# The Future of Interventional Radiology[1]

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Interventional procedures
Interventional procedures, technology
Interventional procedures, utilization
Radiology and radiologists, socioeconomic issues

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**Abbreviations:**
ACGME = Accreditation Council for Graduate Medical Education
AHC = academic health care center
MCO = managed health care organization
PTA = percutaneous transluminal angioplasty
RSNA = Radiological Society of North America
SCVIR = Society of Cardiovascular & Interventional Radiology

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Origins in imaging, procedural emphasis, and dependence on innovation characterize interventional radiology, which will continue as the field of image-guided minimally invasive therapies. A steady supply of innovators will be needed. Current workforce shortages demand that this problem be addressed and in an ongoing fashion. Interventional radiology's major identity problem will require multiple corrective measures, including a name change. Diagnostic radiologists must fully embrace the concept of the dedicated interventionalist. Interspecialty turf battles will continue, especially with cardiologists and vascular surgeons. To advance the discipline, interventional radiologists must remain involved in cutting-edge therapies such as endograft repair of aortic aneurysms and carotid stent placement. As the population ages, interventionalists will experience a shift toward a greater emphasis on cancer treatment. Political agendas and public pressure will improve access to care and result in managed health care reforms. Academic centers will continue to witness a decline in time and resources available to pursue academic missions. The public outcry for accountability will result in systems changes aimed at reducing errors and process changes in the way physicians are trained, certified, and monitored. Evidence-based medicine will be the watchword of this century. Interventional radiology will maintain its role through development of methods for delivery of genes, gene products, and drugs to specific target sites; control of angiogenesis and other biologic processes; and noninvasive image-guided delivery of various forms of energy for ablation.

It was a special honor to deliver the first Annual Oration of the millennium on "The Future of Interventional Radiology." I will review some of my deepest convictions about interventional radiology. Some of what I present will be unpopular, but I am too old for popularity contests and I am not running for public office, so I do not care.

Let us begin with what I consider to be the fundamental theme of interventional radiology. Interventional radiology is a discipline with a procedural foundation rooted in diagnostic imaging and dependent on innovation but with a clinical focus that demands our attention and deserves center stage in our practice. We really do possess a special blend of knowledge and expertise that, when applied skillfully and with care, can save and improve lives. We are fortunate to do every day exactly what we set out to do when we first chose a career in medicine. The fact that we use sophisticated imaging equipment, catheters, and devices to do it is a bonus. I hope we can remain so privileged.

My emphasis on clinical interventional radiology is, of course, not new. It was second nature to Charles Dotter, father of angioplasty and of interventional radiology, 36 years ago when he had his own angioplasty admitting service at Oregon Health Sciences University (Portland). We all remember him as a brilliant innovator, author of 300 publications, and Nobel prize nominee who, in the world's first angioplasty article (1), predicted most of what eventually came to pass in the field in the past 36 years (Fig 1). We are in awe of all this, but we should also acknowledge his vision of the interventionalist as a clinician. Here is a quote of his from the American College of Surgery meeting in 1968, 4 years after his original report on angioplasty: "If my fellow angiographers prove unwilling or unable to accept or secure for their patients the clinical responsibilities attendant on transluminal angioplasty, they will become high-priced plumbers facing forfeiture of territorial rights based solely on imaging equipment others can obtain and skill still others can learn."

What does any of this have to do with today's topic? Everything. You see, I am not going

to spend the remainder of my space presenting a series of images and predicting the obvious, that magnetic resonance (MR) angiography will replace catheter-based angiography in the imaging evaluation of vascular disease. Indeed, it is already doing so. I am not going to "wow" you with three-dimensional images and try to convince you how they will aid our interventions. Nor am I going to try to persuade you that computed tomography (CT) is the ideal modality for a variety of vascular conditions. Any number of readers could deliver a better presentation than I on the future of vascular imaging, and several have. I know that advances in vascular imaging are integral to our future. But rather than dwell on certainty, I will focus on matters most vital to the future of interventional radiology as a clinical discipline. Let us start with some perspective.

