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During the last 20 years, techniques in interventional neuroradiology have evolved from procedures that were dangerous, often ineffective, and seldom used to those that are safe, effective, and used daily to treat hundreds of patients throughout the world. Improvements in imaging, catheters and other devices, pharmaceuticals, the understanding of cerebrovascular diseases, and establishment of formal training programs in interventional neuroradiology have all combined and converged to account for this progress. During the last 20 years, many of these advances have been described and illustrated in the pages of the *AJNR*.

Tools

Although the invention and development of CT and MR imaging revolutionized the diagnosis of central nervous system diseases, it was the invention and development of digital subtraction angiography (DSA) that provided the foundation on which the growth and development of interventional neuroradiology could be based. The first volume of the *AJNR* contained one article describing a prototype DSA device and, a second, regarding clinical experiences using intravenous digital video subtraction angiography for evaluation of the extracranial vasculature (1, 2). Six months later, in volume 2, a report described the use of this technique for imaging intracranial vasculature (3) and, within another year, Manelfe and colleagues (4) had accumulated experiences with intravenous video subtraction angiography in a series of 1000 patients. Only 3 years after its initial description, Sherry and colleagues (5) discussed the use of DSA as an aid for performance of therapeutic neuroradiologic procedures. The infancy and preteen years of the *AJNR* (1980–1989) included reports by Brant-Zawadzki comparing DSA obtained after the intra-arterial injection of contrast medium with film-screen angiography, by Hieshima documenting the utility of the technique as an intraoperative tool, and by Schumacher describing digital rotational radiography (6–8). It is no coincidence that, parallel with rapid dissemination and acceptance of DSA, there was a simultaneous increase in both the number and type of therapeutic interventional procedures reported in the *AJNR*.

The milieu created by the availability of DSA was a fertile one for the rapid evolution of interventional techniques. Prior to 1980, these procedures had almost entirely been limited to ones that were performed working through catheters placed in the extracranial vasculature—most procedures being variations on a theme where appropriate delivery of injected particulate material was governed solely by vascular geometry and blood flow. In a very real sense, the ‘‘toolbox’’ of the interventional neuroradiologist was almost empty. In this regard, the second issue of volume 1 of the *AJNR* is especially important because of the presence of back-to-back articles by Kerber (9) and Berenstein (10). Kerber describes catheterization of intracranial arteries achieved by using a novel, flow-directed balloon catheter, and Berenstein illustrates the use of a new liquid embolic agent. Although neither of these techniques proved to be of widespread utility, they clearly demonstrated the potential for improvement in the endovascular approach. (These two articles also mark the start of multiple future contributions by authors who, 20 years later, continue to be among the leaders in innovations that are advancing the capacity of interventional neuroradiology.) During the 5 years that followed, the interventionalist’s armamentarium expanded rapidly as Debrun (11) described use of a latex detachable balloon for the treatment of giant aneurysms, Mehringer (12), working with Heishema, reported use of a silicon detachable balloon for management of vascular trauma, and Tomsick (13) discussed use of both balloons and coils during performance of neurointerventional procedures. By 1987, Jungreis (14) showed that the sophistication of catheters and guidewires suitable for use in the intracranial vasculature had evolved to the extent that catheterization of intracranial arteries was no longer dependent upon the use of flow-directed catheters. By 1990, both over-the-wire and flow-directed catheters suitable for use in the intracranial circulation had become widely available. Investigators now began efforts to improve both the safety and the functionality of these new devices further (15–18). As these new access devices (catheters and guidewires) and therapeutic agents were described, soon there followed reports of their use in clinical practice.

Applications

In the early years of the *AJNR*, few therapeutic devices were designed specifically for use in the vasculature of the head and neck. Thus, many procedures required not only innovation but also modification of devices and techniques that were designed for other applications. Kerber’s report (19) of angioplasty of a proximal carotid stenosis during performance of an endarterectomy at the carotid bifurcation is a significant example of this aspect of early interventional procedures.

Between 1980 and 1985, Berenstein and a group from New York University (20) described treatment of carotid cavernous fistulas with detachable balloons and Fox and colleagues in London, Ontario (21), described improvement in neurologic function after the embolization of Rolandic arteriovenous malformations (AVMs) with 2-isobutylcyanoacrylate (IBC). These early articles were among the first that demonstrated, in a substantial number of patients, that there was clear clinical benefit to be derived from the endovascular approach. Another report, again generated from New York University (22), is important, because it not only represents an early attempt to define and describe techniques for embolization but also correlates radiologic, pathologic, and clinical results. During these early years, provocative descriptions of percutaneous transluminal angioplasty (PTA) in the brachiocephalic (23, 24), the external carotid artery (25), and the cavernous segment of the internal carotid artery (26) set the stage for future development of this technique.

