Cambridge University Press
978-1-107-04262-9 - Pediatric Interventional Radiology
Edited by Richard Towbin and Kevin M. Baskin
Excerpt
More information

Chapter 1

Introduction

Richard Towbin, Kevin M. Baskin, David Aria and Robin Kaye

History

The subspecialty of interventional radiology has its roots in the late 1950s and early 1960s with the development of catheterization techniques for cardiovascular angiography. The following two decades resulted in a remarkable growth and development of both diagnostic radiologic techniques and biologically compatible materials. This evolution of equipment and methodology has played a major role in the development, acceptance, and utilization of interventional radiology.

Cross-sectional imaging with ultrasound (US), computed tomography (CT), and magnetic resonance imaging (MRI) has, in most instances, allowed the radiologist to accurately localize and describe a pathologic process anywhere in the body. More recently, the addition of positron emission tomography (PET) has allowed radiologists to observe the regional physiology of a lesion and help plan interventional procedures accordingly. Using these powerful imaging techniques, the interventionalist can plan the safest approach to the lesion and target the most active region while avoiding uninvolved structures.

The development of new devices, especially in small sizes, has led to an ever-increasing number of non-vascular and vascular interventional procedures in the pediatric population. The advances in materials were generally targeted for use in the adult population. However, it was not long until children were also benefiting as a result of the creativity of interventionalists working with all ages and sizes of pediatric patients. Over the last several years there has been a substantial increase in the number of interventionalists specifically trained to treat children as well as a rapid growth in the number of interventional procedures being performed.

Pediatric Interventional Radiology, ed. Richard Towbin and Kevin M. Baskin. Published by Cambridge University Press.

An overview of our practice growth over the last three decades defines the changes that have occurred in the field. In the late 1970s we began to make the transition in the name of the specialty from special procedures to interventional radiology. In the early years the practice consisted mainly of the "ographies" – diagnostic angiography, myelography, arthrography, etc. In this period a busy service might do 50 to 75 cases per year. The introduction of cross-sectional imaging with CT and US significantly propelled the field of pediatric interventional radiology forward.

The 1980s were a time of innovation and experimentation that resulted in a markedly expanded procedural menu. Many new image-guided procedures were introduced including aspiration and drainage of fluid collections, percutaneous biopsy, percutaneous feeding (nasojejunal tube insertion, percutaneous gastrostomy, percutaneous gastrojejunostomy), esophageal dilation, nephrostomy tube insertion, ureteral stent placement, Whitaker perfusion testing, and endopyelotomy, to name a few. Toward the end of the 1980s, procedural volumes had increased by more than five- to ten-fold, with the busiest services reaching a milestone of 1,000 procedures per year and rivaling the pediatric surgical services in both complexity and volume of procedures.

The period of the 1990s continued the trend of rapid growth but in a more sophisticated manner. The most substantial group of new procedures of this decade were in the area of venous access. During this period we learned and perfected the approaches to insertion of tunneled central lines, ports, and peripherally inserted central catheters (PICCs). New procedures of this era also centered around the biliary tree with a substantial volume of percutaneous transhepatic cholangiograms, biliary drainages and dilations, liver biopsies in patients with liver transplants, transjugular liver biopsy, hepatic chemoembolization, and an occasional pediatric transjugular intrahepatic portosystemic shunt (TIPS) or experimental liver cell transplant. Also, new vascular procedures such as arterial and venous thrombolysis and IVC filter placement were added to the emerging procedural menu. The interventional treatment of children with hemangiomas and vascular malformations began in earnest and quickly became a unique area of subspecialization for pediatric interventional radiologists. Additionally, musculoskeletal procedures such as bone and soft tissue biopsy, joint injections, and percutaneous excision of osteoid osteoma were becoming more frequent. By the end of this decade procedural volumes had again more than doubled.

This led into the new millennium. For the past 14 years the menu of new procedures has been growing; as the maturing caseload has increased so has the complexity and acuity of the patients. There are now a number of practices in North America with high (>70%) utilization rates in two, three, or more interventional suites. There has been a parallel shift toward greater clinical involvement in the patient's care and management both before and after procedures, with a greater interventional radiology presence at the bedside, in clinical conferences, and in specialty and multidisciplinary clinics. Perhaps one of the most encouraging elements of current pediatric interventional radiology practice is that it has achieved a seamless position alongside other procedure-based medical specialties. In reviewing the history of our specialty to date, we have come a long way from the days when we were defined by the "special procedures" we performed. It has been both a difficult and an immensely rewarding journey so far; fraught with political, clinical, and philosophical challenges, as well as the fulfillment of seeing so many children enjoy beneficial outcomes, especially those referred as poor medical and surgical risks. Today, our value exists in the body of technique, experience, judgment, and clinical acumen that defines the interventional practitioner, leading often to more frequent success and significantly fewer complications for the same procedure when performed by the interventional service than by any other. The future is certainly exciting and bright. New frontiers such as molecular medicine, cell- and gene-based therapies, and nanotechnology will change the nature of interventions and of medical care for the better and whatever happens, we are certain that pediatric interventional radiology will be in the center of it.

Overview

This text is designed to fulfill three overarching functions: guidance, advisory, and reference, and to integrate these three functions across the scope of practice of the pediatric interventional radiologist organized under the theme of a modular approach to procedure development. In terms of clinical and procedural guidance, each procedure is introduced with some context regarding its history and its differentiation over time from procedural alternatives. Since in the majority of cases an interventional procedure has been developed as an alternative to an open surgical procedure, relevant comparisons are presented that highlight both advantages and challenges relative to the surgical alternative. Next, clinical indications and contraindications are identified that will assist the reader in achieving the correct response at the right time in the right patient, as well as understanding conditions under which a given procedure should be altered, deferred, or avoided in order to optimize both safety and effectiveness. Although this text is focused on the practical rather than the academic, the authors have extensively reviewed the literature on each topic to assure that the advice we offer from our own experience is in line with best practices and peer-reviewed evidence where it is available and applicable to pediatric conditions.