## PERSPECTIVES ON INTERVENTIONAL RADIOLOGY

In a recent issue of *The Journal of the American Medical Association,* Koplan and Fleming (2) of the Centers for Disease Control and Prevention wrote that a few major advances in the past century have extended life expectancy from 45 years to more than 75 years and have improved quality of life: *(a)* childhood immunizations, *(b)* antibiotics, *(c)* fortified foods, *(d)* clean water, and *(e)* knowledge and attitudes about healthy behaviors and safety. But they issued 10 challenges for the decades ahead, including the need to *(a)* institute a rational health care system, *(b)* eliminate health care disparities, *(c)* focus on children's emotional and intellectual development, *(d)* achieve a longer "healthspan" (not just lifespan), *(e)* integrate physical activity and healthy eating into our daily lives, *(f)* clean up and protect the environment, *(g)* prepare to respond to emerging infectious diseases, *(h)* recognize and address the contributions of mental health to overall health and well being, *(i)* reduce the toll of violence in society, and *(j)* use new scientific knowledge and technologic advances wisely.

By comparison, these imperatives seem to dwarf the field of interventional radiology. However, a closer look reveals that, although we are few in number, interventionalists play a major role in the treatment of cardiovascular diseases, cancer, liver disease, trauma, and other important killers in our society (3). Of the vascular disorders alone, Figure 2 shows some of the major conditions we diagnose and treat. Figure 3 lists some of the roles of interventional radiologists in the treatment of cancer, the nation's number two killer. Additional therapeutic roles for the interventionalist are evolving. I will come back to them later. For now, let us think of interventional radiology as a field of image-guided minimally invasive therapies that links the most invasive therapies of the past with the future era of prevention. I will also examine factors that will influence the future of interventional radiology.

**Dotter's Predictions in World's First PTA Paper**

- Balloon angioplasty
- Recanalization devices
- Outpatient PTA
- Cost savings relative to surgery
- Coronary, renal, carotid, vertebral PTA
- Endovascular "splints" (stents) that "reintimalize" (endothelialize)

**Figure 1.** Dotter's predictions in his 1964 article (1) on percutaneous transluminal angioplasty (PTA).

**Vascular Condition Diagnosed and Treated by IRs**

- Peripheral arterial diseases (PAD, PVD)
- Renovascular disease
- Extracranial cerebrovascular disease
- Venous thrombosis
- Pulmonary thromboembolic disease
- Trauma

**Figure 2.** Vascular conditions diagnosed and treated by interventional radiologists *(IRs). PAD* = peripheral arterial disease, *PVD* = peripheral vascular disease.

**Role of IRs in Cancer**

- Needle biopsy
- Subcutaneous port catheter placement
- Embolization
- Chemoembolization
- Ablation with RF, toxic injection
- Management of disease complications (eg, IVC filter placement

**Figure 3.** Roles of interventional radiologists *(IRs)* in the treatment of cancer. *IVC* = inferior vena cava, *RF* = radio frequency.

### Innovation

Our future depends on innovation, the heart of our discipline. Consider the clinical problems listed in Table 1, the surgical solutions to which have been completely or partially replaced by minimally invasive therapies. Given their breadth, it is no wonder that a decade ago, it was estimated in a *New York Times* article that 30% of what used to be accomplished with surgery is now accomplished less invasively with interventional radiologic methods. Moreover, since then, the percentage has increased. One could argue that interventional radiology is modern-day surgery. Today, image-guided interventions abound, and newer ones are evolving rapidly. Carotid artery stent placement as an alternative to endarterectomy is already a clinical reality (Fig 4). So is transluminal endograft placement in the treatment of aortic aneurysms (Fig 5). I will return to these later.

