Overview of Pediatric Interventional Radiology: Clinical Care

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Introduction

Interventional radiology techniques are increasingly being applied to children as pediatric interventional radiology (IR) services are being developed and expanded in institutions worldwide. The practice of interventional radiology (IR) within a pediatric setting shares many similarities to that in an adult practice but has some specific or unique differences [1–4]. This chapter outlines many practical considerations involved in a pediatric PIR service: the interventional suite itself, the delivery of a pediatric service and program, and the operation of a pediatric PIR clinic. The next chapter will outline various clinical aspects of care during the pre-, intra-, and post-procedure phases. Inevitably there will be some overlap between these chapters, but intentionally these will be kept to a minimum. Procedure-specific aspects of care will be addressed in each individual chapter. The examples included throughout both chapters are drawn from the authors' experience to highlight those points of difference from an adult practice and to provide examples of both common pediatric situations and uniquely pediatric clinical scenarios.

Evolution of Pediatric IR

From the outset, interventional radiology procedures have been performed in children, even during the early years of the field of IR. For instance, the first published paper on percutaneous nephrostomy included a case report of three patients, two of whom were children [5]. Just as the field of "adult" IR developed within diagnostic radiology departments, there was a parallel evolution within several pediatric radiology departments. Pioneering pediatric radiologists sought creative minimally invasive ways to resolve urgent clinical problems, leading to early PIR procedures [6, 7]. While many PIR procedures and devices are adapted from existing "adult" techniques, pediatric interventionalists are continually modifying them to suit the needs of children. In addition, many pediatric diseases and pathologies are distinctly different from those seen in adults, so for certain pediatric clinical situations, there is no suitable adult equivalent. The development of uniquely pediatric solutions or modifications has therefore been driven by clinical need (e.g., percutaneous cecostomy for children with spina bifida and fecal incontinence) [8, 9].

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M. Temple and F.E. Marshalleck (eds.), *Pediatric Interventional Radiology: Handbook of Vascular and Non-Vascular Interventions*, DOI 10.1007/978-1-4419-5856-3_1,

Originally practiced in only a handful of centers worldwide, pediatric PIR has steadily grown and is now widely—though not yet universally—available. While it is clearly a subspecialty of both pediatric diagnostic radiology and adult IR, pediatric IR is being increasingly recognized as a unique subspecialty with its own distinct opportunities and challenges. In 2007, the maturing field of PIR reached another formal milestone with the development of a new society, the Society of Pediatric Interventional Radiology (SPIR) [10].

As with any new business line (e.g., adult IR, "general" IR, or PIR), the building of a pediatric IR service requires dedicated equipment, personnel, space, resources, and a commitment on the part of the institution [2, 11, 12]. Without such resources, growth and development is extremely slow if not impossible. In addition to these physical components necessary for success, a pediatric PIR program must also assume a large element of clinical care into its practice in order to flourish and a willingness on the part of the interventionalist to be a clinician as outlined by Dotter in 1968. It is no longer adequate for an IR program—adult or pediatric—to limit itself to providing the technical aspects of care by performing its procedures in isolation [13]. Rather, there is an appropriate expectation that interventional radiologists, like other treating physicians, provide a clinical service beyond the procedural period itself. This represents a shift in focus and a new emphasis for IR practices over the last several decades, which is necessary for several reasons outlined below.

It is not medically acceptable to perform a requested procedure without ensuring that it is indicated, appropriate, and technically feasible and that its risks and benefits have been fully considered and explained to the patient. Although a referring provider may understand much of what is involved in an IR procedure, it is the IR physician who can best evaluate its applicability to a specific patient. He or she is also best qualified to evaluate the results of a procedure and to recognize the early signs of an unexpected outcome. In addition to improving the safety of procedural care, establishing IR as a consultative service rather than a technical one improves the overall medical experience for patients and their families. Better medical care is provided through longitudinal continuity of contact with the team before and after the procedure. Therefore, when assessing the requirements of a pediatric PIR service, one must include the clinical care component as a vital requirement and integral part of the program. A modern pediatric PIR service extends well beyond the procedure room to include ward rounds and an IR clinic. As a PIR service further develops into a more complete program, it includes other aspects of care such as audit, morbidity and mortality reviews, quality improvement programs, fellowship training, and education [14].

