The "Cutting" Edge: A Modern Day's Look at the Procedural Physician

Mangaladevi Patil, BS; Alexandria Jo, MD; Shantanu Warhapande, BS; Gaurav Gadodia, BS; Sun H. Ahn MD

1Division of Interventional Radiology, Department of Diagnostic Imaging, Warren Alpert Medical School of Brown University, Providence, Rhode Island; 2Department of Radiology, University of Michigan; 3The Ohio State School of Medicine, Columbus, Ohio; 4Emory School of Medicine, Atlanta, Georgia

A 70-year old man is rushed to the emergency room after his wife finds him slumped over the dining room table. His exam reveals a left facial droop with significant left-sided hemiparesis. As early as 20 years ago, this man’s prognosis would have been devastating and grim.

A group of physicians gather around his CT scan images to discuss the treatment options available. The ER physician determines he is unable to treat the patient medically. The neurosurgeon recommends emergent intervention, however expresses his concerns about the patient’s fitness for surgery. The interventional radiologist (IR) suggests that she will be able to treat the patient most effectively with the fewest complications.

She expertly guides a specialized catheter from the patient’s right common femoral artery all the way through a clot that completely compromises a branch of the patient’s right middle cerebral artery. The IR physician is able to fully appreciate the dynamics of the occlusion in real-time and multiple angles, via x-ray fluoroscopy. As she lyses and retrieves the clot, she concurrently assesses the recovery of the patient’s motor strength, asking him to lift his left arm and leg. Within an hour, the patient has recovered a remarkable amount of his lost function.

Vascular Interventional Radiology is a novel breed of medicine on the frontier of procedure-based medicine. It offers alternative treatment options that combine the strengths of intervention and clinical medicine to provide the most effective and innovative patient-care.

HISTORICAL PERSPECTIVES

The field of radiology was born at the end of the 19th century when German physicist Wilhelm Roentgen1 photographed his wife’s hand using his newly discovered “Roentgen rays” – later renamed “x-rays”, the “x” representing the classic unknown variable from algebra. By the late 1920s, radiologists were using angiography to image vascular lumens and, subsequently, organ perfusion. While this formed a foundation for later endovascular interventions, both the imaging and the method of obtaining vascular access would acquire significant improvement during the progression to image-guided medicine.

Through the 1940s, angiographic imaging consisted of injecting a large bolus of contrast and capturing a single picture. A radiologist was forced to hope that the timing of the image was perfect1. It was not until the 50s that automatic cassette changers became available, allowing for multiple, serial images to be taken and thus, the flow of contrast to be captured.

Vascular access was obtained through surgical cutdown for the first half of the 20th century2. Due to the method’s invasiveness and
high rate of complications, angiography remained a sparingly used tool until 1953, when Dr. Seldinger of Sweden published his revolutionary technique of using a needle to pierce a vessel in order to introduce a guidewire, over which a catheter could be placed into the vascular lumen. The number of angiograms performed greatly increased with this safer method, and modified versions of his technique continue to be used by radiologists and interventionalists today.

With these advents, the stage was set for radiologist Dr. Charles Dotter of Oregon to propose the idea of using angiographic instruments as surgical tools at a seminal lecture in Czechoslovakia in 1963. Shortly thereafter, on January 16th, 1964, Dr. Dotter performed the first-ever angioplasty on an 82-year-old woman suffering from rest pain and toe gangrene due to superficial femoral artery (SFA) stenosis. Since the patient refused to undergo an amputation, Dr. Dotter attempted to dilate the artery with progressively larger catheters. Despite the skepticism of his surgical colleagues, the woman’s rest pain abated, and she was able to keep both of her feet until her death, two years later, from unrelated causes. Dr. Dotter continued to pioneer novel techniques and inventions in the emerging field. He was the first to use stents to keep angioplastic dilatations open. His groundbreaking work earned him a nomination for the Nobel Prize in Medicine in 1978, and made him the father of what we now call “Interventional Radiology” – a term coined by Dr. Alexander Margulis in 1967.

Though Dr. Dotter found reproducible success with his innovative operations, endovascular procedures were scarcely performed in the United States outside of Portland for many years. Most early adopters were in Germany, where names like Zeitzler and Portsmann quickly rose to prominence in the field. However, it was another German doctor working in Switzerland, cardiologist Andreas Gruentzig, who truly brought therapeutic endovascular procedures to new heights with the invention of balloon catheters in 1974. He performed the first coronary balloon angioplasty about two years later, spawning the field of interventional cardiology.

Between the successes abroad and advances made by Dotter and his students, interest in interventional radiology reignited in the United States and spurred the founding of the Society of Interventional Radiology in 1973. The recruitment of Gruentzig to Emory University in Atlanta and the invention of the balloon-expanding stent by Dr. Julio Palmaz in San Antonio in the 1980s solidified the young field as a fixture in the evolving landscape of medicine, both in the US and abroad.

