CME

Update on Interventional Neuroradiology

By Amon Y Liu, MD

Emergence of interventional neuroradiology has marked a transition from the radiologist's traditional role as a consultant: Interventional neuroradiologists serve not only as consultants but as clinicians who assume an active role and responsibility in treatment.

Introduction

Interventional neuroradiology—a relatively new medical subspecialty known also as endovascular neurosurgery—treats cerebrovascular, head and neck, and spinal disease by using minimally invasive techniques. Interventional neuroradiology was originally developed in the 1980s by neuroradiologists and neurosurgeons. Since that time, dramatic advances in interventional neuroradiology have been made possible by similarly rapid advances in medical technology, such as neuroimaging (particularly digital subtraction cerebral angiography and angiographic road-mapping), and development of revolutionary medical devices. Many medical conditions which could not be treated effectively 15 years ago can now be treated curatively using current endovascular techniques. Indeed, even within the field of interventional neuroradiology, new technology and devices introduced within the past five years have allowed interventional neuroradiologists to increase the number of life-threatening cerebrovascular diseases which can be treated effectively.

This article provides a brief overview of the historical basis for interventional neuroradiology, current treatment options for different types of cerebrovascular disease, and anticipated future developments in the field. This article also discusses current status and future plans for the Interventional Neuroradiology program at Kaiser Permanente (KP) Medical Center in Redwood City, California.

Historical Basis of Interventional Neuroradiology

Diagnostic Neuroradiology

Diagnostic neuroradiology is a subspecialty of radiology. The first report of cerebral angiography (visualization of the cerebral vascular anatomy) in a living human subject, in 1927,[1] described a small surgical incision made in the neck to puncture the common carotid artery, after which radiopaque contrast material was injected as a bolus for serial filming of the cerebral arteries and veins. In the ensuing decades, cerebral angiography advanced considerably in accuracy, efficacy, and safety. Direct surgical incision was replaced by percutaneous direct carotid puncture, a procedure which has subsequently been supplanted by percutaneous transfemoral catheterization (ie, insertion of a catheter through the common femoral artery after percutaneous needle puncture) and use of safer radiopaque contrast materials for cerebral angiography. In addition, modern mechanical devices for injecting contrast material, advent of digital subtraction angiography, new techniques for obtaining high-speed serial films, and manufacture of modern high-performance catheters also have contributed to the evolution of cerebral angiography as an imaging modality which is safe and effective when used by experienced operators.

Concurrent with these developments, noninvasive advanced technology such as ultrasound, computed tomography (CT), and magnetic resonance imaging (MRI) have sometimes allowed interventional neuroradiologists to make more accurate diagnoses and to plan endovascular interventions without making a skin incision to see inside the body. Further improvements in noninvasive imaging equipment and powerful computer processors have led to new techniques for visualizing the cerebral vasculature using CT or MRI. These techniques—computed tomographic angiography (CTA) and magnetic resonance angiography (MRA)—are now often used to screen patients for suspected cerebrovascular disease. These techniques reduce (but do not eliminate) the need for diagnostic cerebral angiography, which currently has greatest sensitivity for detecting subtle abnormalities or diseases of the small and distal cerebral vessels.

Interventional Neuroradiology

Interventional neuroradiology is a radiologic subspecialty which was introduced in the 1980s to help neuroradiologists and neurosurgeons to find effective techniques for treating patients for whom tradi-

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tional treatments (ie, open brain surgery) were neither possible nor feasible. Conditions precluding traditional treatment included giant cerebral aneurysm, surgically inaccessible aneurysm, large arteriovenous malformation, clinically significant medical comorbidity, or a combination of these conditions. Introduction of cerebral angiography provided an avenue for achieving more effective treatment for patients with these conditions.