There is no one "right way" to create a pediatric PIR program. Each program will have a different style or character and will evolve to suit the environment and individual needs of the hospital and patient population it serves. Once established the pediatric interventional program must adapt and embrace change, so as to continue to survive and grow. Given the wide variety of local needs, regulations, referral patterns, and specialty services, there will necessarily be some diversity in application of the basic requirements, although the fundamental needs and structure of a clinical service do not vary. By learning from the successes of different approaches adopted, one can apply those successful features of other programs—adult or pediatric—that have applicability or are suitable to one's own environment.

Requirements for a Pediatric IR Service

Although many successful IR programs evolved from humble beginnings—using portable C-arms in operating room space, diagnostic fluoroscopy suites, or shared resources with cardiology and being staffed by physicians who worked primarily as diagnostic imagers or adult interventionalists—it is inappropriate in the modern era to contemplate starting a pediatric PIR program without dedicated resources. At a minimum, these include:

(a) IR suite – suitable procedure room(s)
(b) Equipment—appropriate imaging and procedural

(c) Personnel—physician, team, and support personnel
(d) IR clinic and longitudinal clinical care
(e) Building and growing an IR service—commitment from all stakeholders

At the other end of the spectrum, many already established IR programs are evolving with the creation of hybrid suites for combined procedures with other disciplines, e.g., surgery, cardiology, etc.

IR Suites

Room Features

The IR room(s) may be located within the diagnostic imaging department or the operating room or may be freestanding units in a separate space, depending on local factors such as available space and historic and political factors. Pediatric IR suites should be large enough to accommodate patient populations of all types, from the patient in the neonatal intensive care unit (NICU) in an incubator to the adult-sized teen in a large bed. In addition to fixed equipment (the angiographic unit, anesthesia logans, and machines), the rooms must also hold mobile equipment such as an ultrasound unit and accommodate any additional pieces of equipment that may be brought by other teams who may perform concurrent procedures in the IR suite (e.g., an endoscopy tower for combined biliary or urological interventions). Around all the fixed and mobile equipment, the IR rooms must have sufficient space for safe access to the patient by the IR team, anesthesiology, and visiting teams, which may be present. The rooms should have restricted or limited access to public traffic. Ideally, they should also meet the standards for strictly sterile procedures (e.g., for port insertions), including being compliant with the required number of air changes per hour (ACH) for operating room standards (e.g., ACH of 15/h). Of course, they must be lead lined to meet the radiation safety standards, dictated by the equipment housed in the room.

Equipment

Imaging Equipment

Ultrasound (US) plays a more significant role in pediatric PIR than it does in adult PIR. Given their lack of abdominal fat and smaller size, the neonate and child are ideally suited to the use of US for image guidance. US guidance is therefore used in many pediatric procedures, which in adults would be performed using CT guidance. Advantages of ultrasound include its inherent lack of ionizing radiation, its ability to provide real-time guidance (which increases speed), an enhanced visualization of vascular structures, and increased versatility. Therefore, the ultrasound machine itself is a major piece of equipment for pediatric PIR.

The US scanner used for pediatric PIR procedures should be a high-end machine with color Doppler capability and a wide variety of probes suitable for procedures on children of all sizes and ages (500 g neonate to >100 kg teenager). The US must be capable of providing adequate visualization of a wide range of structures, from the very superficial <1 mm vein being targeted for PICC placement in a baby to the small nodule deep in the liver of a large teenager being targeted for biopsy. It is therefore necessary that there be a wide range of probes available. Some of the most frequently used probes include:

(a) 15 MHz small "hockey stick"-type probe (e.g., for vascular access, joint and tendon injections)
(b) 8 MHz vector probe (e.g., for intercostal access/mediastinal approaches/pleural drainage, infant nephrostomy, liver and renal biopsies) [15]
(c) 5–7 Mhz curved probe (e.g., large patient organ biopsies, deep pelvic drainage)
(d) Endocavitary probe (e.g., transrectal) with a guide (e.g., for pelvic abscess drainage)
(e) 10–12 MHz linear probe (e.g., for neonatal percutaneous cholecystography, superficial pulmonary lung nodule localization and biopsy) [16, 17]

Newer equipment with sophisticated software that smoothes the ultrasound image for diagnostic purposes can, ironically, have a negative impact upon the visualization of needles used for intervention. The preset imaging parameters may therefore need to be adjusted to improve needle resolution for IR work. The capability of angled or steered beams with some of the newer technologies has the potential to overcome some of this limitation. Many US probes have attachable needle guides, the use of which can make a procedure faster and more accurate with less need for needle repositioning compared with freehand technique, depending on user experience and preference.