Dr. Dotter’s dream to make interventional radiology a procedural specialty with a strong clinical foundation was officially recognized in 2012 when the American Board of Medical Specialties approved the establishment of a new Dual Primary Certificate in Interventional Radiology and Diagnostic Radiology, just the 37th primary certification created in the USA.

**CURRENT IR LANDSCAPE**

The current landscape of interventional radiology encompasses a vast array of procedures and organ systems. In this section we attempt to provide an overview of some of the emerging areas of innovation and patient care within IR.

**Endovascular Work**

Various venous pathologies can be treated via a catheter by an interventional radiologist. For example, an interventional radiologist is sometimes the best line of defense against a dreaded pulmonary embolism (PE). Pulmonary embolisms are unfortunately a common occurrence in cancer patients or in post-operative patients and occur when a clot forms in a deep vein of the leg. If this clot, called a deep venous thrombus (DVT), dislodges, it can travel...
up to the pulmonary artery and block deoxygenated blood from flowing into the lung. An interventional radiologist plays a vital role in the management of DVT’s and PE’s. First, they can solve the problem by destroying the venous clots through a technique called catheter-directed thrombolysis. In this procedure, a catheter is inserted into the culprit vein and clot-busting agents are injected directly onto the clot. If a PE does occur, IR can also use a catheter to ‘bust’ the clot or mechanically remove it from the pulmonary artery. Finally, some patients are unable to receive blood-thinning medications for various reasons. In these patients, IR specialists can deploy an inferior vena cava filter (IVCF) that acts as a barrier to any dislodged clot, preventing a PE.

IR is also heavily involved in arterial work. Again, the tool of choice for an IR specialist is the catheter. One additional tool that has proven extremely useful has been the stent. If a patient has a clotted artery anywhere in the body, an IR specialist can reopen this artery through an angioplasty. An angioplasty involves guiding a catheter to the site of the arterial obstruction and then deploying a stent that will reopen the artery. Angioplasties by an IR specialist are routinely done in an outpatient setting (arteries in the legs or carotid arteries) or in the emergency setting (mesenteric artery ischemia).

The basic strategy underlying any endovascular procedure involves gaining access to a vein or artery with a catheter (small, hollow tube) using ultrasound-guidance and then threading the catheter to where the problem is. The catheter is manipulated from the point of access to the point of interest using live x-ray guidance, called fluoroscopy. This is where a strong foundation in vascular radiology comes into play. Knowing which blood vessel is which, the possible anatomic variants, what a diseased vessel looks like as opposed to a normal vessel - comfort with these concepts can only be achieved with a strong radiology foundation. Indeed, IR specialists are some of the most well regarded experts in medicine as far vascular anatomy goes.

**Interventional Oncology**

In the past 15 years, there has been a growing subspecialty within IR: interventional oncology (IO). Interventional oncologists target tumors in a loco-regional manner and their armamentarium is growing every year. Currently, IO procedures include trans-arterial chemoembolization (TACE), trans-arterial radioembolization (TARE), cryoablation, and radiofrequency ablation.

Any tumor in the liver is going to hijack the hepatic arterial supply. Interventionalists can use this to their advantages by maneuvering an intra-arterial catheter into the artery supplying the tumor using fluoroscopic guidance and then injection nano-beads coated with chemotherapy. These chemo-embolic beads not only block off the artery feeding the tumor but also slowly leach off high-doses of chemotherapy that selectively go only to the tumor.

Interventional oncologists can also percutaneously "cook" a tumor using radiofrequency ablation (RFA). The RF probe is guided to the tumor by imaging guidance. Bone masses, lung masses, liver masses, and even pancreatic masses can be ablated using RFA. Clinical trials are being conducted nationwide to discovered new applications of RFA in oncology. Conversely, renal masses can be destroyed via freezing by cryoablation. In this procedure, the tumor is accessed percutaneously and the cryoprobe then freezes the adjacent tissue.

In addition to these therapeutic procedures, interventional radiologists also provide ancillary procedural support by conducting percutaneous image-guided biopsies, port placements for long-term chemotherapy, central venous access with a variety of catheters, and management of tumor-related
complications such re-opening obstructed bile ducts, arteries, veins.10, 11

Finally, IO has become involved in pain management, including palliative pain management for oncology patients. Pain procedures include neurolytic blocks to anesthetize nerves (and thus alleviate pain), joint injections, and kyphoplasties. A kyphoplasty is a therapeutic procedure for spinal fractures in which bone cement is injected into the vertebra to provide stability and return the fractured vertebra to a more normal position. Kyphoplasties can be used to treat vertebral fractures secondary to both osteoporosis as well as tumor metastases.