Next, the technical aspects of each procedure are given. We have adopted a "cookbook" approach, listing the equipment and supplies we have found to be of practical value in daily use over an extensive and comprehensive experience. The intent is not to be prescriptive, exhaustive, or encyclopedic, but to provide a basic compendium that works. Individual practitioners will likely find local solutions that add value in their practice for their patients; this is characteristic of the inherent tendency to innovate that is a hallmark of interventional radiology in general and of pediatric interventions in particular. It has been our goal to provide a foundation with a proven record of success; a reliable starting place that can also serve as a point of departure as practitioners gain individual experience. Likewise, issues of patient preparation are reviewed for each procedure that focus the reader's attention especially on items that should be incorporated into effective planning. Such issues will include preprocedure imaging, laboratory analysis, prophylactic medications, necessary preparation of the operative site, positioning, comfort, protection (i.e., from cardiorespiratory compromise, hypothermia, nerve compression or stretching, hyper- or hypovolemia, etc.), and preprocedure consultation and discussion that will all contribute to a safer, more orderly, and more satisfying procedural event.

The heart of each section is the description of the "standard procedure." Again, this is meant to be practical but not prescriptive. The idea is that a practitioner with appropriate training in the fundamental techniques of interventional radiology and associated clinical care, and with suitable experience in the diagnosis, care, and treatment of pediatric disorders should be able to safely and effectively reproduce each of the procedures described in the "ordinary" case. We have attempted to apply the Pareto Principle (also known as the "80–20" rule) to help the reader focus attention on those elements of a procedure that really make a difference to the outcome.

Where we have used or have knowledge of common or particularly helpful alternative approaches to the standard procedure, these are presented as "technical variations." In some cases, these alternatives are simply another common approach to accomplish the same end (for example, transgluteal versus transrectal drainage of a pelvic abscess). One alternative may fit better with the practitioner's "comfort zone" than the other, or may provide a workable option when there is some impediment to the standard procedure. In other cases, the alternatives presented may allow the practitioner to select from a menu of relative advantages – where selection of a modality, use of ionizing radiation, patient position, or other factors may make one choice safer, better, faster, or less expensive than the other for a given patient on a given day. In some cases, such as aspiration and drainage procedures in the abdomen and pelvis, there are regional considerations that represent variations on a general theme, so that after a general description of the drainage procedure, only those elements that differentiate one variation from the other are necessary (e.g., drainage of a deep pelvic abscess versus drainage of a pancreatic pseudocyst, etc.).

The reader is then directed to "postprocedure and follow-up care" for issues in longitudinal care of the interventional patient. A number of procedures have an associated "technical problems and pitfalls" section intended to help prepare the reader to anticipate and recognize issues that can lead to a failed procedure or an adverse outcome, to prevent these where possible, and to respond to them systematically and effectively when they do occur. A "complications" section outlines those adverse events that may be expected over time when a volume of these procedures are performed, both from our own experience and a review of the literature. In many cases, there is insufficient data available regarding complication rates in pediatric patients. Here, we have tried to extrapolate reasonably from the literature in adult patients and from the limited information available in children in order to help pediatric practitioners communicate more realistically with patients, families, and colleagues, as well as offering general guidelines for the purposes of quality assurance and continuous process improvement.

In constructing each chapter, we have grouped procedures by anatomic location or organ system. Where overlaps occur, procedures had to be delegated to a single chapter to avoid redundancy, but these instances are noted in other related chapters to assist readers in finding information efficiently. Chapters build on the unifying modular procedure development theme (see next section), from procedures based primarily on target visualization and access to those that develop the access tract to those that modify completion elements. Numerous transitional elements (e.g., guide wire stabilization, simultaneous biplane techniques, non-linear and curvilinear pathway development, percutaneous reduction and internal fixation, methods of parent artery protection) are offered to the reader to illustrate solutions integral to the procedures with which they are associated, but also to provide an intellectual framework that encourages the reader to think in broad and abstract ways when trying to solve more complex clinical problems. These elements should support practitioners' own innovation as they seek solutions to problems beyond the scope of this text as well as those not yet imagined.

In this spirit, Chapter 2 focuses on venous access and acquired disorders of the central venous system. The emphasis is on optimizing both decision-making and technique to minimize opportunity for complication, and to develop high-value options for the management of common challenges. Chapter 3 provides a comprehensive view of thoracic procedures from the management of parapneumonic effusions, mediastinal collections, and pulmonary abscesses through intrathoracic biopsies to tracheobronchial stenting. Chapter 4 offers a tour de force of interventional diversity in the abdomen and pelvis. The gastrointestinal procedures, which, with central venous access, form the backbone of most pediatric interventional practices, are surveyed in detail, followed by application of drainage and biopsy procedures across the spectrum of abdominopelvic places and spaces. The chapter concludes with treatments of strictures and retrieval of foreign bodies in the hollow viscera. In contrast, Chapter 5 delves into the more high-end, high-risk procedures in the liver, gallbladder, and spleen that characterize treatment of liver transplant patients. Throughout this text, the reader familiar with adult interventional radiology will recognize that despite the different disease profile in children, the procedural armamentarium of the pediatric interventional radiologist is every bit as demanding and sophisticated and, perhaps, even more complex. Chapter 6 presents procedures in the genitourinary system, which are emblematic of the modular procedural development concept, from target visualization and access (e.g., renal biopsy, Whitaker perfusion test) to tract development (e.g., nephrostomy, percutaneous nephrolithotomy) to modification of completion elements (e.g., treatment of ureteral strictures, percutaneous endopyelotomy). Chapter 7 highlights interventional applications in the musculoskeletal system and soft tissues, an area where pediatric interventional radiologists have led their adult colleagues in innovation and integration of techniques from across other procedural specialties, largely owing to the historic nature of pediatric interventional radiology as a multimodality, multisystem specialty and to its early adoption of ultrasound as an especially potent and versatile guidance modality. The text concludes in Chapter 8, where classic angiography and endovascular procedures meet the pediatric subspecialty treatment of vascular malformations.