Many pediatric PIR services perform procedures at the bedside in the NICU or the pediatric intensive care unit (PICU). A portable US machine is invaluable for these procedures. Image quality is still of primary concern, but with improving resolution among the newer generation of small portable and even laptop-based machines, some of these devices are now adequate for the simpler type of bedside procedures. Having such a machine available (in addition to a dedicated unit in the IR suite) increases flexibility and efficiency in the IR schedule, as it can be taken to the floor without interfering with ongoing cases in the suite [18].

Endovascular ultrasound (IVUS) is a newer modality that has many potential applications for vascular diagnosis and intervention. It is a helpful adjunct in certain situations. Having such a machine available in the IR suite is ideal, but not an absolute necessity at this point in time [19, 20].

The X-ray equipment built into a pediatric IR suite should be chosen with pediatrics and radiation protection in mind (see Chap. 2). The imaging chain should be capable of low-dose fluoroscopy (e.g., 1, 3, 7 pulses/s and greater), last image hold, and electronic zoom. Many new units are capable of capturing fluoroscopy loops, which provide adequate resolution for the purpose of documentation in some situations (e.g., venous stenosis or collaterals during placement of a venous access device) but with significant radiation reduction as compared to traditional digital image acquisition. High-quality digital subtraction angiography (DSA) is necessary for evaluating large and small vessel diseases in children. Biplane imaging is very important in pediatric IR. In addition to its classic role in adults for neuroangiography and cardiac interventions, biplane is useful in a wide range of other pediatric procedures because the simultaneous acquisition of images in two planes reduces injected contrast volume and improves safety of accessing small organs (such as the stomach for G tube placement, infant kidneys for nephrostomy placement, or infant thecal sac for lumbar puncture).

The functionality and dose reduction features of X-ray equipment continue to evolve. Rotational angiography, virtual CT, and remote guides have become standard on new angiographic machines. The traditional image intensifier has been replaced with digital flat panel technology with associated benefits of dose reduction for children. However, it is important that the actual presets, parameters, and outputs of the equipment as suggested by the manufacturer are assessed and measured to ensure that the settings are optimized and tailored for children to achieve maximum dose savings with adequate image resolution [21]. Pediatric-specific protocols need to be developed for each institution. Easily accessible information is available for pediatric dose reduction in PIR, CT, and fluoroscopy at the Image Gently website, including the Step Lightly section (www.imagegently.org) [22].

Non-imaging Equipment

Each room should have adequate ambient lighting and more focused, directional task lighting at the procedure table for catheter and wire manipulation, suturing, and other technical aspects of work undertaken during a wide variety of procedures (e.g., subcuticular suturing for port insertion, mixing sclerosants or embolic agents, examining adequacy of a biopsy specimen). Each room should be equipped to provide general anesthesia to children of all ages. This includes having piped gases and suction, as well as physiological monitoring (ECG, O_2 saturation, capnography, and invasive venous or arterial pressures). An assorted range of BP cuffs appropriate for all ages is necessary for noninvasive blood pressure measuring in neonates, infants, children, and teenagers.

These physiological parameters need to be displayed in real time and visible by the operator, the anesthesia/sedation team, and others who may be involved in monitoring the patient. Ideally, the data would also be displayed on slave monitors in the control room to permit the team to step away during DSA acquisitions.

Temperature control is a very important topic in children, as their ability to control their own temperature is limited. Infants and young children can rapidly lose body heat and become profoundly hypothermic, which negatively impacts their ability to withstand stress and infection [18, 23, 24]. The temperature of most imaging rooms is designed to suit high-energy electronic equipment and the leaded, gowned operator and is thus lower than would be appropriate for pediatric applications. Temperature-preserving equipment is therefore vitally important. Devices include simple warm blankets, cloth head covers or bonnets, plastic covers for the intubated child, warm air blowers (e.g., Bair Hugger, Augustine Medical Inc., MN, USA), warm air mattresses, and chemical blankets for the very low birth weight <1.5 Kg [24]. Monitoring of the child's peripheral and/or core temperature should routinely be done for any child <1 year and for older children undergoing a procedure of any significant length. This can be done using the temperature probe on the anesthetic equipment for those under general anesthesia but must also be available independently for children having procedures under IR-administered sedation.

