about the renal parenchyma. Doppler US is valuable for the detection of blood flow, to confirm arterial perfusion, or to exclude renal thrombosis. Measurable blood flow parameters from spectral Doppler analysis include peak systolic velocity, end-diastolic velocity, and acceleration times. Calculated values such as mean velocity, volume flow rate, flow impedance, and pulsatility can also be obtained.

The normal renal artery has a prompt systolic upstroke with an acceleration time of 70 msec or less and a visible early systolic peak (Fig. 107-4). The systolic resistive index depends on patient age; it may be as high as 0.9 in a preterm infant and falls to around the adult value of 0.7 in the first few months of life. Elevated renal artery velocities relative to the aorta, or a delayed systolic upstroke, may indicate arterial stenosis (see Chapter 150). Diminished diastolic or reversed diastolic arterial flow indicates increased renovascular impedance, which may be seen in medical renal diseases, venous obstruction, and renal transplant dysfunction (see Chapter 149). Abnormally increased diastolic flow may indicate renal artery stenosis or abnormal arteriovenous communication.
Color Doppler is also useful for evaluating potential uterine artery constriction. The impedance in an acutely obstructed kidney may be increased, leading to decreased renal arterial diastolic flow and an increase in the resistive index. Additionally, urethral inflow to the bladder can be assessed by looking for normal "jet" with color Doppler. A unilateral diminished frequency or absence of ureteric flow may indicate ipsilateral ureteral obstruction.

In evaluating scrotal pain, testicular torsion and ischemia can be differentiated from epididymitis, tumor, orchitis, or appendectomy torsion using color Doppler sonography. This technique is accurate in older children and adults and can be used successfully in infants and young children.

Contrast-Enhanced Ultrasonography

Ultrasound contrast agents are widely available worldwide, except in North America. Most of these agents are variants of gas-filled microbubbles that are injected intravenously. These agents increase signal on both gray scale and color Doppler, enhancing the depiction of parenchymal and vascular structures. Contrast-enhanced US provides better anatomic information in difficult patients and permits the evaluation of renal perfusion.

Contrast-Enhanced Cystosonography

The intravesical instillation of ultrasound contrast agent in the urinary bladder allows the sonographic evaluation of VUR. The ultrasound transducer is positioned internally over the bladder, ureters, and kidneys while the bladder is filled, as with VCUG. Reflux appears bright echoic and is thus detectable by US, especially with the use of harmonic imaging and contrast-specific acoustic pulse techniques. Although this technique does not avoid catheterization, it does eliminate radiation exposure. Results indicate that the sensitivity of gas-filled cystosonography is similar to that of standard techniques, although urethral visualization is more difficult.

COMPUTED TOMOGRAPHY

CT is one of our most useful imaging tools. High-quality images can be performed in patients of all ages and sizes and is not limited by bone or bowel gas. Relative insensitivity to movement and reposition, explanation of the procedure, the presence of a parent, sedation, and immobilization all contribute to a successful diagnostic study. Faster multidetector scanners obtain the need for sedation in most patients. Multidetector reformatting, especially in the renal, hepatic, and chest regions may depict the entire course of the collecting system.

Noncontrast imaging is performed for calcifications or nephrolithiasis (see Chapter 147), but most CT imaging is performed with IV contrast. Contrast enhancement is critical for the visualization of renal lesions and the vessels of the abdomen. Delayed imaging is useful for assessing the integrity of the collecting system (such as after trauma), for assessing the course of the ureter, and for evaluating renal masses and cysts. As with all ionizing radiation, CT doses should be reduced and optimized based on patient size and purpose of the study.

In small children, contrast material is administered by hand injection, although a power injector should be considered in older patients to provide more controlled contrast administration. Careful visual monitoring of the IV line is important during injection to ensure that extravasation is not occurring. Scanning begins based on the speed of the particular CT scanner and the information being sought. By showing the progression of contrast enhancement of the cortex, medulla, and collecting system of the kidney, CT provides some assessment of renal function as well as anatomy.

MAGNETIC RESONANCE IMAGING

MRI is a sectional diagnostic technique that depends on proton density, T1 and T2 relaxation, flow phenomena, magnetic susceptibility, and diffusion to produce images. Advantages include good spatial resolution, good contrast resolution, multiplanar imaging, and lack of ionizing radiation. Lipid suppression techniques are helpful in the abdomen, particularly after contrast enhancement, by removing the contribution of high signal from fat. Degradation resulting from metallic foreign material and patient motion can have a significant effect on the image. Use of surface coils, the ability to reduce motion artifact, and the development of appropriate contrast materials and faster scanning times has resulted in improved imaging. Patient irradiation is required in very young or agitated patients to obtain sufficient immobility during the scan.

MRI is not always readily available, and because of its cost and requirement for sedation in younger patients, it may not be considered a primary imaging modality. However, its superior image characteristics, multiplanar capabilities, and ability to gather functional as well as anatomic information without ionizing radiation make it an increasingly important tool in pediatric imaging.

Rapid scan techniques—such as rapid acquisition relaxation enhancement (RARE), half-Fourier acquisition single-shot turbo spinecho (HASTE), and single-shot fast spinecho (SSFSE)—gradient echo and fast spin echo, and three-dimensional acquisitions all improve the speed of data acquisition and image quality. The use of surface coils can enable improved resolution, with an improved signal-to-noise ratio at smaller field of view. However, the pediatric urogenital tract is often too small to be evaluated effectively.

The standard planes in which MRI is performed are the axial, coronal, and sagittal. In addition, oblique imaging or off-axis reconstructed images are often useful to provide optimal display of anatomy. Blood within vessels may be bright or dark, depending on the sequence or contrast technique used. Urine in the collecting system and ureter and other pelvic structures have low signal intensity on T1-weighted images and higher signal intensity on T2-weighted images. The kidney is easily visualized with intermediate signal on T1-weighted sequences. The renal cortex has an intermediate signal close to that of the spine, and the medullary pyramids show a lower signal on T2-weighted images. On T2-weighted images, urine is usually seen as hypointense, reflecting a low signal to noise ratio. The renal sinus is usually identified as a low signal intensity structure in the renal parenchyma, similar to the central sinus seen in CT imaging. The renal cortex, medulla, and sinus are well visualized with good contrast resolution, and T2-weighted sequences hold great promise in terms of physiologic information for the evaluation of pediatric urologic disorders. These studies are most commonly performed during the evaluation or follow-up of urinary tract.
Color Doppler is also useful for evaluating potential obstruction. The implication for an acute obstruction may be increased, leading to decreased renal arterial diastolic flow and an increase in the resistive index. Additionally, ureteric reflux to the bladder can be assessed by looking for an "jet" with color Doppler. A normal diastolic frequency or absence of ureteric flow may indicate ipsilateral ureteral obstruction.