A modular approach to interventional radiology

Historically, interventional radiology (IR), like other subspecialties of radiology and other procedure-based specialties, developed episodically and empirically. New procedures, imaging technologies, and techniques originated and evolved based on a variety of needs and opportunities. For example, in the past a child with an osteoid osteoma was conventionally treated by open surgical resection of the tumor, using inexact image guidance with portable fluoroscopy or nuclear imaging. Disadvantages of this approach included frequent persistence or recurrence of the tumor, a high rate of postoperative morbidity, prolonged hospitalization, and high cost. Now, increasing use of percutaneous removal or ablation with CT guidance has improved outcomes and shortened treatment time while reducing morbidity and cost.

Over the past few years we have tried to think more systematically about how and why our interventional radiology practice has grown and developed new and more complex procedures. We have struggled to find a logical basis for our approach. Like Neo in *The Matrix*, who received this guidance from the boy bending spoons with his mind, *"Do not try to bend the spoon. That's impossible. Instead only try to realize the truth. . ."* we were struck by the need to simplify our approach to problem-solving but not to be confined to conventional approaches. As a result of this introspection we have come to better understand the underlying unifying and organizing process that initially was subliminal but now has become conscious.

We have come to recognize two central themes. First, new procedure development must be driven not by the tools and procedures with which we are familiar but by the problems that our patients need to have solved. This applies in practice what many experts have been advocating in theory; a learner-centered, problem-based approach to learning. The second, and perhaps more evolutionary, theme is that there is no simple continuum of expertise. Rather, we must be willing to use whatever tools are available to us regardless of the practice area in which they reside, or to create new tools when our current practice is insufficient to solve a problem. Sometimes we are forced to laboriously reason forward in step-by-step fashion, as novices often do, linking known facts in a line from problem to solution. This is an inherently laborious process because of the numerous possibilities that branch from each step, and the therefore relatively high likelihood of less effective choices that may crowd out or obscure the "best" choice or that may lead to a procedural dead-end.

When our deeper expertise permits, we may be able to more expeditiously create a solution in fewer steps using existing procedural elements through *backward reasoning*, working from the intended goal back along a chain of modular procedural elements that logically connect the end objective of the procedure to an achievable beginning. When gaps remain they may require innovation or invention to create a continuous linkage between elements and so achieve an effective solution. The smaller that the gaps can be made, the more easily they may be overcome. Recognizing the "modularity" of new procedure development frees us to attack new procedures by breaking them down into a series of smaller tasks that are less daunting, because most of the modular tasks are already familiar to us (although perhaps in other locations or applications).

The concept of a modular approach to pediatric IR is intended to present a "thought template" to be considered when trying to solve technical or intellectual problems. It is in no way intended to suggest that this is the best or only way to modify existing approaches or to create novel solutions. On the contrary, it is our hope that this will be used as a springboard to open up thinking and enhance creativity so that we may be able to consider unexplored opportunities and to merge what on the surface may seem to be disparate or contradictory methods, materials, techniques, and technology into new, minimally invasive diagnostic techniques and interventional therapies for the patients that we treat.

Core module

The core module can be defined in several ways. We can look at an individual technique such as image-guided needle placement or a whole procedure such as nephrostomy tube insertion as a basic unit. The core module should, however, be the most fundamental building block of the procedure being performed. For example, the retrograde gastrostomy procedure can be considered the core module for cecostomy insertion (Chapter 4). Some procedures may involve linkage of two or more core procedures, such as hemangioma (interstitial/venocapillary) sclerotherapy (Chapter 8), lymphocele (cystic) sclerotherapy (Chapter 4), and abscess drainage (Chapter 4), which when linked together provide the conceptual basis for sclerotherapy and partial gland ablation of ranula (Chapter 7).

Transitional module

A transitional module is one that facilitates completion of the procedure or development of a new procedure, but on its own does not complete the task. One of the most common modular techniques that fits this definition is insertion of a guide wire. The guide wire enables the use of dilators or the placement of sheaths and catheters, but on its own does not bring the procedure to an endpoint. Any device that fulfills the same function can be used in the same modular context, from the introducer catheter of an Amplatz® serial dilator (Figure 4.20) in the dilation of a nephrostomy tract for percutaneous nephrolithotomy (Chapter 6) to the Steinman pin (Figure 7.23b) for delivery of a compression screw for internal fixation of a fracture (Chapter 7). Another common transition module is tract development. Tract dilation with or without placement of a sheath is frequently done to develop and maintain a connection between the skin surface and target site. This subset of modular techniques and procedures is very important as it enables the development of more complex or layered procedures and unlocks the door to creative solutions to clinical problems.

Completion modules

Completion modules are the evolutionary components of the procedural groups. It is by combining and adding new modular subunits that new solutions and novel procedures are born. These modules may already be in your toolbox, reside in the toolbox of another subspecialty, or may need to be developed anew. When considering a new approach to a problem, the addition of a creative completion module is a perfect place to "think outside of the box." Novel combinations of materials, methods, and technologies are the raw materials that can lead to new and exciting outcomes.