The room should be equipped with a variety of lead screens, above table for the head and neck region of the operators during hand injections, and lead screen skirts to protect the legs of those around the table. It is no longer adequate to have a table skirt just at the side of the table. Ideally leg protection for personnel at the top of the table is important, i.e., for the nurse or anesthesiologist who may be holding a child and for the operator standing at the head of the table, as more procedures are performed from a jugular approach. Transparent mobile lead screens are important for the anesthesiologist and other team members who may be required to stay in the room during imaging runs. A supply of personal protective devices should be available for the IR team and visitors to the suite, e.g., lead glasses (prescription, nonprescription, over personal glasses), lead gloves, and a variety of sizes of lead aprons with thyroid shields.

A fully equipped pediatric crash cart should be available nearby. It must contain a range of sizes and appropriate selection of oral airways, endotracheal tubes, masks for bag-mask ventilation, as well as resuscitation drugs with weight-based dose calculation tables. A defibrillator with both pediatric- and adult-sized paddles should also be available.

In addition to the above requirements, which are universal, there is an ever-increasing array of additional equipment that may be desirable. The specific needs of a facility will depend upon the types of cases being performed there. For example:

- Electrocautery equipment and required grounding pads are frequently part of the armamentarium of an IR suite that performs port insertions, other procedures that require a wide incision, or combined procedures with a surgical team.
- Image-guided percutaneous radiofrequency alblation (RFA) is the treatment of choice for osteoid osteomas; those facilities that perform this procedure or that use RFA to treat other tumors and lesions in other organs will require RF generators, probes, and grounding pads [25].
- Thrombolysis and thrombectomy are increasingly being used in the treatment of pediatric patients with arterial or venous occlusions. Mechanical thrombectomy procedures require dedicated catheters, pumps, and other devices [26].
- Interstitial or endovascular laser technology is finding a role in the management of vascular malformations, with a concomitant need for laser generators, optical fibers, and glasses and related protective gear [27]. Local regulations and requirements vary but the use of a laser will require compliance with all the training and safety requirements and usually the presence of a laser safety officer during the procedure.
- A variety of other devices, e.g., electric or battery-operated orthopedic drills, and a host

of other tools can be "owned" entirely by the IR suite or can be shared with other services [28]. However, in-servicing and training in the use of all auxiliary devices is necessary for the entire team, as there is potential for adverse events with any of them.

Finally, given the acuity of cases that frequently present to an IR lab, having in-room point-of-care testing capability for critical laboratory variables is highly desirable. Many test units are handheld devices that can provide a variety of results based on a tiny amount of blood (e.g., iStat, Abbott Laboratories, Abbott, IL). Different cartridges are available that will test for hemoglobin, electrolytes, glucose, blood gases, etc. These devices require regular supervision and calibration by the hospital laboratory. IR suites, which perform a significant number of cases with anticoagulation, may own or have access to an ACT machine to measure the patient's anticoagulation status.

Personnel

Personnel of the Pediatric IR Team

Making the commitment to provide IR services requires that the institution provide appropriate infrastructure and resources. A critical and difficult aspect of this obligation is recruiting and retaining the personnel who run the program. Since, as already described, IR has evolved into a broad clinical service, its staffing needs have expanded from the core team of nurse, technologist, and interventionalist to include midlevel practitioners, hospitalists, Child Life specialists, pediatric vascular access specialists, sedation specialists, administrative personnel, etc. [2, 3, 29].

The core team that actually performs IR procedures includes nurses, medical radiology technologists, interventional radiologists, and, in the pediatric environment, anesthesiologists. At some institutions, nurses and technologists rotate through IR from other modalities, thus providing a broad pool of individuals with various specialized expertise in other imaging modalities (e.g., CT). Other institutions utilize a team of nurses and technologists who are specifically assigned to IR. The latter fosters a cohesive team spirit and enhances the expertise and comfort level with procedures and devices that are unique to IR. There is no single credentialing process for nurses and technologists who wish to become members of the pediatric PIR team. Most come with related prior experience, and they train on the job to acquire the unique set of skills needed. Ideally a nursing background might include experience in a high-acuity area, such as NICU or PICU, or emergency department (ER) nursing.