In evaluating renal pain, testicular torsion and ischemia can be differentiated from epididymitis, tumors, orchitis, or appendix torsion using color Doppler sonography. This technique is accurate in older children and adolescents and can be used successfully in infants and young children.

**Contrast-Enhanced Ultrasonography**

Ultrasound contrast agents are widely available worldwide except in North America. Most of these agents are variations of gas-filled microbubbles that are injected intravenously. These agents increase signal on both gray scale and Doppler imaging, enhancing the depiction of parenchymal and vascular structures. Contrast-enhanced US provides better anatomic information in difficult patients and permits the evaluation of renal perfusion.

**Contrast-Enhanced Cystosonography**

The intravascular injection of ultrasound contrast agents in the urinary bladder allows the sonoographic evaluation of VUR. The ultrasound transducer is positioned intravesically over the bladder, ureters, and kidneys while the bladder is filled, as with VCUG. Refocused fluid appears uniquely with the use of harmonic imaging and contrast-specific sonographic pulse techniques. Although this technique does not require intravenous contrast injection, it does eliminate radiation exposure. Results indicate that the sensitivity of VUR detection is comparable to that of standard techniques, although renal visualization is more difficult.

**COMPUTED TOMOGRAPHY**

CT is one of our most powerful imaging tools. High-quality CT can be performed in patients of all ages and imaging is required for bony and/or boneless gas-related procedures, the presence of a foreign body, and the need to evaluate the internal composition of the renal parenchyma. This can differentiate the single-shot turbo spin echo (HASTE), and single-shot turbo spin echo (SSE)—gradient echo and fast spin echo (FFE)—techniques, and three-dimensional acquisition and volume reconstruction can provide the speed of data acquisition and image improvement. The use of surface coils results in improved image quality and an improved signal-to-noise ratio but also limits the field of view. However, the pediatric image can be evaluated effectively. The standard protocol in which the choice of contrast material is dependent on the axial, coronal, and sagittal; in addition, the image imaging or off-axis reconstructed images is for the optimal display of anatomy. CT may be bright or dark, depending on the contrast technique used. Used in the collection of blood vessels with different contrast techniques, the technique used in the collection of blood vessels can define the rate of flow in the renal parenchyma. The kidney can be imaged with intermediate signal on T1-weighted images.

**MAGNETIC RESONANCE IMAGING**

MRI is a noninvasive diagnostic technique that does not use ionizing radiation. T1 and T2 relaxation, flow phenomena, and magnetic susceptibility, and diffusion to produce images. Advantages include good spatial resolution, contrast resolution, multiparameter imaging, and diffusing radiation. Lipid suppression techniques are useful in the abdomen, particularly in the detection of fatty tissue removal, the more frequent use of fat-saturated T1-weighted and T2-weighted images, and the development of faster imaging protocols have improved imaging. Fat suppression in the liver and muscle is often performed to improve the detection of lesions.

**TABLE 107-1**

<table>
<thead>
<tr>
<th>Table 107-1: Radiopharmaceutical Dosage Guidelines and Dosimetry for a Five-Year-Old Child</th>
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<tr>
<td><strong>Radiopharmaceutical</strong></td>
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<tr>
<td>Te-99m MAG3</td>
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<tr>
<td>Te-99m DTPA</td>
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<tr>
<td>Te-99m sulfur colloid</td>
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<td>Te-99m DMSA</td>
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Intensity signal on T1-weighted images. On T2-weighted scans, renal signal is uniformly high (Fig. 107-5).

Although MRI is usually performed to obtain anatomic information, it is proving to be a powerful dynamic imaging modality capable of providing functional information as well. Magnetic resonance urography (MRU) provides exquisite anatomic information, and by using rapid scanning techniques to track the progression of contrast material from the vascular space to the collecting system, renal functional information can be obtained. With the administration of diuretics, washout information analogous to that achieved with nuclear medicine studies can be obtained. Though still undergoing refinement, these MRU techniques hold great promise in terms of providing a complete and detailed renal evaluation.

**NUCLEAR MEDICINE**

Nuclear medicine imaging of the pediatric urinary system serves a vital role, providing both anatomic and physiologic information for the evaluation of pediatric urologic disorders. These studies are most commonly performed during the evaluation or follow-up of urinary tract obstruction.
dilation or obstruction (hydrocephrosis or hydronephrosis), urinary tract infection (acute pyelonephritis or pyelonephritic scarring), VUR, or congenital urinary anomalies (duplex, ectopic, or dysplastic kidneys). This section covers the basic technical and interpretive aspects of the nuclear renogram, cystogram, and cortical scan as they apply to pediatric patients.

The pediatric patient requires special considerations when performing nuclear medicine studies. Specifically, radiopharmaceutical dosage adjustments—based on body weight (Table 107-1) (From Society of Nuclear Medicine Guidelines Manual, March 2003) or body surface area—must be made to achieve satisfactory images while keeping radiation doses as low as possible. In particular, efforts should be made to minimize the time tracer-bad urine remains in the bladder. This is especially important in girls, to minimize the ovarian absorption dose. This can be achieved with bladder catheterization or hydration and frequent voiding.

For most children, nuclear studies of the urinary tract can be performed without sedation. Very young infants can be swaddled gently for immobilization. Older children can be distracted during imaging by the parents or with cartoons or movies. Sedation may be necessary for some studies, such as renal cortical single-photon emission computed tomography (SPECT) imaging and a standard protocol should be followed, including continuous cardiovascular monitoring.

For all nuclear studies discussed in this chapter, the agent used is technetium-99m. This agent is ideal for nuclear imaging because it is readily available, has an appropriate half-life (6 hours) with a low-energy photon peak (140 keV), and has excellent chemical binding to the agents used to image the kidney parenchyma (dimercaptopropanoic acid (DMSA) or glucoheptonate), urinary system (mercaptetate (MAG3) or DTPA), or VUR (calf colloid). The radiation doses associated with this agent are well within the diagnostic ranges for other urodiagnostic studies (see Table 107-1).

Standard imaging parameters include a single-head gamma camera for planar acquisitions using either a low-energy all-purpose or low-energy high-resolution collimator with 128- or 256-matrix spatial resolution. Optimal evaluation of the renal parenchyma in young children with cortical scintigraphy requires pinhole collimation; SPECT acquisitions may be preferred by some radiologists in older children.

**Diuretic Renography**

Diuretic renography was first described in the late 1970s and is used to distinguish obstructive from nonobstructive hydronephrosis. It attempts to quantify urinary obstruction based on the relative function of the hydrostatic kidney compared with the normal kidney and the rate of urinary excretion of radiotracer from the renal pelvis (and, in the presence of hydronephrosis, from the ureter) after a diuretic challenge. The graphic presentation of renal excretion using a time vs. intensity curve is termed an renogram (Fig. 107-6); normal, equivocal, and obstructed patterns of excretion following a diuretic challenge, termed fusion, have been described (Fig. 107-7).