Consider a few examples of successful new procedures using completion modules, which at the time might have seemed to be unusual or to merge discordant techniques and technologies, such as the use of a radio frequency probe through a guide needle to ablate tumors, or using endoscopes in collaboration with urologists to incise a stenotic ureteropelvic junction or to remove a stone. In the future the only limitation to replacing open surgery with minimally invasive techniques may be our imagination and ingenuity. There are certainly many resources and combinations that remain untried and in time many new materials and possibilities will be made available. However, the exciting prospect is that we all have the opportunity to discover new solutions.

Ultrasound-guided access

Image-guided needle placement is a fundamental core module, as it forms the basis for the majority of percutaneous image-guided procedures in pediatric IR. With the advent of cross-sectional imaging and improvements in instrumentation, many procedures previously performed under surgical control are now done more safely, effectively, and economically with minimally invasive techniques using image guidance. Real-time two-dimensional US has played a major role in this transition. Sonographic guidance of needle placement serves as a prototypical modular procedure, as it is useful for such a broad variety of applications in many organ systems. For this reason, its general elements are discussed here, rather than repeating the discussion in the majority of chapter sections that follow throughout this text.

Since US is portable and radiation free, it can be used at the bedside, in the emergency room, in the operating room, or in the interventional suite. In experienced hands, US guidance facilitates precision needle placement and is a useful initial modality in multimodality procedures; for example, in conjunction with fluoroscopy or CT when necessary. In inexperienced hands, US may increase the risk of adverse events over conventional non-image-guided alternatives when a poor understanding of the image volume leads the operator to violate vital structures and treat non-target tissues. The authors have borne witness to numerous examples over the years of iatrogenic injuries and catastrophic complications resulting from misuse of US guidance. Several are recounted within the remaining chapters of this text.

A preliminary scan should be performed to thoroughly evaluate the target lesion and plan the route. When choosing the needle entry site it is important to know the technique that will be used. In other words, the skin entry site will be different depending on whether a biopsy guide or freehand technique is being used. (A brief word here on the use of biopsy guides: many experienced interventionalists do not use them, others do. They should be considered a part of the armamentarium, with this caution: a needle guide will not keep the needle in plane and on-target in all circumstances, and the "needle guides" on the monitor are only a suggestion of where the needle is likely to go if it is not deflected.) The skin entry site will also be influenced by a choice to scan in the long or short axis. Once the entry site has been determined the skin is marked. The skin is then sterilely prepared and draped with the skin mark positioned appropriately in the field.

Before beginning the procedure it is helpful to position the US machine so that the monitor is as close as possible, and directly in the operator's line of sight (Figure 2.9). This will maximize hand–eye coordination and comfort. Always perform the procedure in the most physically comfortable position possible. Physical discomfort is both fatiguing and distracting and can significantly impair performance. We find that it is usually best to grasp the transducer in the non-dominant hand (when feasible), keeping the ulnar surface of this hand in contact with the patient when the transducer contacts the skin (Figure 1.1). This position will improve stability and reduce fatigue of the scanning hand.

Ideally, when scanning in long axis, the entire course of the needle, including its tip, and the target lesion should be seen in the imaging field throughout the procedure. A common source of difficulty in accomplishing this objective arises when the

Cambridge University Press
978-1-107-04262-9 - Pediatric Interventional Radiology
Edited by Richard Towbin and Kevin M. Baskin
Excerpt
More information