Like their nurse and technology colleagues, the physicians who enter the field of pediatric interventional radiology do so without a single specific credentialing pathway. Some do fellowships in diagnostic pediatric radiology, others in adult interventional radiology, and many have done both [30]. This varied training is often reflected in their subsequent practices, which may include both diagnostic and interventional radiology or a combination of adult and pediatric IR. These mixed interests and skill sets are actually quite beneficial during the building phase of a pediatric PIR program, when the case volume may initially be too low to support a dedicated pediatric interventionalist. Conversely, having some degree of cross coverage by primarily diagnostic pediatric radiologists or by adult IRs is very helpful in sharing otherwise onerous call coverage and has the added benefit of providing additional expertise and skills which might be difficult for a solo pediatric interventionalist to achieve in an isolated practice [30].

It is clearly understood that children undergoing painful or unfamiliar procedures may be frightened and unable to cooperate fully. Therefore, providing conscious sedation, such as in a child undergoing PICC placement, or, more often, deep sedation or general anesthesia is an indispensable component of a pediatric IR practice. The specific process for delivery of sedation will vary by institution, with some using nurse-administered sedation under IR supervision, others using OR-based anesthesiologists, and still others using ICU, ER, or roving sedation teams [30, 31]. Irrespective of the approach used, it is imperative that those administering sedation have the knowledge, skill, and judgment to do so safely and that they be

capable of managing the pediatric patient who experiences respiratory compromise or other complications of sedation. Usually this requires PALS certification. The topic of sedation is dealt with in detail in another chapter (Chap. 3).

Other important team members are the Child Life specialists who provide unique service to the pediatric patient during procedures using a variety of distraction techniques [32]. They provide the child with coping mechanisms that empower them and maximize their ability to cooperate, thereby reducing the need for sedation. These individuals can make the difference between success and failure during an interventional procedure. Furthermore, by improving the quality of a patient's experience during a given procedure, the participation of a Child Life specialist can significantly reduce the fears of children who must undergo subsequent repeat procedures.

The longitudinal clinical work required outside the IR suite may be performed primarily by a member of the core IR team (interventionalist, IR fellow, or IR nurse) or by an additional IR staff person such as nurse practitioner. Having an individual dedicated to clinical management allows that effort to occur in parallel with the procedural work, thereby reducing disruptions to the daily schedule. In many cases, the salary of this person can be paid through the billable work that he or she provides. Patients who are admitted to the hospital for observation or recovery after a procedure are, in many institutions, managed by the IR service alone, while in others they are admitted to a hospitalist service with the IR team following. Each facility needs to arrive at a system that best suits its patient population and procedure mix. Irrespective of the approach adopted, the inclusion of adequate staff, time, and resources to provide longitudinal clinical participation and ward rounds into the IR practice is now a standard of care requirement [2, 3].

Other important but commonly overlooked members of the IR team are the staff who schedule cases and those who maintain and turn over the procedure rooms. The daily schedule in an IR suite is usually a fluid one, with frequent adjustments being necessary to accommodate urgent procedures. In most active centers, such "add-on" cases constitute more than half of a day's workload. It is imperative that the individuals who manage this schedule have a good understanding of the procedures being requested and maintain close communication with the operating team. Similarly, those who turn over a room between procedures—quickly cleaning and restocking it—are integral to the overall efficiency of the practice. The competency and skill level of these team members are crucial to the efficiency of the IR service. As respected and integral members of the team, these individuals have a role that can be rewarding and fulfilling, with opportunities to interact with patients and their families.

Despite all the different roles described above, it is critical for patient safety and quality of care that the successful IR team function as a unit [33]. Different tasks are suited to different unique professional roles, but the highest quality care can only be achieved through mutual respect and a shared ownership of the overall effort by all team members.

Pediatric IR Clinic and Longitudinal Care

Members of the IR team are the group of healthcare professionals most knowledgeable about the risks and complications of their procedures. The IR team therefore must play a pivotal role in the periprocedural care of its patients. It is the IR service that should determine and organize the necessary preprocedure investigations tailored to the planned IR procedure (e.g., blood work, imaging, anesthesia consults, etc.). Similarly, it is the IR team which should directly manage or, at the very least, actively follow its patients post procedure to ensure that complications are recognized and appropriately addressed. This activity does not have to be done in isolation, but may be done in conjunction with a hospitalist or specialty services as needed [1, 33]. Although initially daunting for many interventional radiologists, assuming this broad clinical role can be assimilated gradually, over time becoming the routine way of practice. Just as embracing the philosophy of ward rounds pre and post procedure was a change for many proceduralists, so too the development of a clinic-based practice, providing longitudinal and

excellent patient care, is a natural evolution. The development of a pediatric PIR clinic is a natural outgrowth of this endeavor [34–36].