### The Future Innovators

Our future will depend on a steady supply of innovators. Researchers at academic health care centers (AHCs) will continue to collaborate with industry. Important sources of research funding, including the Cardiovascular and Interventional Radiology Research and Education Foundation, or CIRREF, which fulfilled its Interventional America 2000 campaign this year (4), and the Research & Education Foundation of the Radiological Society of North America (RSNA) will continue to provide young and established researchers with opportunities. The RSNA has generously funded cardiovascular and interventional research over the years. In 1999 alone, four of seven new RSNA Scholar awards went to individuals and projects with cardiovascular and interventional themes (5). But the face of research is changing, and, as new knowledge is derived increasingly at the molecular level, the types of scientists we must train will change (6). We also will need funded research-training centers. Funding from the National Institutes of Health (NIH) would be ideal, but, realistically, NIH funding of radiology research

**TABLE 1**
**Clinical Problems with Surgical Solutions Replaced by Minimally Invasive Solutions**

| Clinical Problem | Surgical Solution | Interventional Radiology Solution |
|---|---|---|
| Acute abdomen | Exploratory laparotomy | CT- and image-guided drainage |
| Hydro- and pyonephrosis | Surgical nephrostomy | Percutaneous nephrostomy |
| Nephrolithiasis | Surgical nephrolithotomy | Lithotripsy, percutaneous nephrostolithotomy |
| Malignant biliary obstruction | Surgical choledochoenterostomy | Percutaneous biliary drainage, stent placement |
| Undiagnosed tumor mass | Open surgical biopsy | Image-guided needle biopsy |
| Symptomatic peripheral arterial disease | Endarterectomy, bypass | PTA and stent placement |
| Upper gastrointestinal tract bleeding due to varices | Portocaval shunt creation | Transjugular intrahepatic portosystemic shunt creation |
| Ostial renal artery stenosis | Bypass, endarterectomy | Renal artery stent placement |
| Feeding problems | Surgical gastrostomy | Percutaneous (and endoscopic) gastrostomy |
| Peripheral or pulmonary arteriovenous malformations | Surgical resection | Embolization |
| Symptomatic uterine fibroleiomyoma | Hysterectomy, myomectomy | Embolization |
| Lower gastrointestinal tract bleeding (colonic) | Colon resection | Angiography, embolization |
| Subarachnoid hemorrhage due to aneurysm | Craniotomy, aneurysm clipping | Detachable coil embolization of aneurysm |
| Severe symptomatic coronary artery disease | Coronary artery bypass graft | Coronary PTA, coronary stent placement |

**a.** **b.**

**Figure 4.** Right-sided amaurosis fugax. **(a)** Right anterior oblique digital subtraction arteriogram of the right carotid artery bifurcation before intervention. Misregistered washer on the image at the angle of the mandible is an external calibration marker used in the measurement of the diameter and length of the diseased segment. Just anterior and superior to the washer is a severe right internal carotid artery stenosis (arrow) involving the bulb and proximal internal carotid artery. **(b)** Lateral digital subtraction arteriogram obtained after placement of a nitinol self-expanding stent (arrows).

to date, which has been through the Biomedical Imaging Program of National Cancer Institute (7), is barely 0.8% of the NIH budget (8). If the Academy of Radiology Research is successful, the establishment of a National Institute of Biomedical Imaging and Bioengineering could go a long way to help, and that might happen now that the U.S. House of Representatives version of the legislation has passed (9). We will see what happens in the Senate in the weeks ahead. (Note: Since the time of this Annual Oration, the Senate has passed the Establishment Act, and President Clinton signed it into law.)

## Training and Certification of Practitioners in Interventional Radiology

Our future also depends on an adequate workforce supply of the right type. In the late 1980s, the Society of Cardiovascular & Interventional Radiology (SCVIR) leadership recognized the need to ensure a steady supply of qualified and certified practitioners of interventional radiology. The "Special Requirements for Subspecialty Training in Interventional Radiology (Vascular and Interventional Radiology)" were written in 1989. After approval by the Accreditation Council for Graduate Medical Education (ACGME), accreditation of training programs began in academic year 1992–1993. Today there are over 100 fellowship training programs in North America, nearly 90% of which are accredited by the ACGME. About 200 individuals complete accredited training each year. In early 1995, the American Board of Radiology began to offer examination and certification in interventional radiology. As of February 26, 2001, 2,154 individuals have earned a certificate of added qualification (Capp MP, personal communication, 2001).