**Women's Health Procedures**

A growing branch of IR involves procedures related to women's health. Though there are other procedures and pathologies IR tackles in this realm, the most notable procedure is the uterine fibroid embolization (UFE). Fibroids are very prevalent amongst young women and up until very recently, the procedural treatment options were hysterectomies and myomectomies, both which are highly invasive, surgical procedures. Interventional Radiologists innovated UFE as an alternative therapeutic procedure that was minimally invasive and has since become a very popular option for the treatment of fibroids.12, 13

In a UFE, the operator first gains access to the arterial circulation via the femoral artery and then maneuvers the catheter to the pelvic vasculature. Contrast dye is then injected into the pelvic vasculature to delineate the vessels and identify the arteries feeding the uterus/fibroids. These vessels are then embolized. The clinical results are usually remarkable and the medical community has quickly embraced UFEs.

**Emergent Procedure**

An interventional radiologist serves a critical role in the trauma setting, on a transplant team, and on a surgical team.

In the past, a bleeding vessel anywhere in the body would require an open surgical procedure to stem the bleeding from the outside, an interventional radiologist can embolize (stop blood flow) to many bleeders from inside the vessel. In bleeder embolizations, the operator identifies the bleed by injecting contrast dye into the vasculature and finding the source of the bleed. A catheter is then brought as close the bleeding site as possible and embolization coils or beads are injected into the vessel to stop the bleed.14

IR also manages many post-surgical complications. Complications include narrowing of vessels (arteries, veins, bile duct), bleeding vessels, or abscess formations. Interventionalists can tackle each of these problems in a minimally invasive fashion.15

Finally, IR also plays a role in management of portal hypertension. If a patient needs immediate decompression of his portal venous system, an IR operator can place transjugular intrahepatic portosystemic shunt (TIPS). This procedure is life-saving and requires all of the interventional radiologist's skillset: procedural as well as imaging expertise.15

As is abundantly clear, interventional radiologists perform procedures on every organ system present. Brain, blood vessels, liver, kidneys, and GI tract: nearly every organ is within a catheter's reach for an interventional radiologist. With the innumerable procedures that already exist and with new ones being innovated regularly, it is no wonder that IR has become its own primary specialty.

**TRAINING IN IR**

The *DIRECT Pathway*, implemented by several institutions such as University of California, San Diego and Georgetown University, allow up to two years of clinical training at an ACGME approved program during PGY-1 and 2 to count toward the DR certificate and subspecialty VIR
This pathway required a special approval through the American Board of Radiology (ABR) which previously only permitted no more than one year of credit for non-radiology clinical training. The remaining radiology training will consist of 27 rotations of DR and 9 rotations in IR during PGY-5, instead of during PGY-6 as it is done in a traditional IR fellowship pathway.16 This model will be gradually phased out as programs transition into a more integrated curriculum, allowing residents to complete their clinical, research, and IR training spread throughout their six years of IR training.

The Clinical Pathway, implemented by institutions such as University of Virginia and University of Michigan, better exemplifies the new ACGME approved Integrated IR Residency pathway. The Clinical Pathway does not require a special approval by ABR since it fits within the approved curriculum requirements of a traditional radiology residency.16 Similar to the Traditional Pathway (1-year internship, 5-year DR residency, 1-year IR fellowship), a year of non-radiology clinical training at an ACGME approved program is required during the PGY-1. 7 rotations during PGY-2 to 6 will be dedicated to IR related research and clinical training (i.e. consult service for cardiology, nephrology, vascular surgery, oncology, hepatology, gastroenterology, or other non radiology clinical rotations). Of these 7 rotations, at least 3 rotations must be dedicated to research activities. Residents will be required to complete 32 rotations of DR training during their PGY-2 to 5. 9 rotations during PGY-5 will be dedicated to IR training, which consist of noninvasive peripheral vascular lab, MRA, CTA, neuroangiography, neurointerventions, cardiac MRI or IR. The last PGY-6 year will consist solely of IR fellow level training.19

As aforementioned, the Clinical Pathway will serve as the cornerstone of the new 2014 ACGME approved Integrated IR Residency pathway. The reader should note that the unofficial name, IR/DR Dual Certificate Pathway, might be often used synonymously with the IR Residency Pathway until the official name is popularized. The Integrated IR Residency curriculum must consist of five years (PGY-2 to 6) of DR and IR education, of which 36 rotations must be concentrated in DR. During PGY-2 to 4, three rotations must be in IR, and residents must fully participate in research, non-procedural patient care, clinical training similar to that of the Clinical Pathway. The final two years of the program should be focused primarily on IR training (i.e. procedural rotation, ICU, in-patient care, consult, and out-