While a few simple image-guided procedures can be scheduled and performed without consultation by the IR service (e.g., cecostomy (C), gastrostomy (G), gastrojejunostomy (GJ) tube checks and changes), most require some level of IR evaluation prior to treatment. At one end of this consultation continuum is brief assessment by the extended IR team if available, such as a member of a vascular access service prior to venous access device placement or removal, or by an enterostomy team or IR nurse for G tube assessment. More complex patients may require physician consultation with the referring requesting service and include a ward visit or a mapping ultrasound pre procedure, prior to booking (e.g., fluoroscopy and ultrasound mapping to assess technical feasibility of a G tube placement in an infant with complex abdominal anatomy). Still more complex patients—especially outpatients—require a full and detailed IR evaluation. Procedures carrying material risk, those in which the IR procedure is the major therapy responsible for an admission, high-risk procedures, and low-risk procedures on high-risk patients should be preceded by a visit to the IR clinic.

During the IR clinic visit, the interventionalist obtains a detailed history and physical assessment, discusses with the family the alternatives for treatment, explains the intended procedure, creates a management plan, organizes further consultations or preprocedure investigations that may be required, and obtains informed consent. If appropriate, the interventionalist might also use the clinic visit to perform some of his/her own imaging to assist in planning. For instance, if the planned procedure is an ultrasound-guided biopsy, he or she may use office-based ultrasound to assess the acoustic window, judge the safety of access (presence of overlying vessels and adjacent critical structures), and determine the ease or difficulty of the intended procedure [3].

The IR clinic visit also provides an opportunity to ensure that all procedures planned under the same general anesthetic/sedation episode are coordinated. This "one-stop shopping" concept is very important in pediatrics, where numerous unrelated procedures may be planned for the same anesthetic event in an effort to reduce the total number of such events. Although this can be logistically challenging for the various services that may be involved, parents and children appreciate the efforts of health-care professionals to coordinate all of the involved teams and their necessary equipment. Timing of the separate procedures during a "one-stop shopping" visit, or sequencing of events in a combined procedure, must be thought through to ensure one procedure does not negatively impact the ability to perform another. IR can lead this initiative and invite the other specialties to perform their procedure in their IR suites. IR can advocate for the patient and be a catalyst for change in the delivery of pediatric care. In addition to the safety aspect of minimizing the episodes of anesthesia for a child, this can also minimize parent or guardian time lost from work and patient time lost from school. One factor that impacts the success of pediatric medical care is the impact on and support for the family. For this reason, consideration of family issues, as in the philosophy of "family-centered care," is very important as it has been shown to improve clinical success of pediatric interventions as well as family and staff satisfaction [37].

In addition to facilitating the coordination of clinical issues, a preprocedure clinic visit has other benefits. It offers the patient and family a valuable opportunity to meet members of the team, thereby creating a physician–patient relationship without the stress that exists on the day of a procedure, and allows time for the family to assimilate all the information provided. Furthermore, the clinic setting conforms to the expectation that patients have of meeting their physicians in an office setting. This is how they interact with other clinical specialties, and it should also be the norm for IR. Thus, as the pediatric IR clinic becomes established in a program, it becomes the gateway for most patients into the IR system [2].

The IR clinic also plays a valuable long-term role as the setting for follow-up after procedures (e.g., RFA of osteoid osteomas). During these visits, the IR team is able to assess for complications or

problems (e.g., reassessment of a pseudoaneurysm post thrombin injection) and to discuss and arrange subsequent procedures that might be required (e.g., further interventions for a vascular malformation). Follow-up clinic visits also provide a forum for further education and may thereby prevent future problems (e.g., management of a new C tube so as to prevent tube, site, or bowel problems). Often they can be linked to imaging studies to assess the status of a device (e.g., biliary or ureteric drains, follow-up and evaluation of an abscess with a persistent fistula), thereby keeping the number of repeat hospital visits minimum. This provides assurance for families that they are not abandoned by the system but have ongoing resources available to them.