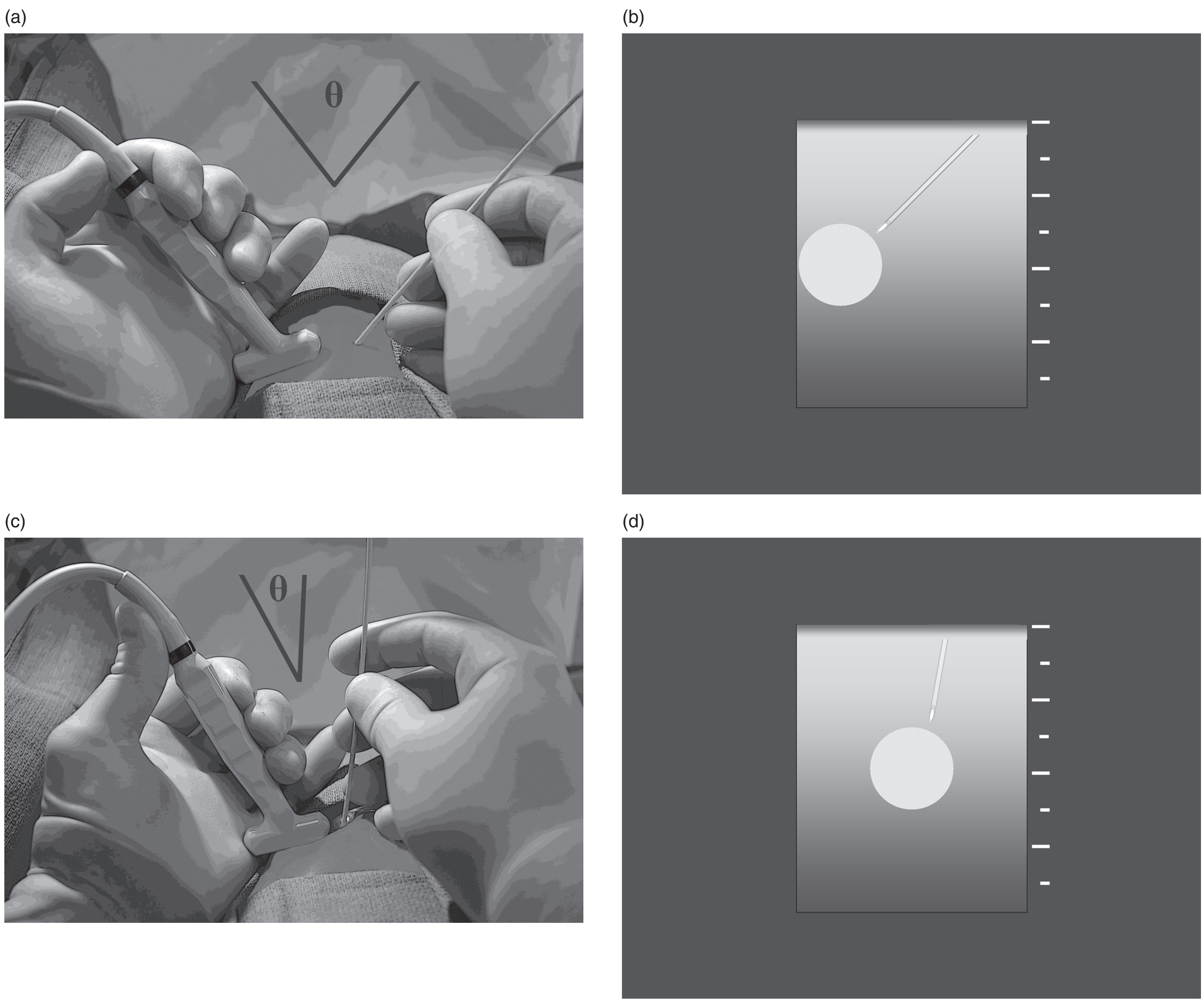

Figure 1.1 (a) Resting some part of each hand against the body surface reduces fatigue and unwanted motion during ultrasound-guided needle access. Obtaining a wide angle (Θ) between the ultrasound transducer and the needle, by entering the skin some distance apart from the transducer, will significantly improve conspicuity of the needle. (b) The wide angle between the needle and the transducer and eccentric location of the lesion within the imaging field allows earlier and more conspicuous visualization of the needle shaft and tip in plane with the target lesion, increasing the opportunity for a successful outcome. (c) A narrow angle (Θ) between the needle and transducer, often created by moving the needle too close to the transducer, may severely impair visualization. (d) With an acute angle between the needle and the transducer, and with the target centered in the imaging field, the needle is visualized poorly and over only a short part of its path. Partial visualization of the needle shaft, motion artifact, and less careful management of the tip location contribute to a higher likelihood of adverse outcomes. (e) When operating at a curved body surface, a needle entry point well away from the transducer allows an optimal (parallel) relationship between the needle and the transducer face. (f) Achieving the ideal parallel relationship between the transducer face and the needle shaft optimizes conspicuity of the needle, including the tip (due to "comet-tail" or "ring-down" artifact) and the entire length of the shaft (with "reverberation artifact"). Again, locating the target eccentrically in the imaging field allows visualization of the greatest possible length of the needle, including tip and shaft, in plane with the target lesion.

needle is located too close to the transducer, and at too acute an angle. Desirable specular reflections from the needle are maximized when the needle is parallel to the face of the transducer and perpendicular to the sound beam. This optimal geometry is difficult to accomplish in practice. Deviation of only 10 degrees from parallel with respect to the transducer face may be enough to impair visualization of the needle. This may require that the needle enter the skin 1–3 cm or more away from the edge of the transducer. Locate the target eccentrically or peripherally in the scanning field, so that the needle can be tracked throughout its entire course.

Although one may wish to scan periodically with color Doppler to identify and avoid vessels, it is best to turn color off or to narrow the color box to just show the relevant vascular structure at risk while advancing the needle in order to keep the screen refresh rate high enough to detect needle tip

(e) (f)