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<tr>
<th>Direct Pathway</th>
<th>Clinical Pathway</th>
<th>Traditional Pathway</th>
<th>IR Residency</th>
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<tbody>
<tr>
<td>PGY-1</td>
<td>2 years of ACGME approved non-radiology clinical training</td>
<td>1 year of ACGME approved non-radiology clinical training</td>
<td></td>
</tr>
<tr>
<td>PGY-2</td>
<td>2 IR + 10 DR</td>
<td>3 IR + 3-4 Research + 29 DR</td>
<td>12 DR</td>
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<tr>
<td>PGY-3</td>
<td>3 IR + 9 DR</td>
<td></td>
<td>12 DR</td>
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<tr>
<td>PGY-4</td>
<td>4 IR + 8 DR</td>
<td>9 IR + 3 DR</td>
<td>12 DR</td>
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<tr>
<td>PGY-5</td>
<td>IR Fellowship</td>
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Figure 1. Table showing outline of different training pathways in IR. A single rotation block is 4 weeks in length.
patient clinic), during which DR education will be limited to only 3 rotations.\textsuperscript{20}

At the time this article is written, no Integrated IR Residency has yet been approved by the ACGME. Due to the lengthy process of application submission, processing, site visits, and evaluation, first approval is to occur in 2015-2016. It is anticipated that the approval process will be gradual for most programs and the nationwide adoption may take several years. ACGME will begin accepting applications for individual programs starting in 2015 and a small number of programs will most likely participate in the 2016 match. As new Integrated IR Residencies are approved, their status will be updated in the ACGME database found here: http://www.acgme.org/ads/Public/Programs/Search. Nationwide implementation of the Integrated IR Residency is projected to take full effect between 2015-2022.\textsuperscript{21}

In addition to the Integrated IR Residency, Independent IR Residency allows residents to enter IR after the completion of a five-year DR training. Instead of the traditional one-year IR fellowship, the Independent IR Residency will be a two-year program during PGY-6 and 7. The two years will include components of PGY-5 and 6 of the Integrated IR Residency such as procedural and patient care experience such as ICU, inpatient service, consult service and outpatient clinic.\textsuperscript{7} Early specialization in IR maybe offered at various DR institutions, preparing residents with sufficient IR training to qualify for advanced entry into the 2nd year of an Independent IR residency. ESIR will allow residents to complete 12 interventional radiology or interventional radiology-related rotations and at least 500 image-guided procedures within the domain of interventional radiology. The resident could then directly enter the second year of Independent IR Residency, only requiring one additional year of IR training.\textsuperscript{20,21}

The transition into the new ACGME approved IR Residency will be a gradual process and vary from institution to institution. During this monumental shift in the training paradigm, applicants will have several options which will include entering a Traditional Pathway with IR fellowships, entering a non-ACGME accredited DIRECT or Clinical Pathway that will eventually become an accredited IR Residency, transfer into an Integrated IR Residency during their DR residency, or apply to an Independent IR Residency after completion of their DR residency. For current applicants hoping to become a IR/DR Dual Certificate physician through an IR Residency, it is strongly recommended that they enter an institution with a strong IR department with plans to become an ACGME accredited IR Residency in the near future.

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**GETTING INVOLVED**

All students interested in learning more about IR can become members of the Society of Interventional Radiology (SIR). Membership is free for medical students and affords benefits such as registration for the annual SIR Scientific Meeting, access to the Journal of Vascular and Interventional Radiology (JVIR) and IR Quarterly, and various networking opportunities. The SIR Resident and Fellow Section (RFS) also provides multiple opportunities to learn more about the field and get involved. By visiting their website (rfs.sirweb.org), students can join a mailing list to receive updates and information about events such as webinars and local conferences. The RFS also has a Medical Student Council (MSC) with the specific aim of increasing knowledge of and participation in interventional radiology amongst medical students across the country. The MSC page on the RFS website offers a wealth of information about topics such as visiting IR rotations and residency programs strong in IR. The site also has an application for the MSC for those students who may want to get involved on a national level.
Another great way for students to get involved on a more local level is to join or start an IR interest group at their medical school. Interest groups host informational talks, educational lectures, provide mentors, research and shadowing opportunities, and student-run local conferences. The MSC webpage has a map and tables where students can find if a group already exists at their institution, and a roadmap on how to start an IR interest group if there is not one already present. There is also programming information for group leaders such as how to host a local conference and educational resources that can be disseminated to their members.

Finally, students can find opportunities for research, mentors to shadow, and short or long-term electives through their home department, their school’s interest group, or the SIR, RFS, or MSC.

REFERENCES