Additionally, the time required for half the tracer in the collecting system to pass across the ureteropelvic junction, termed diuretic time, is stratified to indicate a normal (6 to 10 minutes), equivocal (10 to 20 minutes), or obstructed (>20 minutes) pattern. These values are useful in distinguishing obstructive from nonobstructive hydronephrosis in older children and adults. However, the three guidelines can lead to misdiagnosis of hydronephrosis. A large number of young infants develop a renogram demonstrating on routine renograms. Some clinicians challenged the usefulness of the renogram for surgical planning in the majority of these patients due to its accuracy in less than 80% of them. In the hope of the outcome, specialization in multiple fields have standardized its performance and refine the technique to define obstruction as to better predict surgical correction and which can be managed expectantly. In this regard, the clinician must be careful to consider controversy regarding the renogram. The high capacity of the dilated ureters to absorb tracer and radiolabeled urine output in the setting of obstruction in children younger than 2 years.

**Optimization of the Renogram Technique**

The optimization of the renogram technique includes the following key points:

- **Appropriate patient hydration** is required before and during the examination (10 mL/kg IV 5% dextrose solution with 0.45% normal saline in children younger than one year, or oral hydration and dextrose solution with 0.22% normal saline in children less than one year of age).

- **Adequate bladder drainage** is achieved with frequent voiding in older children who are able to cooperate and with bladder catheterization in infants. An alternative to bladder catheterization is the addition of a suprapubic bladder image after upright positioning.

- **Adequate diuretic challenge** is achieved using 1 mg/kg IV furosemide. The timing of the diuretic is controversial.

- **Recommendations** include 15 minutes before the renogram injection to ensure maximal perfusion and extraction during maximal diuresis (tended 1-15), at the time of renogram injection to minimize...
dilatation or obstruction (hydroureter or hydronephrosis), urinary tract infection (acute pyelonephritis or pyelonephritis scar), vesicoureteral reflux, renal anomalies (cyst, ectopic, or dysplastic kidney). This section covers the basic technical and interpretive aspects of the nuclear renogram, gonad, and cortical scan as they apply to pediatric patients.

The patient requires special considerations when performing nuclear medicine studies. Specifically, body weight (Table 107-3) must be considered while keeping radiation doses as low as possible. In particular, efforts should be made to minimize the time elapsed between studies in the bladder. This is especially important in girls, as the ovaries are particularly susceptible to radiation exposure. This can be achieved without bladder catheterization or induction of frequent voiding.

For most children, bladder washout studies of the urinary tract can be performed without sedation. Very young infants can be distracted gently for immobilization. Older or cooperative children may require sedation using the same agents or methods. Sedation's role is necessary for the early or delayed washout study. A washout study is used to evaluate the function of the normal kidney compared with the normal contralateral kidney. It is performed using a standard renogram or scintigraphy to evaluate the function of the contralateral kidney.

Diuretic Renography

Diuretic renography was first described in the late 1970s and is used to distinguish obstruction from non-obstructive hydronephrosis. It attempts to quantify urinary obstruction based on the relative function of the healthy renal function compared with the renal function in the obstructed kidney (Fig. 107-7). The procedure is performed using a diureticchallenge, termed renography (Fig. 107-7). A diuretic challenge is performed by administering a diuretic (e.g., furosemide) to increase renal excretion of urine. However, application of these guidelines can lead to the misdiagnosis of obstruction in a large number of young infants with hydronephrosis demonstrated on routine prenatal sonography (Fig. 107-8). Some clinicians challenged the need for surgical intervention in the majority of these patients and showed that conservative management was appropriate in more than 80% of patients. In the hope of increasing the utility of the diuretic renogram in neonates and infants, specialists in multiple fields have attempted to standardize its performance and refine the diagnostic criteria for obstruction so as to better predict which patients with prenatally diagnosed hydronephrosis require surgical correction and which can be managed conservatively. Despite numerous modifications, there continues to be considerable controversy regarding the performance and interpretation of the diuretic renogram in these patients. The high capacity of the dilated renal pelvis and relatively low renal urine output in young infants limit the accuracy of this test in the setting of hydronephrosis in children younger than 2 years.

Optimization of the renography technique includes the following key points:
- Adequate patient hydration is required before and during the examination (10 ml/kg IV 5% dextrose solution with 0.45% normal saline in children older than one year, or oral hydration and dextrose solution with 0.92% normal saline in children less than one year of age).
- Adequate bladder drainage is achieved with frequent voiding in older children who are able to cooperate and with bladder catheterization in infants. An alternative to bladder catheterization is the addition of a suprapubic planar image after upright positioning.
- Adequate diuretic challenge is achieved using 1 mg/kg IV furosemide. The timing of the diuretic injection is controversial. Recommendations include 15 minutes before the tracer injection so as to image renal perfusion and extraction during maximal diuresis (termed F-15), at the time of tracer injection to minimize...
examination can be performed directly with instillation of tracer and sterile saline into the bladder (following sterile catheterization or suprapubic puncture) or indirectly following nuclear renography with planar images obtained during voiding. Catheterization should be performed by an experienced individual, and care should be taken to maintain sterile technique throughout. Anesthetic gel should be applied to the female urethral orifice or injected into the male urethral meatus to decrease the discomfort of catheterization. The risk of catheterization-induced infection is very small when the procedure is performed by experienced personnel and can be further minimized by delaying the study in a child with fever or a newly diagnosed urinary tract infection for at least 24 hours after the initiation of antibiotics. Bladder puncture for cystography is rarely performed in North America.

Technical features of the direct nuclear cystogram include the use of a technetium-99m-labeled agent, typically sulfur colloid, instilled into the bladder during the earliest phase of bladder filling, gravity-assisted infusion of saline into the bladder to the expected bladder capacity, and dynamic imaging of the bladder and kidney regions using a posterior gamma camera throughout the filling and voiding cycle. The data can be grouped (in 15- or 60-second intervals) as well as viewed dynamically. VUR is documented when tracer is seen to ascend into a tubular structure corresponding to the ureter or when there is visualization of the renal collecting system. The catheter is left in the bladder to minimize the amount of tracer remaining in the patient after voiding. In older children without VUR, discomfort caused by catheter manipulation can be decreased by allowing it to be expelled during voiding. The voiding phase can be performed supine or upright, depending on the child's ability to cooperate and the physician's preference. As with nuclear renography, mean bladder capacity for children 1 year of age or older is predicted by this formula: 

Patient age (years) / 2 x 50 mL. For infants younger than 1 year, the formula is as follows: 7 mL x Patient weight (kg).