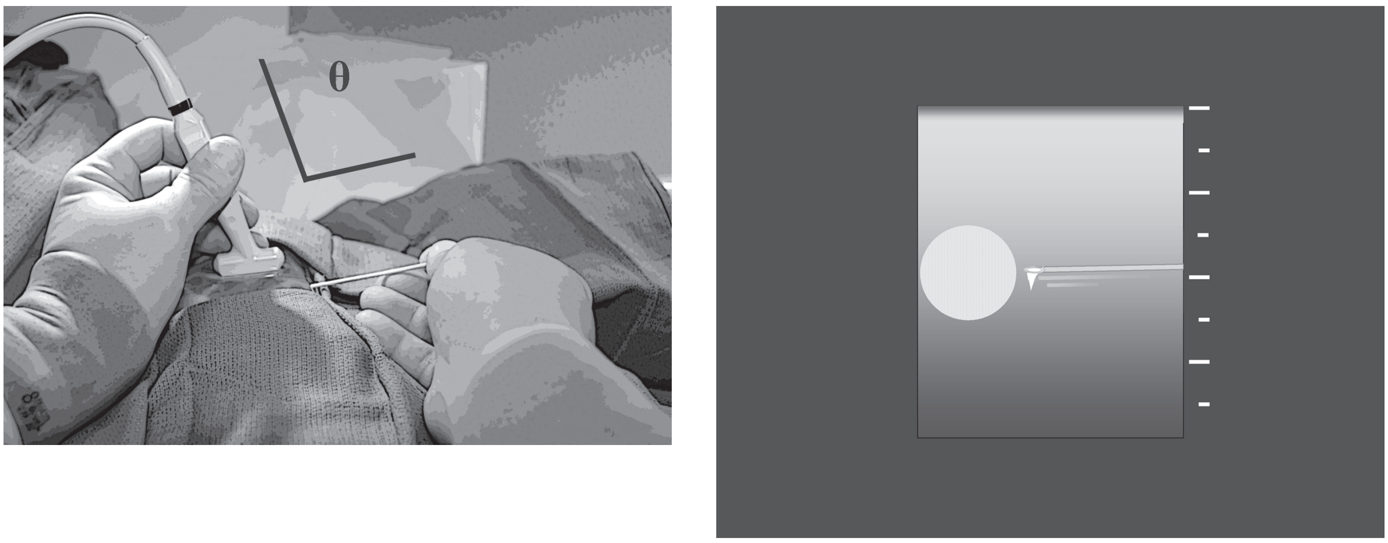

Figure 1.1 *(cont.)*

motion in a timely fashion (Figure 3.23f). Raise the focal zone toward the surface to visualize the needle entering the field. Advance slowly until the tip enters the target, moving the focal zone as necessary.

As much as possible, one should be able to visualize the needle shaft and tip in plane with the target. If at any time this is not what you see, stop. **Look at your hands!** (Unlike diagnostic US, the key to interventional US is relating physical space with the imaging space. Staring at the monitor while moving both the needle and the transducer is unlikely to accomplish this goal, while holding the transducer on target and *looking at* the relationship of the needle to the transducer may be the most efficient way to bring the needle tip and the target into simultaneous view.) With the transducer properly positioned adjust the angle of the needle until it is in plane with the sound beam (parallel to the long axis of the transducer face at its midpoint). If uncertainty persists after repeatedly trying to locate the needle tip, it may be better to withdraw and begin again.

If a lesion is located near a curved body surface (e.g., a focal renal lesion), it can be helpful to scan in long axis and position the long axis of the transducer and the needle entry site perpendicular to each other, ideally arranging the needle path as perpendicular to the sound beam as possible, even if this means that the needle enters the skin several centimeters from the transducer (Figure 1.1e,f). Such an arrangement can increase the conspicuity of the needle significantly.

Clinical practice development

Approach

There is no single right way to approach practice development. However, in over 30 years of being a pediatric interventionalist, my colleagues and I have found that certain approaches work better than others. Here are some of the lessons we have learned. There are three main keys to success: focusing on customer service, being willing to help without reservation, and being an expert.

If we look at critical aspects of the patient/family encounter we find it is important to develop a trusting relationship at the initial meeting. This is made easier when the practitioner presents a professional and positive attitude. Simple gestures that recognize the patient as a person are easy to overlook but have a profound effect on rapport. For example, we try to always introduce ourselves to the patient and the family. If the patient is old enough to understand what is going on, it is often good to talk first with the patient and address their concerns and questions and then talk with the parents. In all cases we give a sufficiently detailed outline of the procedure with a reasonable account of the alternatives, benefits, and risks so the patient and family can understand the implications and choices involved, and give an estimate of how long it will take so they can have realistic expectations about the scope and nature of the encounter. We let the patient and parents know what to expect after the procedure in terms of pain and any limitations that might be imposed, and when the patient will be able to eat again and return to baseline activities.

If there are delays before the procedure (for example, if prior cases are running longer than expected), our staff give a face-to-face explanation and update to help dissipate the heightened stress and frustration that can be magnified by uncertainty and a feeling of being “neglected.” During the procedure, especially if it is taking longer than predicted, it is very helpful to give the family updates. Finally, when the procedure is over it is important to give the family an overview of how the procedure went and to discuss any issues or problems. It is vital to developing an effective trust relationship that the patient and family are given ample time and encouragement to express concerns and to ask questions, from the initial consultation and consent discussion through to the recovery period and any follow-up visits. The referral service also needs to be informed, ideally personally via a phone call, of the outcome of the procedure and any issues or complications that may have arisen. The clinical team also needs to know what postprocedural needs the patient may have and what the plan for future follow-up or intervention may be.

The impact and importance of providing quality customer service is probably obvious to all of us, but somehow it is often difficult to accomplish. You certainly know good service when you see it! The essence of good customer service is to treat everyone – clinicians, patients, and families – as you would like to be treated. However, something crazy often happens when people become the service *provider* – they become less flexible, need to follow both real and imaginary rules, and come up with lots of excuses for not doing something. As one might guess, this approach does not usually get the customer response and positive feeling that is desired. Yet this is the "black hole" into which a service will inevitably be drawn without positive effort and energy. Avoiding this unfortunate state and making customer service a strong point of a practice are complex issues about which many books have been written.

In our experience, a simple and successful solution to this complex problem begins with the most effective, but at times painful, answer to the question, "Will you/can you do…?". Say: "Yes." When the conversation begins with "No" it is *very* difficult to walk away with a satisfied customer. Ironically, we have all had these experiences on call when prolonged contentious discussions ultimately result in the requested case being performed anyway, but with both parties feeling very stressed and dissatisfied. As someone who has been in that situation more than once (or even one thousand times), "No" is seldom the *right* answer even when it seems to be the *correct* answer.

Saying "Yes" instantly changes the tenor of the discussion and makes you an ally of the person seeking your help. Saying "Yes" does not mean that you will do anything and everything asked of you but it does indicate your willingness to meet the other party halfway and to enter into an open discussion that hopefully ends with a mutually satisfying plan to care for the *patient*, which obviously is the real priority. When a requester hears "No" they tend to feel polarized and threatened with an inability to find a solution to their problem; they may escalate rhetoric and tension in a bid to avoid being abandoned. When the requester hears "Yes" they can relax and better hear recommendations about alternative solutions. Thus, saying "Yes" even to a request for help with a hopeless problem or a clearly contraindicated procedure can provide the support and shared responsibility the requester may need to accept and act appropriately on a difficult or challenging reality.