Through the 1980s, neurointerventional techniques were considered largely experimental and were done only for patients who had no other treatment options. In the late 1980s and early 1990s, two key developments in angiographic equipment—digital subtraction angiography and roadmap fluoroscopic imaging—permitted dramatic growth of interventional neuroradiology. Digital subtraction angiography initially had resolution inferior to that of cut-film angiography but allowed more rapid decision making during angiographic procedures by eliminating the need for using time-consuming, conventional film processing after each angiographic injection of contrast material. Roadmap fluoroscopic imaging has allowed interventional neuroradiologists to obtain angiographic images of a blood vessel, lesion (eg, cerebral aneurysm), or both by injecting only a small amount of contrast medium and to maintain this angiographic image on the fluoroscopic monitor while superimposing live fluoroscopic (x-ray) images on the angiographic image. In essence, by giving interventional neuroradiologists a "roadmap" of the blood vessel and lesion, this imaging technique has enabled these specialists to treat the lesion. For example, a "roadmap" can be used to guide a catheter to the proper location within a blood vessel so that materials can be deployed to treat a cerebral aneurysm. The "roadmap" also enables interventional neuroradiologists to then inflate and deploy a balloon within the aneurysm to occlude it. Indeed, interventional neuroradiology would be impossible without the advent of roadmapping.

Equally important for advancement of interventional neuroradiology were the rapid technological improvements in each successive generation of medical devices and materials. In general, therapeutic procedures in interventional neuroradiology are done through a microcatheter measuring between .013 and .021 inches in diameter. The microcatheter is inserted coaxially through a larger catheter (the "guide" catheter, measuring approximately 2 mm in diameter) placed in the groin. Under fluoroscopic (x-ray) guidance, the microcatheter is threaded through the blood vessels leading into the brain. Depending on the disease process being treated, any of several devices or materials may be deployed or injected through the microcatheter.

Despite its strong roots in the field of radiology, interventional neuroradiology has evolved into a distinct medical discipline that combines elements of radiology and neurosurgery. Emergence of interventional neuroradiology has marked a transition from the radiologist's traditional role as a consultant: Interventional neuroradiologists serve not only as consultants but as clinicians who assume an active role and responsibility in treatment. As interventional neuroradiology continues to evolve, radiologists as well as a growing number of neurosurgeons have entered the field. The American Society of Interventional and Therapeutic Neuroradiology was formed in 1992 as the governing body for this multidisciplinary field.

Current Treatment Options in Interventional Neuroradiology

The minimally invasive procedures used by interventional neuroradiologists accomplish a wide variety of treatments (some of which are described in this article) designed to provide pain relief as well as to correct life-threatening conditions. Such conditions include aneurysm (treated by inserting platinum coils into the aneurysm bulge to promote clotting and to prevent rupture), abnormal, enlarged cerebral arteries (treated by injecting embolic material into a arteriovenous malformation to prevent life-threatening hemorrhage), and stroke (treated either by delivering "clot-busting" drugs directly to the site of blockage or by using microdevices specifically designed to retrieve clots). As alternatives to invasive surgery, these forms of therapy are often advantageous because they can lower the risk to patients, shorten hospital stays, and hasten recovery. Endovascular techniques also allow treatment of many lesions which could not be treated with open surgery.

Similarly, interventional neuroradiologists use endovascular and other percutaneous techniques to treat some types of head and neck disease (for example, embolic or sclerosing agents are injected to treat carotid

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blowout syndrome, epistaxis, and facial hemangioma) and some types of spinal disease (for example, a "glue" is injected to treat spinal arteriovenous malformation, or cement is injected into a fractured vertebra to treat pain caused by fracture).

Treatment of Cerebral Aneurysms

Initially, only aneurysms described as giant (> 2.5 cm) or otherwise inoperable were treated using endovascular techniques. These aneurysms were treated by inflating and detaching small silicone or latex balloons within the aneurysm in the hope that filling the aneurysm would prevent its rupture. Other aneurysms were treated, where possible, by using balloons to deliberately occlude the blood vessel both proximal and distal to the aneurysm.