The specific needs of each IR clinic will vary with the volume of the IR practice, the nature and type of its cases, and the clinical setting of the institution. However, for a pediatric PIR clinic, sufficient space must be available to accommodate the family (usually at least the patient and two parents), a child's stroller or wheelchair, and the toys and distraction tools necessary to occupy a child. Some advocate that IR clinics should be physically located with other outpatient clinics, sharing common space with other specialties. The advantage of such a configuration is that IR is then viewed by peers and patients' families as a full clinical service on par with other specialties. A very different option is to create clinic space within or adjacent to the IR suite itself. This proximity allows clinic visits to be integrated with the IR procedure schedule and seamlessly provide any imaging that may be required. Yet another arrangement is to establish multidisciplinary clinics targeting specific pathologies (e.g., combined IR–plastic surgery clinic for vascular malformations). Such clinics facilitate complex treatment planning and reduce the time burden on patients and families. Ultimately, the physical arrangement chosen is of less importance than is creation of the IR clinic itself, no matter how simple or humble its beginnings.

The time allocated to IR clinic activities will depend on the nature of the practice and the availability of physician extenders. Clinic activities need to be incorporated into the physician schedule to ensure there is sufficient time for both new patient consults and return visits. Published figures from adult IR and general pediatric clinics suggest time allocations of 60 and 15–30 min, respectively, for these appointments [2, 38].

Documenting the clinic visit is of critical importance. It creates a record of the IR team's assessment of the clinical situation, outlines the rationale for a treatment plan, and may be indispensible in communicating that information to other providers and to the patient's insurance company. Radiologists are accustomed to dictating radiology reports and to the use of radiology information systems and PACS, but they are not generally familiar with direct medical correspondence. Yet while detailed radiology reports are invaluable in documenting a procedure and may reveal some clinical involvement, a personal letter written to a referring physician, outlining the patient's IR clinic visit and the resulting management plan, is an extremely powerful tool [2, 3]. A letter is recommended over a radiology report for clarity and quality of care and for marketing and communication with other medical colleagues and referring physicians.

IR Clinic Coordinator

While the final decision-maker in treatment planning for patients in the IR clinic may be a physician, the person responsible for day-to-day operation of the clinic and the main point of contact for patients and their families is more likely to be a nurse or midlevel provider. The role of a pediatric PIR clinic coordinator is a valuable and rewarding one and can be tailored to the specific IR clinic population. The IR clinic coordinator is involved at all stages of interaction with the patient, pre, peri, and post procedure. He/she plays an important role in taking the history, performing the physical assessment, and organizing any relevant investigations prior to the procedure. During a visit, it is often the coordinator who explains any planned procedure, in terms the child can understand, and allays as much anxiety as possible. He or she can give a virtual tour of the procedure suite through pictures or computer images, so the child understands what to expect.

The coordinator/nurse can discuss coping strategies and pain medications beforehand (e.g., Child Life, distraction techniques using videos, music, ipod, etc.). He/she also is an important contact for the patient after discharge should any need arise. Many clinics use these individuals to make post-procedure phone calls to enquire about patient progress following invasive procedures. In this way, any unexpected issues can be identified early and triaged for referral to the interventionalist as needed.

As the IR clinic evolves, the IR clinic coordinator has the opportunity to be involved with creating information pamphlets for patients and their families. Through firsthand experience, the coordinator knows the common concerns, the frequently asked questions, and the common pieces of advice that are required. Some may find it fulfilling and rewarding to create paper pamphlets or electronic web-based information tools for procedural information, preparation, consent, and informed discharge. Such patient guides provide the families with take-home documentation and ensures consistency of message between different practitioners.

Building and Growing an IR Service

Interventional radiology is unique as a medical specialty in that much of its contribution to an institution, through the minimally invasive approaches it employs, is in costs saved rather than charges generated. Reduced morbidity, shortened hospital stays, and decreased use of higher-cost procedures done in an operating room (OR), impact strongly on a balance sheet, but their specific dollar value is not readily quantified. Nor can one put an exact price upon the enhanced prestige that accrues to an institution when it offers truly comprehensive pediatric care and the greater willingness of outside referrers to send patients to such an institution. To be sure, elective outpatient procedures done by a pediatric PIR service can and do produce high-dollar billing opportunities that might not otherwise exist, but to focus solely upon those opportunities is to vastly undervalue the whole of the pediatric PIR service.