After 1985, both the number and the sophistication of articles related to interventional techniques increased significantly. Small clinical series rather than isolated case reports became more common (ie, regarding PTA [27]; parent artery occlusion for the treatment of giant intracavernous carotid aneurysms [28]; and preoperative embolization of brain AVMs [29]). Hieshima (30) clearly illustrated the potential for endovascular treatment of saccular aneurysms by describing, in 1986, treatment of a carotid ophthalmic artery aneurysm performed using a detachable balloon placed within the aneurysm, which allowed preservation of the parent artery. During this period, Hieshima and his colleagues at UCSF (31), greatly advanced the understanding and scope of endovascular therapeutic procedures (ie, Higashida [32], PTA of the basilar artery; Halbach [33], techniques and indications for treatment of a variety of arteriovenous fistula). Before 1990, Theron (34) reported on attempts to use the endovascular approach to treat ischemic stroke by using intra-arterial administration of thrombolytic agents.

As the ‘‘Decade of the Brain’’ began in 1990, the ‘‘toolbox’’ of the neurointerventionalist was much fuller than it had been only 10 years earlier. Nevertheless, serious limitations persisted, especially in regard to the availability of therapeutic materials—the ability to access intracranial vessels had improved greatly, but the ability to intervene once at the disease site was still very restricted. Soon, availability of new over-the-wire catheters, reliable detachable and nondetachable balloons, and pushable platinum coils improved this situation. Now, for the first time, it appeared that the goal of applying endovascular techniques for the treatment of patients with saccular aneurysms was a realistic one. Reports using detachable balloons for treatment of aneurysms while preserving patency of the parent artery (35) and, of angioplasty of a stenotic middle cerebral artery (36), stimulated both physicians and industry to increase efforts for development of devices that were designed specifically for use in the vasculature of the brain. Between 1990 and 1993, articles describing treatment of AVFs (37, 38) and an acutely ruptured saccular aneurysm (39), by using pushable platinum coils, appeared in the *AJNR*. Although the use of pushable coils for the endosaccular treatment of aneurysms would be short-lived, these experiences were of great value as they stimulated further development of more ideal tools for aneurysm treatment. Pushable coils would prove to be of great utility in the treatment of a variety of other vascular diseases. Adding further to the armamentarium of the interventionalist during these early years of the Decade of the Brain were reports of a retrieval device designed specifically for use in small vessels (40, 41), a technique for percutaneous vertebroplasty (42), Doppler guidewire use for monitoring blood flow during endovascular procedures (43), and mechanical clot disruption and PTA as techniques in the treatment of acute ischemic stroke (44, 45). In 1994, an article from UCLA discussing the importance of aneurysm neck size in determining the outcome of treatment of saccular aneurysms with electrically detachable coils and a commentary regarding a Phase III trial testing the efficacy of intra-arterial thrombolytic administration for the treatment of acute ischemic stroke marks a time when, like the *AJNR*, interventional neuroradiology reached maturity (46, 47). Between 1995 and the present, interventional techniques have assumed a major role in the management of patients with cerebrovascular disease. Safety, precision, and effectiveness have all been improved. Analysis of large clinical series undergoing carotid test occlusion (48, 49), attempts to modify physiologic parameters during such testing (50), and the use of transcranial Doppler monitoring during carotid test occlusion (51) were all important in advancing understanding, safety, and utility of this technique. During these 5 years, there was also a large increase in the number of reports describing the use of PTA and stenting for neurovascular applications. Reports of performing PTA to open an occluded internal carotid artery (ICA) (52), the use of stents for treatment of pseuroaneurysms or dissections of the extracranial segments of the ICA or vertebral artery (53, 54), and the use of PTA plus stenting for treatment of intracranial carotid stenosis (55) all were significant. Recent description of a clinical series describing the use of PTA for treatment of symptomatic middle cerebral artery stenosis from Korea (56) and a report of a small clinical series with angiographic follow-up after intracranial PTA from Japan (57) have expanded the understanding of both the techniques and the indications for this procedure. Further maturation of the endovascular treatment of aneurysms is also evident in reports that appeared during this period. Techniques were described that expanded the number of aneurysms that could be managed using the endovascular approach (58, 59). Reports of pathologic changes in humans after treatment of aneurysms with the Guglielmi detachable coil (GDC) appeared (60, 61) along with analysis of factors predicting successful outcome after GDC treatment (62, 63) and a study of the cost effectiveness of this treatment (64).