The early 1990s brought a revolutionary advance to interventional neuroradiology: the Guglielmi Detachable Coil, GDC (Boston Scientific, Natick, MA). This device is an electrolytically detachable platinum coil which can be delivered into a cerebral aneurysm to promote clotting within the aneurysm. If satisfactory positioning of the coil cannot be achieved, it can be withdrawn through the microcatheter. Currently, interventional neuroradiologists planning treatment of aneurysms can choose from among several types of FDA-approved coils: bare platinum coils, 2- and 3-dimensional coils, aneurysm-conforming coils, bioactive coils, and hydrogel-coated coils. These coils differ from one another in performance characteristics, advantages, and disadvantages. When used in the appropriate setting, these newer-generation coils are expected to improve the stability of aneurysm coiling and thereby reduce the need for repeat embolization.

The International Subarachnoid Aneurysm Trial (ISAT)[2] was designed to compare the efficacy of aneurysm coiling versus open surgery in patients with ruptured aneurysms. In 2002, investigators showed that patients who were treated with coil embolization had improved outcomes compared with patients who received open surgery.[2]

The next revolutionary advance in endovascular treatment of cerebral aneurysms came in 2003 with the introduction of the first stent approved by the FDA for intracranial use. The Neuroform stent (Boston Scientific, Natick, MA) facilitates treatment of wide-necked cerebral aneurysms by bridging the neck of the aneurysm with a very thin meshwork which prevents coil loops from prolapsing into the parent vessel and thereby reduces the risk of a treatment-related stroke.

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Treatment of Cerebral Vasospasm

Interventional neuroradiologists are also frequently called upon to treat cerebral vasospasm, one of the devastating sequelae of aneurysmal subarachnoid hemorrhage. Endovascular treatment of vasospasm may include use of a microcatheter for intraarterial injection of vasodilating agents, or balloon angioplasty of the intracranial vessels.

Treatment of Cerebral Arteriovenous Malformations and Dural Arteriovenous Fistulae

These types of vascular malformations can often cause debilitating symptoms such as headaches or pulsatile tinnitus ("ringing or buzzing in the ears") and can cause life-threatening intracranial hemorrhage. Depending on the type of arteriovenous vascular malformation involved, interventional neuroradiologists can very effectively treat these lesions by injecting embolic agents such as polyvinyl alcohol (PVA) and n-butyl cyanoacrylate (colloquially known as "glue" and approved by the FDA in 2003) into arteries supplying the lesions. In August 2005, the FDA approved Onyx (Micro Therapeutics, Irvine, CA), a nonadhesive liquid embolic system composed of ethylvinyl alcohol dissolved in dimethyl sulfoxide, for preoperative and radiosurgical embolization of arteriovenous malformations. Other types of vascular malformation can be treated using platinum coils placed through a transvenous approach.

Treatment of Intracranial and Extracranial Atherosclerosis

Increasingly, interventional neuroradiologists are also treating these conditions by using endovascular techniques, such as balloon angioplasty, stenting, or both techniques. In patients who have symptomatic intracranial atherosclerosis and who have suboptimal results of medical management using antiplatelet agents or anticoagulants, stroke is highly likely to develop shortly after this medical treatment;[3,4] in such cases, use of intracranial angioplasty, stenting, or a combination of these techniques can make the disease less debilitating by improving cerebral perfusion, by reducing the risk of thrombotic/embolic events, or by both actions. The FDA has recently approved the first intracranial stent, the Wingspan (Boston Scientific, Natick, MA), for use in atherosclerotic disease, further raising the prospects for improved outcomes in affected patients. Stenting of the extracranial carotid and vertebral arteries has also advanced greatly. Carotid endarterectomy done by an experienced surgeon remains a highly effective method of treating symptomatic carotid stenosis, and most interventional neuroradiologists reserve stenting for patients who are poor candidates for carotid endarterectomy. (In these patients, the procedure is precluded by recurrent postendarterectomy stenosis, radiation-induced stenosis contralateral carotid occlusion, high-cervical stenosis, or clinically significant medical comorbidity). However, multicenter randomized clinical trials, such as the Carotid Revascularization Endarterectomy vs Stenting Trial (CREST),[5] are well underway to determine whether carotid stenting done by experienced operators is superior, equivalent, or inferior to endarterectomy for treating carotid stenosis. Early results of this study have been encouraging for stenting.