The dose of tracer is dependent on bladder volume: 300 μCi for bladder volumes up to 300 mL, 600 μCi for bladder volumes of 300-600 mL, and 900 μCi for larger bladder volumes. A cyclic cystogram is recommended for children younger than 2 years, for those with previously documented or high suspicion for VUR, and for children who void before the expected bladder capacity is reached. The procedure is identical to the standard cystogram; however, the catheter is left in the bladder after the first voiding cycle and is used to refill the bladder for a repeat void. As with VCG, cyclic studies increase the diagnostic yield (Fig. 107-10), identifying an additional 10% to 15% of children with VUR compared with monovyclic voiding studies.

Cyclic voiding studies increase the detection of VUR in infants.

The major technical pitfalls of nuclear cystography include tracer-laden urine contamination within the field of the gamma camera and motion artifact. Tracer may contaminate clothing or linens and can obscure or be
CHAPTER 107 — GENITOURINARY DIAGNOSTIC PROCEDURES

FIGURE 107-9. Markedly enlarged left kidney with central photopenic regions consistent with marked hydropnephrosis. The renogram shows tracer accumulation and retention throughout, with no discernible washout after diuretic administration. Note that the renogram tracings of the two kidneys are superimposed during the first few minutes after injection of the tracer (arrow). This indicates nearly equal split renal function, as shown on the function table between 1.5 and 3 minutes.

- Adequate renal-to-background visualization is achieved with technetium-99m MAG3. This agent has better renal extraction than DTPA, substantially reducing background activity (especially important with respect to the liver and spleen) and optimizing renal parenchymal visualization, even in the presence of reduced renal function. MAG3 can be used to determine effective renal plasma flow. For children older than 2 years, technetium-99m DTPA is an adequate and less expensive alternative; it can be used to determine glomerular filtration rate (GFR).

Additional technical factors that have been optimized for diuretic renography include appropriate renal parenchymal and pelvic regions of interest, as well as background subtraction regions of interest.

In general, the diuretic renogram is useful in the evaluation of hydronephrosis in adults and older children. In infants, the examination is less accurate but can be optimized with consistent application of a standard technique, correlation of the renogram washout curve with the split renal function, and correlation with serial ultrasound examinations. Increasing hydronephrosis, decreasing split renal function of the hydronephrotic kidney, and worsening washout curve all suggest the possibility of significant obstruction (Fig. 107-9).

Renography requires strict attention to technical details, including patient hydration, bladder drainage, adequate diuretic challenge, and appropriate choice of radiopharmaceutical.

Nuclear Cystography

Nuclear cystography is performed for the assessment of VUR and is an alternative to fluoroscopic VCUG. The examination can be performed directly with instillation of tracer and sterile saline into the bladder (following sterile catheterization or suprapubic puncture) or indirectly following nuclear renography with planar images obtained during voiding. Catheterization should be performed by an experienced individual, and care should be taken to maintain sterile technique throughout. Anesthetic gel should be applied to the female urethral orifice or injected into the male urethral meatus to decrease the discomfort of catheterization. The risk of catheterization-induced infection is very small when the procedure is performed by experienced personnel and can be further minimized by delaying the study in a child with fever or a newly diagnosed urinary tract infection for at least 24 hours after the initiation of antibiotics. Bladder puncture for cystography is rarely performed in North America.

Technical features of the direct nuclear cystogram include the use of a technetium-99m-labeled agent, typically sulfur colloid, instilled into the bladder during the earliest phase of bladder filling, gravity-assisted infusion of saline into the bladder to the expected bladder capacity, and dynamic imaging of the bladder and kidney regions using a posterior gamma camera throughout the filling and voiding cycle. The data can be grouped (in 10- or 60-second intervals) as well as viewed dynamically. VUR is documented when tracer is shown to ascend into a tubular structure corresponding to the ureter or when there is visualization of the renal collecting system. The catheter is left in the bladder to minimize the amount of tracer remaining in the patient after voiding. In older children without VUR, discomfort caused by catheter manipulation can be decreased by allowing it to be expelled during voiding. The voiding phase can be performed supine or upright, depending on the child's ability to cooperate and the physician's preference. As with VCUG, mean bladder capacity for children 1 year of age or older is predicted by this formula: (Patient height (cm) + 2) x 30 ml. For infants younger than 1 year, the formula is as follows: 7 ml x Patient weight (kg). The dose of tracer is dependent on bladder volume: 300 µCi for bladder volumes up to 300 ml, and 600 µCi for larger bladder volumes. A cystic cystogram is recommended for children younger than 2 years, for those with previously documented or high suspicion for VUR, and for children who void well before the expected bladder capacity is reached. The procedure is identical to the standard cystogram; however, the catheter is left in the bladder after the first voiding cycle and is used to refill the bladder for a repeat void. As with VCUG, cyclic studies increase the diagnostic yield (Fig. 107-10), identifying an additional 10% to 15% of children with VUR compared with noncyclic voiding studies.

Cyclic voiding studies increase the detection of VUR in infants.

The major technical pitfalls of nuclear cystography include tracer-laden urine contamination within the field of the gamma camera and motion artifact. Tracer may contaminate clothing or linens and can obscure or be
acutely with VUR. Reth, the use of nonlabeled tracer, in the follow-up 99m pertechnetate scan, can result in artifact or "shaking out" of the tracer and mimic reflux (Fig. 107-11). Nuclear cystography offers two main advantages over voiding VUCG. First, with continuous imaging during the filling and voiding cycles, there is no artifact of VUR (Fig. 107-12). Second, with voided techniques, nuclear cystography has a substantially reduced radiation dose compared to VUCG with modern fluoroscopy equipment. VUCG has approximately a 160-fold greater radiation dose than nuclear cystography.

Disadvantages of nuclear cystography include a lack of simultaneous visualization of the urethra and collecting system if these structures need to be evaluated. Urethra VUG is the procedure of choice. For those, most whose urethra must be examined for ureteral strictures or diverticula or patients with dysfunctional voiding should have a standard fluoroscopic VUCG and the initial workup. If VUR is confirmed, then with nuclear cystography is sufficient. Nuclear cystography does not show bladder abnormalities, such as diverticula or thickened ureteral walls, that may result in VUR. Additionally, if obstruction or VUR with nuclear cystography is suspected, it may not be identified with VUCG; the nuclear cystography may not identify it.

Coronal Cystography

Coronal cystography is performed for the assessment of intrarenal neoplasms, atrophied renal scarring in the United States, the clinical utility of this study is limited by the fact that urinary tract infection, which results from uterine prolapse, is treated with antibiotics. However, in other practices a large number of infections that persist or recur, localization of the infection is helpful, since often in the presence of atrophy or an obstructed ureter, cystography is performed after surgery to determine definitive diagnosis. While renal cystography was never done medically, in which case each scan should lead to an alteration in clinical management. The coronal cystography can also be used to evaluate the extent of infection or location, although a diagnosis of infection is made before surgery, because of its increased availability, better contrast, and lower cost.