Considering these points, and also bearing in mind the relatively high capital costs of equipping a pediatric IR service, it is evident that having the support of administration is of vital importance. Building a good business case is essential, but beyond that the approach required to leverage support from administrative leaders will depend upon the individual institution and the health-care system of the country in question. While some administrators will recognize the larger picture that includes revenues generated and costs saved, others will not see beyond the business case, billing, and expected profit. Both groups may be concerned about the issue of turf conflicts with other specialties (e.g., vascular surgery), with other disciplines, and even with the IRs' own diagnostic colleagues. For those reasons, a newly proposed IR service is far more likely to meet with administrative approval if it targets a need unmet by existing competitors than if it seeks to share an existing patient population. It may be necessary to begin with a smaller and narrower focus than one hopes to achieve in the longer term. Are patients going to the OR for open biopsies? If so, propose a CT- or ultrasound-guided biopsy alternative. Are they being sent to another facility for embolization of vascular malformations or for RFA of liver masses? If so, start there. Even the most limited patient group can, over time, form a strong foundation from which the value of the service becomes evident and the case for expansion can be made.

When starting a service or during times of growth, it also behooves the interventionalist(s) to have input from, and the support of, other members of the team, especially anesthesiology, nursing, and technology. These people should be actively involved in planning, design, choice of equipment, construction, and finally equipment installation. The planners should cultivate a good working relationship with medical engineering and plant and environmental services during any construction or renovation project. Time must be made in the day to attend frequent planning meetings. The representatives of the team must actively participate at the planning meetings to ensure their influence is felt. Infection control needs to be consulted for advice at various steps

along the way. Physical space for the suite should be fought for, and given the large numbers of health-care workers and sometimes different teams involved in combined procedures, as much space as possible should be acquired for the IR room(s).

Even if the physical space has already been allocated, developing an IR service requires hard work in a multipronged approach, at various levels. It requires active liaison with referring teams; willingness to assume the clinical roles and responsibilities, by paying due diligence for patient care pre, peri, and post procedure; collaborating with surgical and medical colleagues on difficult cases; attending radiology–clinical rounds; and an openness to considering new strategies for treatments. It also involves advocating for IR at hospital committee and administrative levels whenever the opportunity arises, as well as creating the opportunities for such interactions. All these measures assist in the move towards creating an effective service and, eventually, a fully operational clinical IR program.

A more developed pediatric PIR program likely will include various supportive networks or systems, which provide the infrastructure to run the program efficiently. These might include such things as a vascular access service (for triaging and troubleshooting vascular access issues), an enterostomy service (for triaging and troubleshooting G and gastrojejunostomy issues), a vascular malformation service (combined expertise with plastic surgery, dermatology, IR), a sedation service, dedicated IR morbidity and mortality reviews, IR educational/lecture series, IR fellowships, a quality improvement program or QI rounds including radiation protection, and research and development, to mention just a few [14, 39]. All these aspects will draw from different areas within the hospital and from different disciplines (e.g., dietitians, quality and risk, medical physics, etc.). In this way resources are shared and a growing IR service does not need to "reinvent the wheel" at every step. Growth and development can be achieved by continually striving for excellence in clinical care and new or better ways to do things.

Challenges

The challenges faced by IR will vary from center to center. Some of these are specific to an institution or region, but many are shared common issues. Examples include workforce shortages and the recruitment and retention of staff. A workforce survey of PIR published in 2007 demonstrated a high level of reported burnout due to call frequency, lack of department and institutional support, and severe difficulty in finding and recruiting qualified PIRs [30]. Others struggle with an institutional commitment that may vary from day to day, with change in leadership, budget constraints, and competing draws on resources. For others, it is the problem of finding the funding for optimum equipment, establishing admitting privileges, addressing turf issues, and sharing procedural space with other services that do similar procedures (e.g., general surgical service). Pediatric interventionalists face additional challenges that are unique to pediatrics, such as having reliable access to ancillary services, e.g., Child Life services and anesthesiology. Those who work in pediatric hospitals must also identify adult practitioners who are willing and able to take over the management of chronic patients (e.g., children with epidermolysis bullosa, C tubes, and vascular anomalies) once they have "graduated" or passed the upper age limit for the institution. Avoiding burnout is a common challenge as one struggles with any of these issues. Having a determined, respectful, consistent approach to these issues, with a clear business case delivered to the correct people at the relevant level, is critical for success.

Summary

Creation, development, or expansion of a pediatric IR service is a multifaceted challenge. The main driver or goal is the provision of high-quality patient care. This can evolve from simple beginnings and grow with time and considerable effort into a major program. Attention to equipment, space, and personnel is key. Creation of a committed and competent team is vital.

Acknowledgment of the clinical role in terms of preprocedure assessment and post-procedure follow-up is important. Support of the administration is crucial to ongoing growth and development. Willingness to adapt to change and embrace new challenges and opportunities is necessary for survival and to avoid stagnation.

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