Vertebroplasty

In many cases, painful spinal compression fracture (osteoporotic or traumatic), isolated vertebral bone metastasis, and vertebral hemangioma can be treated effectively with vertebroplasty when the pain is not relieved by analgesic medications. In such cases, a large spinal needle is guided percutaneously into the fractured bone under x-ray guidance, and a bone cement mixture is then carefully injected into the bone to treat the fracture. In approximately 90% of appropriately selected patients, the pain is either partially or completely relieved after completion of this procedure.[6] Many patients who receive the procedure can safely eliminate or substantially reduce their use of pain medication.

Future Developments in Interventional Neuroradiology

The rapid pace of technological innovation in interventional neuroradiology makes this a very exciting field. Although we cannot precisely predict what new devices may become available in the next five years, we can certainly expect continued improvement in successive generations of the coils and stents used for treating aneurysms. The Onyx liquid embolic system (Micro Therapeutics, Irvine, CA) has also been used successfully in clinical trials to treat selected cerebral aneurysms,[7,8] and the manufacturer is expected to seek FDA approval for this indication within the next two to three years. This embolic material may ultimately be used in conjunction with coils or may in some cases replace use of coils for aneurysm treatment.

In August 2004, endovascular treatment of acute ischemic stroke was advanced substantially by FDA approval of the Merci Retriever device (Concentric Medical, Mountain View, CA). The device is designed to restore flow to the brain by retrieving embolic material (or blood clot) within an occluded cerebral vessel. Nonetheless, the device is only approximately 50% effective in appropriately selected patients.[9] Further improvement in this and other similar devices is anticipated.

Continuing improvement in imaging technology is also expected to enhance the capabilities of interventional neuroradiologists. Angiographic equipment improvements in image resolution, 3-D imaging, and imaging of soft tissue all will help interventional neuroradiologists to make more effective treatment decisions.

The Interventional Neuroradiology Program at the KP Redwood City Medical Center

The Interventional Neuroradiology program at the KP Redwood City Medical Center is led by Amon Y Liu, MD; Gwinette Cowan, RN (Manager, Interventional Services); and Beverly Land, RN (Interventional Neuroradiology Nurse Coordinator) and includes a team of six angiography technologists and five staff nurses. In September 2005, the team was joined by a second neurointerventionalist, Sean P Cullen, MD.

The goals of the Interventional Neuroradiology program at the KP Redwood City Medical Center are

- to extend the range of cerebrovascular and head and neck diseases that can be effectively treated;
- to improve rates of morbidity and mortality associated with treating cerebrovascular and head and neck disease; and
- to improve continuity of care and to reduce treatment delays in the KP Northern California Region.

As the regional service center for the neurosciences, the KP Redwood City Medical Center has been able to form this cohesive team, which uses a multidisciplinary approach to treating patients diagnosed with neurological disease. With regard to patients with cerebrovascular disease in particular, specialists in interventional neuroradiology, neurosurgery, and neurology-critical care work closely with each patient to determine the best course of treatment and management. At present, the Interventional Neuroradiology service can provide all FDA-approved treatments that do not require participation in clinical trials (except treatments for acute ischemic stroke, which are treated on a case-by-case basis). Participation in selected clinical trials is considered if a potential benefit to a patient can be established. The service expects to offer complete coverage for acute ischemic stroke upon certification by the American Stroke Association as a comprehensive stroke center. ❖

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Suggested Reading

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The Mysterious

The most beautiful thing we can experience is the mysterious.
It is the source of all true art and science.

—Albert Einstein, 1879-1955, physicist, 1921 Nobel Laureate in Physics