The coronal cystography is typically performed with fluoroscopic nonlabeled DMSA. This agent is extracted sharply and has a high in the renal cortex. The scan is typically performed with the patient in the sitting position, with radionuclide acquisition in the medulla or collecting system. This imaging for the scan appears to determine with relative renal scarring. The imaging typically occurs 2 to 3 hours after tracer acquisition with a dual-headed camera, allowing in outlining renal cortex.

FIGURE 107-13. Normal DMSA pinhole image. Note the relative hyperechogenicity of the medulla due to a lack of uptake by the deeper portions of the loop of Henle. Also note the increased intensity of the polar regions due to the relatively thinner polar cortex when compared with the midpolar region. LPO, left posterior oblique; RPO, right posterior oblique.
confused with VUR. Rarely, the use of nonlabeled tracer, in the form of technetium-99m pertechnetate, can result in the systemic absorption of tracer and mimic reflux (Fig. 107-11).

Nuclear cystography offers two main advantages over fluoroscopic VCUG. First, with continuous imaging throughout the filling and voiding cycles, there is increased detection of VUR (Fig. 107-12). Second, with standard techniques, nuclear cystography has a substantially reduced radiation dose compared with VCUG. With modern fluoroscopic equipment, VCUG has approximately a 10-fold greater radiation dose than nuclear cystography.

Disadvantages of nuclear cystography include a lack of detailed anatomic visualization of the urethra and collecting systems; if these structures need to be evaluated more thoroughly, VCUG is the procedure of choice. For this reason, boys whose urethra must be examined for posterior urethral valves or strictures or patients with dysfunctional voiding should have a standard fluoroscopic VCUG as part of the initial workup. If VUR is confirmed, follow-up with nuclear cystography is sufficient. Nuclear cystography does not show bladder abnormalities, such as periureteric diverticula, that may result in VUR. Additionally, the classification of VUR with nuclear cystography is less refined than that with VCUG; the nuclear grades of low, intermediate, and high roughly correspond to the fluoroscopic grades of 1, 2 or 3, and 4 or 5, respectively.

Cortical Scintigraphy

The renal cortical scan is performed for the assessment of acute pyelonephritis or its sequelae, atrophic pyelonephritic scarring. In the United States, the clinical utility of this study is limited by the fact that urinary tract infections, whether cystitis or pyelonephritis, are treated with the same course of antibiotics. However, in some instances in Europe and Australia, localization of the infection is clinically relevant because pyelonephritis is treated more aggressively; this is thought to decrease the incidence of subsequent scarring. A common indication for this examination is to assess for renal parenchymal involvement in the setting of recurrent urinary tract infections, such as a patient with neurogenic bladder or one in whom VUR is being managed medically, in which case a positive study would lead to an alteration in clinical management. The cortical scan can also be used to identify renal anomalies of fusion or location, although scintigraphy is the examination of choice because of its lack of ionizing radiation, increased availability, better anatomic detail, and lower cost.

The cortical scan is typically performed with technetium-99m-labeled DMSA. This agent is extracted by and then binds to cells of the proximal convoluted tubule. It does not accumulate in the medulla or collecting system, thus accounting for the scan appearance of cortical uptake with relative central photopenia (Fig. 107-13). Imaging typically occurs 2 to 3 hours after injection and should be performed with pinhole collimation, or SPECT acquisition with a dual-detected camera. The accuracy in demonstrating acute pyelonephritis is excellent, reported to exceed 95%. The pinhole images, obtained in both posterior and posterior oblique positions, have a higher specificity but lower sensitivity than SPECT images. A defect that appears as a vague area of photopenia not associated with volume loss is more consistent with acute pyelonephritis, whereas a triangular, well-demarcated photopenic focus with volume loss is typically considered an atrophic scar (Fig. 107-14), although it may also be related to focal renal dysplasia. Most areas of infection resolve without residual scarring, especially in older children, but this may take 6 months or longer after the acute infection. Therefore, a definitive diagnosis of scar requires a follow-up study at least 6 months after the acute infection. Scarring can also result from trauma, and recovery of function in a fractured kidney can be documented with cortical scintigraphy (Fig. 107-15). Rounded defects identified with cortical scintigraphy should be further characterized with US to assess for cyst or mass (Fig. 107-16).

Miscellaneous Renal Nuclear Studies

Quantitation of renal function is possible with nuclear imaging techniques. The relative function of each kidney can be assessed during the renogam before tracer exits the renal pelvis, or with cortical scintigraphy. Regions of interest for each kidney are drawn from a posterior
image, and relative function is given in terms of a percentage of total renal counts. The normal value is 50%. Various techniques for absolute renal function are inaccurate in children owing to factors related to patient size and renal depth correction.

Absolute renal function quantitation in terms of GFR or effective renal plasma flow can be performed with technetium-labeled MAG3 and DTPA, respectively, but these techniques require one to four blood samples. These measurements can assist in the evaluation of patients with chronic renal disease, the assessment of those requiring potentially nephrotoxic medications (chemotherapy), or in follow patients with hydronephrosis of a solitary kidney or with bilateral hydronephrosis. In the latter case, individual renal GFR can be obtained with a combination of camera-based techniques to determine relative renal function and laboratory-based techniques for assessment of total GFR. Renal function increases rapidly in the first 2 years of life and reaches adult values, when normalized to body surface area (normal values range from 80 to 140 ml/min/1.73 m²) by age 2 years.

SPIKE OF SPECT INTENSITY

graphic procedures are not confirmed to be the source of the patient's hypertension, and an abnormal ACE inhibitor renogram can be used to determine whether a stenosis is functionally significant.

ACE inhibitor renography requires strict attention to the patient's hydration status, as well as a consideration of anti hypertensive medications that may affect the results. The use of a baseline renogram to compare with the ACE inhibitor study has been recommended. Specific interpretive criteria have been suggested, and they vary depending on the specific agent used. A more thorough discussion of ACE inhibitor renography is beyond the scope of this text and can be found in nuclear medicine references.

VASCULAR STUDIES

Diagnostic vascular procedures performed in children include inferior vena cava catheterography, abdominal angiography, selective renal arteriography, digital subtraction angiography, renal venography, and selective venous renin studies. These studies have largely been supplanted by CT and MRI, which allow diagnostic information to be obtained noninvasively and provide superior depiction of adjacent anatomy. The remaining indications for angiographic evaluation and intervention are discussed in Chapter 185.