The medical expert engenders confidence in others and is able to solve a wide range of problems. Other professionals will seek out the expert to get their opinions on subjects within the expert's scope of practice and will be open to the expert's advice. In order to gain expert status it is essential for the interventional radiologist to be current in the field, attend and, if possible, participate in local, regional, and national meetings, maintain high professional standards, and expect and strive for excellent outcomes.

Seek out mentors and advisors. Very few who perform pediatric interventional procedures have the luxury of multiple colleagues within the same practice, and every pediatric interventionalist, from the most experienced to the most recently trained, benefits from sharing ideas, concerns, and outcomes with others who have overlapping interest, experience, and scope of practice. Early in your career this is essential in order to form foundational technical skills and problem-solving approaches to a variety of cases. It is also important to maintain relationships with mentors and colleagues with whom you can discuss challenging cases and problems throughout your career because all of us are continually learning. When we exchange ideas we challenge what we think we know. The excellent practitioner can learn from everyone, including practitioners outside of our field.

The interventional radiology team

One of the major keys to developing a successful pediatric interventional practice is building a strong interventional team. A typical pediatric interventional team consists of interventionalists, interventional radiology technologists, and pediatric radiology nurses. Each member brings a skill set that is additive and helps provide the highest level of care. Substitution for or omission of any one of these individuals can significantly impair the team's effectiveness. The number of persons in each subgroup depends on many factors including the number of interventional suites that are in use per day, the number and type of cases performed, and the availability of adjunctive staff such as schedulers, aides, or others to answer phones and assist with other functions. With increasing volume, efficiencies improve significantly with at least two full-time equivalent pediatric interventionalists, nurses, and technologists.

The leader of the team is an interventional radiologist who is committed to the concept and ideal of pediatric interventional radiology. The team leader must have knowledge of pediatric conditions, diseases, and special needs, the technical training to deal with this diverse patient population, and the commitment to focus on the care of children. The pediatric interventional radiologist must also be able to develop a rapport with the pediatricians, pediatric surgeons, and pediatric subspecialists who will be referring patients to the interventional service. They must demonstrate a willingness to participate in a child's care regardless of the type of procedure or level of difficulty that is required. A willingness to live in the pediatric world, to be responsive to pediatric problems and an investment in the "art of the possible" characterizes the practice leader likely to achieve success. The practitioner who works at the end of an "umbilical cord" from another practice environment, who is willing to do only what must be done, and who conceives of pediatric interventions as an imposition on other priority commitments, is not likely to inspire the interventional team or potential referring clinicians.

The interventional technologist also has a complex and challenging job. Their skills and enthusiasm make them an indispensable member of the team. In many practices, the lead technologist is responsible for workflow management, as well as purchasing and inventory control. The technologists are responsible for setting up instrument and supply trays, anticipating the technical needs of the case, and safely and effectively setting up the equipment. On many occasions, a technologist will be the first assistant during a procedure. We always have a technologist, together with a nurse, circulate in the room to supply equipment and technical support as needed. Compared to technologists in the adult interventional environment, the pediatric interventional technologist is often significantly more integrally involved in the performance of the procedure, rather than simply managing the related imaging and documentation. At the completion of the procedure the technologist will complete paperwork and label and submit images to the picture archiving and communication system (PACS) for review and interpretation.

Pediatric interventional nurses are the third vital part of an effective IR team. The interventional nurse must have advanced skills in pediatric patient care, usually with critical care experience such as in the intensive care unit, transport team, or emergency department, with skills and experience in the evaluation, assessment, and care of children with a wide variety of illnesses, acuities, and developmental levels. Unfortunately, in some places this type of pediatric nurse is left off the team or substituted for with a nurse trained in other areas of pediatrics, which can leave a significant deficit in team composition.

When familiar with the procedures, the IR nurse adds to the breadth and complexity of procedures that may be performed on a sedated or anesthetized child. The nurse working in the IR suites will meet the family, ready the child for the procedure, and discuss nursing issues relating to the forthcoming procedure to be performed. If a procedure is performed with the patient under sedation the nurse is responsible for administering the medication and monitoring the child's vital signs. At the completion of the procedure, the nurse is responsible for coordinating the patient's recovery, either until discharge to home or until transfer to a recovery facility (i.e., pediatric anesthesia care unit or intensive care unit) or to an acute care unit. If the child is to be discharged home, written instructions are given to the family and questions are answered by the nurse. The day after the procedure nurses make follow-up phone calls to check on the patient and make sure all questions are answered. In addition to these duties, the interventional nurse is often involved with the team making hospital rounds and seeing children in IR clinic. And finally, in our practice, in addition to nursing duties during cases, the nurse is responsible for same-day patient scheduling and daily case management. On its best day and in all but the quietest practices, interventional radiology is a study in controlled chaos. With all these responsibilities it is important that the interventional nurse be well trained, flexible, friendly, and fast.

Some practices also incorporate mid-level providers (i.e., nurse practitioners or physician assistants) who act as physician extenders and work within the scope of practice of the supervising physician to perform procedures, provide patient histories and physical examinations, participate in clinic visits, consultations, ward rounds, and patient and provider education. They can become the face of the practice to the patient and provider community, tying loose ends, improving communication and accessibility, and freeing the interventional radiologist to focus on "big picture" elements essential to the long-term success of the practice.