These and other studies solidified the concept that the future of aneurysm therapy likely would be one that uses an endovascular approach (65). The use of endovascular techniques for the treatment of ischemic stroke continued to evolve, as evidenced by reports showing that complete vascular recanalization reduced the extent of tissue that progressed to infarction (66). Additional studies demonstrated that there was a pressing need to define and improve techniques for selection of patients who were suitable for this therapy (67, 68). The ''toolbox'' was expanded as fibered GDC coils were described (69), and early experiences with a novel rheolytic catheter were reported (70, 71). Reports of the use of MR angiography for studying patients who had undergone aneurysm treatment with GDC coils (72, 73) or as a tool for assessing patients suffering an acute ischemic stroke (74) are significant, as they mark what will almost surely become the widespread use of this technique by the endovascular therapist.

Laboratory Studies and Training

The *AJNR* has, since its inception, been a leading source for the dissemination of information gleaned from preclinical laboratory investigations. These studies have been critical both to furthering the understanding of basic mechanisms involved in cerebrovascular diseases and to developing and testing of devices that could be used for their treatment. In 1986, a report from Spiegal and colleagues (75) described experiments that led to techniques useful in adjusting the polymerization time of IBC. Pile-Spellman and colleagues (76) used experimental arteriovenous fistulas to describe the angiopathy that occurs under conditions of long-term increased flow and pressure. An experimental stroke model suitable for testing the effect of selective infusion of thrombolytic agents was described in 1988 (77), and the first attempt to develop the swine rete model as a tool for testing embolic agents was reported by Lee and colleagues (78) in 1989. Early in the Decade of the Brain, a series of articles described animal models and techniques that were useful either for understanding fundamental issues related to aneurysm hemodynamics or for testing devices that were intended for use in aneurysm therapy (79–84). During this same period, other investigators described and developed animal models that were useful for testing and developing stents and embolic materials (85–87). Together, these experimental studies resulted in a significant improvement in the understanding of the pathophysiology of aneurysms and vascular malformations. They were also of real value in guiding the evolution of the therapeutic tools that ultimately would be useful in clinical practice. Between 1995 and the present, animal models continue to be used for development of new techniques or for modification of stents, coils, and embolic materials (88–94). The potential for adding additional goods to the toolbox is indicated by reports describing a new concept for the endovascular treatment of aneurysms and the use of intravascular sonography as a means to obtain clear definition of aneurysm ostia (95, 96).

Many of the experimental models described in the preceding paragraphs have also been of utility in the training of physicians. The swine rete model, the experimental canine aneurysm model, and the swine arteriovenous fistula model are especially noteworthy in this regard. Clear evidence exists that experience improves outcome (97).

The Future

These and numerous other experiences have created a basis that now provides today's interventionalist with the capacity to work in an environment where real-time biplane acquisition of vascular images having submillimeter resolution is possible. Postprocessing capacities and appropriate workstations allow for three-dimensional reconstructions as well as other interactive capacities (eg, endovascular viewing). Using widely available tools, it is possible to perform catheterization on most vascular structures of the brain safely and quickly. Once at the site of an abnormality, many options exist for its correction. What will further improve this situation? In my opinion, the major factors that limit further expansion of the capacity to treat cerebrovascular disease by endovascular approach are: 1) the inability to clearly see at the site where an intervention is being performed; 2) the inability to monitor and control energy sources that might be delivered to abnormal tissue; and 3) the inability to monitor, in a precise way, changes in physiology that may be occurring as the result of an intervention. All of these may be removed if techniques are developed so that the endovascular therapist can work in an MR environment rather than in one that is dependent upon X-ray fluoroscopy and angiography. Using MR imaging, easily refreshable three-dimensional data sets of both parenchyma and vasculature, combined with endovascular imaging, should allow much improved visualization of the site of pathology as well as of the effect produced by an intervention. Temperature-sensitive imaging, in conjunction with interactive real-time MR images, offers the promise for monitoring and control during delivery of energy from a variety of sources (eg, sonography, radiofrequency, and laser). Diffusion and perfusion imaging provide an ideal method for identification of those patients with acute ischemia, who may benefit from local thrombolysis; these imaging sequences should also serve as tools to monitor the progress of such therapy. Available microelectronics embedded in catheters and guidewires that are made from appropriate materials can transform these devices from simple access products to ones that can be used for the detection of and perhaps even regulation of local changes in physiology. The *AJNR* will continue to be the primary medium through which these advances are reported. How great it would be to be just beginning a career in interventional neuroradiology!

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