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SUGGESTED READINGS

Fetal Urologic Imaging
Contrast Media
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Immediately after renal transplantation, nuclear renography can be used to evaluate graft perfusion, urinary leak, and obstruction, although Doppler US has largely replaced nuclear techniques for these indications. Subacute rejection and acute tubular necrosis may have identical renograms and are differentiated by their time course, differences from baseline renograms. Nephrotoxic drug reaction and chronic rejection may be difficult to differentiate based on alterations in the renogram perfusion, extraction, and excretion phases and may coexist. Biopsy is often required in these cases.

Systolic hypertension affects 1% to 5% of children, and a specific cause is more frequently found in children than in adults, especially in neonates and infants; up to 48% of these young patients have secondary hypertension. The most frequently identified causes of secondary hypertension in children are abnormalities of renal vascular supply or drainage. These abnormalities are termed renal vascular hypertension and account for approximately 5% to 25% of pediatric hypertension. Identifying which children should undergo imaging evaluation and determining the specific imaging studies that should be performed are discussed in Chapter 150.

An underperfused kidney maintains filtration across the glomeruli by increasing the pressure in the postglomerular arteriole. This process is mediated by angiotensin. The renogram of such a kidney may be abnormal at baseline or become abnormal (tracer retention or decreased split function) following the administration of an angiotensin-converting enzyme (ACE) inhibitor. Nuclear renography using an ACE inhibitor is performed in some pediatric centers, either before or after angiography. Angiography reportedly finds a renal vascular lesion in approximately 85% of kidneys with ACE inhibitor–induced abnormal renograms. Additionally, approximately 15% of stenoses demonstrated angiographically are not confirmed to be the source of the patient’s hypertension, and an abnormal ACE inhibitor renogram can be used to determine whether a stenosis is functionally significant.

ACE inhibitor renography requires strict attention to the patient’s hydration status, as well as a consideration of antihypertensive medications that may affect the results. The use of a baseline renogram to compare with the ACE inhibitor study has been recommended. Specific interpretive criteria have been suggested, and they vary depending on the specific agent used. A more thorough discussion of ACE inhibitor renography is beyond the scope of this text and can be found in nuclear medicine references.

VASCULAR STUDIES

Diagnostic vascular procedures performed in children include inferior vena cava cavography, abdominal aortography, selective renal arteriography, digital subtraction angiography, renal venography, and selective venous renin studies. These studies have largely been supplanted by CT and MRI, which allow diagnostic information to be obtained noninvasively and provide superior depiction of adjacent anatomy. The remaining indications for angiographic evaluation and intervention are discussed in Chapter 185.

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SUGGESTED READINGS

Fetal Urologic Imaging


Contrast Media


Choyle PL, Kato-Yashida H: Functional magnetic resonance imaging of
Vodou Cytoreduction and Other Procedures


Vascular Imaging and Interventional Radiology

Vascular Imaging and Interventional Radiology

Summary


Computed Tomography


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Urography


Nuclear Medicine


Mandel MA, Eggel DE, Gillian DL, et al. Society of Nuclear Medicine
Oncology: Imaging Gastrointestinal and Genitourinary Tumors

SUE C. KASTE

IMAGING GOALS IN PEDIATRIC ONCOLOGY

The goals of imaging in pediatric oncology can be considered in four stages: initial diagnosis, monitoring of therapeutic response, end-of-therapy evaluation, and monitoring after completion of therapy. Each phase of imaging has a purpose, and the imaging techniques chosen reflect the phase of therapy. Further, imaging choices should reflect the patient population, the risks and benefits of the modality, and the information desired from the study (Tables 108.1 and 108.2).

Several issues must be considered when diagnosing pediatric malignancies. Most important, children should not be treated like small adults. The child’s knowledge base should always be considered, particularly when the child is very ill and the parents are severely stressed by the concept of their child having cancer. Each patient and his or her family are unique, and imaging personnel should be specially qualified to work with this patient cohort. We must also be cognizant of the fact that the effects of radiation exposure are cumulative and make an effort to adjust techniques to optimize while minimizing patient doses (see Chapters 1 and 2). In addition, malignancies may present differently in children versus adults. Masses of similar size may present more acutely in a child than in an adult, owing to greater compromise of smaller structures. Although many tumors have a predilection for certain age groups, we must remember that adult tumors may occasionally be seen in children and adolescents, typically include hepatoblastoma in a 4-year-old, renal cell carcinoma (Fig. 108.2), malignant melanoma, and colon cancer.

At initial diagnosis, imaging is used to identify and characterize the mass, provide a differential diagnosis, and determine the extent of disease both locally and distantly (Table 108.3). As a member of the interdisci-
CASE REPORT

Pulmonary hyalinizing granuloma and retroperitoneal fibrosis in an adolescent

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Abstract We describe a 15-year-old boy who developed pulmonary hyalinizing granuloma (PHG) and retroperitoneal fibrosis (RPF). His PHG and RPF were not associated with histoplasmosis or tuberculosis and appeared to represent idiopathic autoimmune phenomena. This is the first reported case of PHG in a pediatric patient and the fourth reported co-occurrence of PHG and RPF. The use of F-18 fluorodeoxyglucose positron emission tomography in the diagnostic and follow-up evaluation of PHG is reported.

Keywords Pulmonary hyalinizing granuloma · Retroperitoneal fibrosis · FDG-PET · Pediatric

Introduction

Pulmonary hyalinizing granuloma (PHG) is a rare fibrosclerosing inflammatory lung disease of unknown etiology [1]. The patient typically presents with cough, chest pain, dyspnea, or hemoptysis in association with multiple bilateral parenchymal nodules [2]. In 25% of patients the disease is asymptomatic and the nodules are incidentally noted [2]. Chest radiography and CT reveal relatively large, variably circumscribed nodules that might be cavitated or calcified. Open biopsy normally reveals haphazard dense collagen bands surrounded by a lymphoplasmacytic infiltrate that sometimes forms germinal centers [3]. The clinical course is usually self-limited and benign, but 30% of patients develop progressive inflammatory disease, with enlarging lesions and increasing dyspnea [1]. There is no established treatment for PHG, but in patients with progressive disease systemic corticosteroid therapy may be successful.

There have been three reports of retroperitoneal fibrosis (RPF) occurring in patients with PHG. Though the relationship is still obscure, the possibility that PHG and RPF share a common autoimmune etiology has been raised [3].

We report a pediatric patient with PHG and the fourth with co-occurrence of PHG and RPF. We also report the effectiveness of F-18 fluorodeoxyglucose positron emission tomography (FDG-PET) in the diagnosis and follow-up evaluation of PHG and RPF.