Facilities, equipment, and supplies

Another key to having an effective pediatric IR service is having the correct equipment and supplies to do a wide variety of cases. In pediatric IR this means making sure that you have wires, catheters, drains, etc., to use on patients of all sizes. Especially in infants and small children you just cannot "make do" with adult-sized materials. This section is included for someone interested in building a pediatric IR lab from the ground up. It is not intended to be a fully comprehensive list of every single item or piece of equipment you will ultimately use, but rather it is a basic list of materials and equipment that will allow you to start a program and be able to perform a wide variety of basic cases as well as a few of the more complex cases you will be asked to perform.

Angiography suite

Because the conventional access point for many angiographically guided interventions is the adult groin, the location of central and auxiliary components of these angiographic units is oriented to serving the needs of the operator at this location. Pediatric interventions tend to differ in a major way – they are far more often conducted at a location closer to the X-ray generator and detector, the more so the smaller the patient. The head of an adult patient may be under the detector during a neurologic intervention while the operator stands comfortably at the groin, 2 to 3 feet (0.6 to 0.9 meters) away from the detector, looking directly at the monitor, hands easily at the controls. The whole body of a pediatric patient may be under the detector while the operator stands as close to the patient as the pedestal and foot controls will allow, struggling to see the patient in the dark shadows under the detector while craning around the C-arm to see monitors that may not orient easily for viewing from this position, and out of immediate reach of controls. The images generated under such conditions may not reflect these challenges, but the ease and speed of the procedure, the safety of the patient and staff, and the fatigue of the operator may well reflect them. These are all items that should be considered when evaluating potential equipment (and when preparing for a given procedure).

There are different philosophies regarding what the minimal needs of an IR section are. In our view, in order to be able to do the broadest menu of cases it is best to begin with a biplane angiography suite. On the other hand, having only a high-quality single plane suite takes very few procedures off the table. The equipment should have all the modern technology to be able to perform digital subtraction angiography at low dose and do suitable postprocessing of images. A small focal spot (≤0.4 mm) and pediatric-specific presets are central to achieving optimal image quality while conserving total delivered dose of radiation (see "Radiation dose management" below). Rotational angiography is great if affordable and the service is substantial enough in size and complexity to justify the expense. If a second room is needed single plane suites will usually suffice.

Ultrasound

The majority of cases will involve a combination of US for guidance of needle placement followed by fluoroscopic monitoring of the remainder of the procedure. We have found it preferable to have a dedicated diagnostic quality US machine equipped with a full range of transducer sizes, types, and frequencies. An absolute must is a linear high-frequency transducer with a small footprint, which in our practice is our workhorse probe, especially for venous access. More portable notebooks and limited, miniature US machines may have a limited role and can be adequate for less demanding applications but do not have the penetrating power that high-quality machines possess. Although the features of a high-end machine are only intermittently required, it is impossible to predict which cases will *not* require them, so the lower quality machines have not proved adequate for a full service IR department in our experience.

Miscellaneous equipment

The suite must have a high-quality power injector that can accurately inject small volumes of contrast. Ideally the injector is linked digitally to filming.

Safety devices such as Velcro® straps (or "seat belts" in pediatric parlance) that can be cut to desired lengths are a must in order to secure the patient on the table. Also, we often use an Octostop® cradle to secure small infants (<10 kg) and facilitate positioning. This can sometimes reduce the need for sedation and can shorten procedure time, especially for feeding tube insertion and other minor procedures. Other safety devices for positioning patients include arm boards, sponges, gel rolls, and bolsters all in a variety of shapes and sizes.

Warming devices are a must to keep small children warm and dry in order to maintain their body temperature. These can include warming lights, warming blankets, and chemical warming pads. We prefer warm blown air. We use a Bair Hugger® that comes with a variety of sizes and shapes of air blankets, which can be placed under or over the patient depending on the needs of the case. We also find having a blanket warmer in the suite indispensible for patient comfort at both the beginning and end of cases.

Pulse Doppler is a sensor that we place over the dorsalis pedis or posterior tibialis pulse so that we can monitor the distal pulse while compressing the arterial puncture site after catheter/sheath removal.

Catheters, wires, and things

A basic, limited set of catheters will accommodate the vast majority of intravascular procedures (Table 1.1). To the extent possible all catheters should be in 3, 4, and 5 French sizes. Specialty catheters may be in selected sizes for specific uses. The core guide wires are 0.018-inch and 0.035-inch although 0.038-inch can be substituted. The length of the wire is also relevant. The 0.018-inch wires are maintained in 65, 100, and 150 cm when available. Table 1.1 reflects a core stock that we have found covers most situations. Additional equipment and supplies will depend upon the local mix of cases and operator preferences. Procedure-specific equipment and supplies accompany each procedure set throughout the text.

Patient preparation and safety

General principles

Most cases are performed with US guidance with confirmatory fluoroscopy and less frequently with CT guidance. Ultrasound generally allows for shorter and safer procedures. The ability to have continuous needle visualization almost certainly results in greater accuracy in needle tip positioning and a lower incidence of untoward effects. Computed tomography guidance, because of its large radiation dose, is reserved for only those cases in which US guidance is not possible. The result of the improvement in techniques, image guidance for procedures and new and improved materials is an increasing total number of minimally invasive procedures, many of which are being performed safely and effectively on an outpatient basis, e.g., feeding procedures, biopsy, vascular access, angiography, sclerotherapy, arthrography, and lumbar punctures.

It is important that the IR suite is treated like an operating room and strict sterile technique and adherence to universal precautions is maintained. In our practice IR suite entry is restricted. All personnel entering the IR suite must wear hospital scrubs, surgical hats, and masks. Those performing the procedure, including the interventionalist and any assistants, must wear sterile gowns and gloves.

Patient preparation

Informed consent

For interventional procedures, informed consent is necessary prior to elective and urgent cases, and where possible for emergency cases as well. Policies regarding emergency procedures when consent cannot be obtained vary from hospital to