Case report

A previously healthy 15-year-old boy presented to the emergency department with acute severe right flank pain. The rest of his physical examination was normal. CT revealed right hydronephrosis and a retroperitoneal mass obstructing the right ureter (Fig. 1). MRI showed the retroperitoneal mass surrounding the right ureter and the right common iliac artery and vein but without aortic involvement (Fig. 2). The right retroperitoneal mass was partially resected, the ureteral stricture was excised, a ureteroureterostomy was performed, and a right ureteral...
stent was placed. Histopathologic analysis of the mass revealed densely collagenized connective tissue with chronic inflammation consisting of lymphoplasmacytic infiltrates, histiocytes and a few eosinophils, consistent with RPF.

In addition to the retroperitoneal mass, the initial CT incidentally revealed a calcified pulmonary nodule in the left lung base and numerous punctate splenic calcifications. Chest radiograph demonstrated multiple large bilateral pulmonary nodules, some of which were cavitary (Fig. 3). Chest CT identified 17 discrete pulmonary nodules, the majority of which showed partial calcification, many having a cavitary component (Fig. 4). Calcified right hilar and subcarinal adenopathy was also identified. There was no evidence of mediastinitis. Despite these radiographic findings, he had no pulmonary symptoms or signs.

In preparation for percutaneous CT-guided biopsy of a pulmonary nodule, a baseline coincidence FDG-PET/CT evaluation was performed; it demonstrated increased uptake in multiple pulmonary nodules, including the largest of the left-side cavitary lesions (Fig. 5). Increased activity was also demonstrated in the calcified subcarinal lymph nodes and at the site of the retroperitoneal mass (Fig. 6). CT-guided biopsy of one of the FDG-PET/CT active nodules (Fig. 7) revealed dense collagenous bands, focally lamellar, intermixed and surrounded by lymphoplasmacytic infiltrate. These findings were consistent with PHG.

Because both PHG and RPF can be associated with tuberculosis (TB) and histoplasmosis, the patient was evaluated for these and other infections [4]. Pathologic examination (including cultures and stains) of the pulmonary nodule and retroperitoneal mass revealed no evidence of TB, Histoplasma, or other fungal infection. A TB skin test, urine for Histoplasma antigen, and a fungal battery (including Histoplasma antibody by immunodiffusion and Histoplasma mycelial and yeast antibodies by complement fixation) were negative. His sedimentation rate and quan-
titative immunoglobulin levels were elevated, but the following tests were negative: ANA, rheumatoid factor, ANCA, anti-MPO antibody, anti-proteinase III antibody, ACE, liver transaminases, BUN, creatinine, and serum protein electrophoresis. It was concluded that the patient had idiopathic autoimmune PHG and associated idiopathic autoimmune RPF.

The patient was initially treated with three consecutive daily 1-g pulses of intravenous methylprednisolone, followed by 60 mg oral prednisone daily. Subsequently, he received weekly pulses of methylprednisolone while his daily prednisone was steadily tapered. Six weeks after onset of treatment, repeat coincidence FDG-PET/CT scanning revealed nearly total reduction in metabolic activity in the numerous pulmonary granulomas (Fig. 5), the subcarinal adenopathy, and the area of the right iliac region RPF (Fig. 6), indicating a positive response to the corticosteroid therapy.

**Discussion**

PHG is an uncommon and distinct fibrosclerosing inflammatory disease of the lung. Only 71 patients have been reported, all adults (mean age 42 years, range 19–77 years) [5]. Histologically, the lesions demonstrate haphazard dense collagen bands surrounded by a lymphoplasmacytic infiltrate that sometimes forms germinal centers [3]. This lesion is distinct from inflammatory pseudotumors of the lung (also known as plasma cell granuloma). These inflammatory pseudotumors are relatively rare but have been reported as a common cause of solitary lung masses in children. Histologically, they are composed of a myofibroblastic
stroma infiltrated by a proliferation of either histiocytes or lymphocytes/plasma cells (i.e. plasma cell granuloma). They generally do not respond to steroids. Plasma cell granuloma lacks the dense hyalinized collagen bands that are seen with the pulmonary hyalinizing granuloma.

To our knowledge, this patient represents the first reported pediatric case of PHG. The coexistence of PHG and RPF has been reported only three times, and in each patient the PHG developed several months prior to RPF [3]. RPF is a fibrosclerosing inflammatory process localized to the retroperitoneum. Though more common than PHG, it is also a rare disease. There have been only 35 reported patients younger than 18 years with RPF [6].

The etiologies of PHG and RPF are unknown, but it has been postulated that both represent either a hyperimmune response to infection, a manifestation of a specific underlying autoimmune disease, an isolated idiopathic autoimmune entity, an accompaniment to another fibrosclerosing disease, or an immune reaction associated with malignancy. Most often, however, RPF is idiopathic and isolated [6]. In half of the reported patients with PHG there has been associated exposure to Histoplasma or mycobacterium [4]. There was no evidence that our patient had been exposed to TB, Histoplasma, or any other fungal agent. Up to 60% of patients with PHG have had evidence of a specific underlying autoimmune disease [7], but our patient did not. In addition, our patient did not have any evidence of malignancy. The coexistence of PHG and RPF suggests that both represent versions of the same type of abnormal immune response but in different locations [3].

Chest radiography and CT of patients with PHG typically reveal nodules that range in size from 0.2 cm to 15 cm (mean 2 cm). The nodules have variably circumscribed borders and sometimes have an ill-defined cotton-ball-like appearance. Calcification and cavitation are sometimes noted [3, 4]. In one reported patient a gallium scan demonstrated increased uptake in two pulmonary nodules [8]. Our patient is the first in whom FDG-PET/CT has been used in the evaluation of PHG at diagnosis and after treatment. It helped to guide percutaneous biopsy, identifying markedly increased metabolic activity in an easily accessible lung lesion. FDG-PET has been shown to be of value in evaluating response of RPF to corticosteroid treatment [9]. In our case, a follow-up FDG-PET/CT
demonstrated a marked decrease in metabolic activity in both the RPF and pulmonary lesions after 6 weeks of treatment.

In summary, PHG is a rare fibrosclerosing inflammatory disease that should be included in the differential diagnosis of multiple pulmonary lesions, especially if there is calcification and/or cavitation present. Patients noted to have PHG should be evaluated for other inflammatory disorders, including RPF. Furthermore, when dealing with PHG, FDG-PET/CT might be useful in the selection of lesions suitable for percutaneous biopsy and to assess response to treatment.

References

Catheter-Based Drainage and Agitation for Definitive Cytological Diagnosis of a Ciliated Hepatic Foregut Cyst in a Child

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ABSTRACT

Ciliated hepatic foregut cyst (CHFC) is an uncommon lesion, which rarely presents in the pediatric population. It is congenital in origin and manifests because of the migration of a bronchiolar bud of the foregut through the pleuroperitoneal canal. CHFC is accompanied by a broad list of differential diagnoses and is difficult to diagnose by means of radiologic evaluation. Therefore, fine-needle aspiration with cytology has been used in an attempt to diagnose this lesion. In previously reported cases, this approach has been moderately successful in the diagnosis of CHFC, while in others, no definitive diagnosis was achieved because of the retrieval of scattered, irregular cells insufficient for cytologic evaluation. We report a case of a 16-year-old girl who presented with a CHFC and discuss a promising alternative for obtaining large, intact cellular specimens to facilitate cytologic evaluation and definitive diagnosis.

Key words: ciliated hepatic foregut cyst, chemical ablation, cytology, fine-needle aspiration, interventional radiology, percutaneous drainage

INTRODUCTION

Ciliated hepatic foregut cyst (CHFC) represents a rare hepatic developmental abnormality that is uncommon in the pediatric population [1]. CHFC is typically seen in adults but may present in childhood with abdominal pain, obstructive jaundice, or portal hypertension with associated splenomegaly; other patients are asymptomatic and lesions are found incidentally by CT, MRI, or ultrasound (US) [2,3]. The cyst is thought to arise from the migration of a bronchiolar bud of the foregut through the pleuroperitoneal canal. It is classified as a subcapsular cyst with a lining of ciliated pseudostratified columnar epithelium overlying connective tissue, a layer of smooth muscle bundles, and a fibrous capsule [4]. CHFC was first described by Freidrich in 1857, but the term “ciliated hepatic foregut cyst” was first used by Wheeler and Edmonson [5]. It is regarded as the only ciliated cyst known to occur within the liver [4]. CHFC, interestingly, is found in an identical location in almost all documented cases: subcapsular, anterior in a medial segment of the left lobe or adjacent right lobe, and beneath the attachment of the falciform ligament [5]. CHFC was originally regarded as a benign lesion but has since been reported in 3 cases to have undergone a malignant transformation to squamous cell carcinoma [6–8]. Definitive diagnosis of this cystic lesion is challenging utilizing MRI, CT, and US, so fine-needle aspiration is commonly employed for cytologic evaluation. Some authors have been successful in obtaining sufficient ciliated cellular material, either in clusters or scattered individual cells, to generate a definitive cytologic diagnosis, while others have retrieved scattered, irregular cells...
that were insufficient for the establishment of a definitive diagnosis [6,7,9,10]. We discuss an alternate method of obtaining intact cellular specimens in order to make a definitive diagnosis of this lesion, which involves catheter-based drainage and mechanical agitation for retrieval of cyst lining cells.

CASE REPORT
A 16-year-old girl was referred to our institution with abdominal pain and a history of anorexia. A CT scan of the abdomen was performed, which demonstrated a multilobular hepatic lesion. The mass was further evaluated with abdominal MRI, which defined a nonenhancing fluid-filled mass extending from the porta hepatitis into the anterior segment of the right lobe (Fig. 1). The patient underwent US-guided percutaneous placement of a 6-French pigtail catheter, with drainage of 42 mL of viscous, bilious fluid. With the catheter in place, the cyst was completely evacuated and defined with a contrast cystogram, demonstrating the unilocular, multilobular nature of the cyst. Following drainage, the cyst was filled with 10 mL of saline, and the pigtail catheter was rotated 20 revolutions to agitate the epithelial lining of the cyst as a means of obtaining a greater yield of cellular material from the cyst. Following aspiration of the agitated saline lavage, all of the aspirated material was sent for cytologic evaluation. The patient then underwent a 5-day regimen of sclerotherapy, with each session consisting of 2 washings (20 minutes each) of 98% ethanol. However, a 1-month follow-up US demonstrated persistence of the cyst, which had reformed to the original pretreatment size. Following the unsuccessful sclerotherapy attempt, the patient underwent laparotomy for resection of the lesion.

Pathology
Fluid from the initial aspiration and the subsequent flushes (uncentrifuged) was smeared on slides, which were air-dried and alcohol-fixed, with the remaining material submitted for cytospin preparation. Slides were initially stained with Wright Giemsa and hematoxylin and eosin. Despite the gross appearance of the initial aspiration material, smears and cytospins revealed only a dense population of pigmented macrophages in a background of degenerated acellular debris. Similar examination of the fluid retrieved following the catheter-based agitation demonstrated several individual and scattered clusters of columnar epithelial cells, some with noticeable cilia, along with pigmented macrophages. Goblet cells were not identified. Immunohistochemical stains, carcinoembryonic antigen, cytokeratin, and vimentin were then performed, allowing confirmation of the CHFC diagnosis (Fig. 2A,B). Mucicarmine, bile, and hemosiderin stains were negative. Neither hepatocytes nor significant inflammatory cells were seen. Histologic evaluation of the multilobular, unilocular, smooth-walled cyst (resected intact, 6 × 3.5 × 3.0 cm) confirmed the cytological diagnosis of CHFC, revealing pseudostratified columnar epithelium lining a cyst with a fibrous wall (Fig. 3A,B).

DISCUSSION
CHFC is a rare cystic mass of developmental origin. CHFC is most commonly found in older individuals with an average age of 50 years; the lesions range in size from 1–12 cm [11]. This case represents only the 4th reported case of CHFC in the pediatric age group [4,12,13]. The differential diagnoses that accompany the CHFC include cystadenoma, simple hepatic cyst, mesenchymal hamartoma, undifferentiated embryonal sarcoma, and echinococcal (hydatid) cyst. CHFC is a difficult entity to identify by diagnostic radiologic techniques because it is difficult to distinguish from a variety of other hepatic cysts, including malignant varieties [11,14]. Therefore, fine-needle
aspiration is commonly the diagnostic method of choice. However, definitive diagnosis by fine-needle aspiration is not always possible because of retrieval of insufficient cellular material [6,7]. Our case further confirms this point, with the lack of diagnostic cellular material in the original aspirate.

The catheter agitation and aspiration method we utilized provided sufficient cellular material for a battery of special stains, thus allowing for precise diagnosis. In the event of a small retrieval-fluid volume, concentration of the specimen prior to cytospin and/or cell block preparation may be required. Radiographic contrast injection and aspiration precede the catheter agitation and cell retrieval process and thus should not influence cell retrieval. The percutaneous placement of a pigtail catheter for management of hepatic cysts is appropriate for cysts that are either infected (abscess) or those to be treated with chemical ablation techniques. Catheter-based drainage and chemical ablation have been shown to be effective in various hepatic cysts as a less-invasive alternative to laparotomy and resection [15]. The technique of catheter agitation for retrieval of diagnostic cellular material may be performed with a pathologist in attendance to further expedite the differentiation of benign-versus-malignant lesions prior to attempting chemical ablation.

In conclusion, the technique of mechanical catheter agitation during cyst drainage shows promise as a means of increasing diagnostic consistency and certainty in aspirates retrieved from cystic masses.
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