A problem long recognized by interventional radiologists is the lack of clinical training emphasis in radiology residency programs. Because we faculty have been training and creating young interventional radiologists in our own image, they tend to lack clinical skills and their practices lack the infrastructure to compete with other disciplines. Matthew Mauro, MD, succinctly asked, "Why are we cloning ourselves?" (10) rather than rethinking training? Today we are rethinking training. As a result of a proposal from SCVIR to the American Board of Radiology, a new clinical pathway (Table 2) provides a more in-depth clinical experience. The concentration is similar to the concept of the Holman pathway (11).

An internship and a vascular and interventional fellowship take up 24 of the 72 months of the clinical pathway; 9 months of

vascular and interventional radiology training in the 4th year and 3 months during the other years of residency make the total 36 months. Seven months, including research and clinical rotations, bring the total to 43 months. With 29 months of non–vascular and interventional radiology rotations, the total is 72 months. Although this pathway is promising and a few residents have started it, there are obstacles. Because the new track removes funded radiology trainees from imaging rotations, there will be resistance and pressure to not use it. We can support the future of interventional radiology by supporting the clinical pathway in our departments. Remember that strength in interventional radiology is rooted in clinical know-how and patient care.

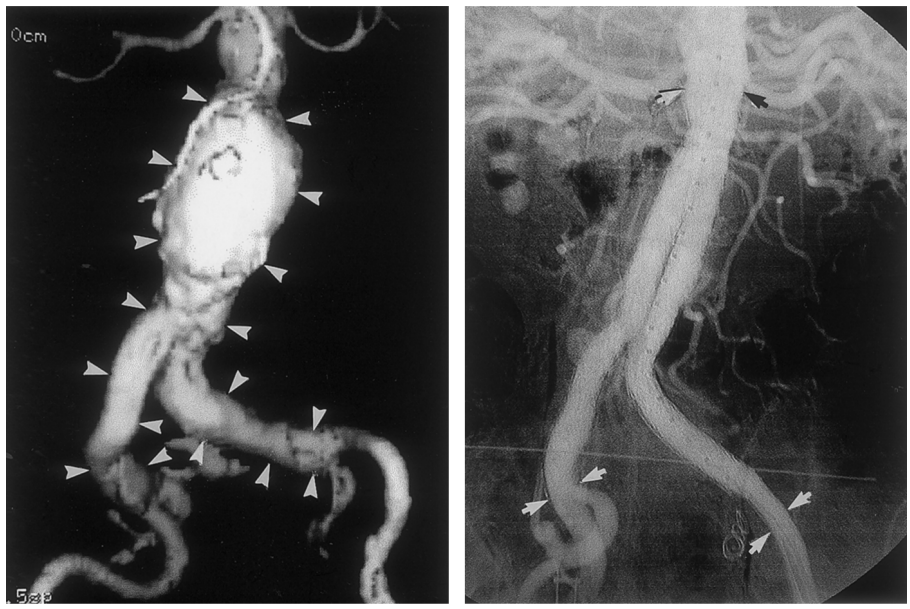
### The Image Problem of Interventional Radiology

Interventional radiology has an image problem. Few people outside the field understand who we are and what we do. Many prospective fellow trainees we interview find their way to interventional radiology careers by way of a chance encounter—a case that impressed them during a surgical or medicine clerkship. Crewson and Sunshine (12) have provided data that might make us ask, "Why should we be any better known?" For decades, only 5% or so of medical school graduates have chosen radiology training, and interventional radiology can claim only about 8% of them—that is 28% of the 28% of radiologists who subspecialize (Fig 6) (12). But ours is a growth field. And results of recent surveys (13) show that 15% of the many radiology job positions now available are in interventional radiology. We are in demand and we provide a valuable service, so we ought to be better known and understood.

With respect to the public, the problem is clear. It is our name. It is simply too hard for the public to learn. Imagine you are John or Jane Doe with a renal artery stenosis and severe hypertension discovered by your primary doctor. What does the word "interventional" tell you? Nothing. What does the word "radiology" tell you? If you are informed, you will know it has to do with medicine and imaging. Even so, you cannot imagine a radiologist in a role other than that of diagnostician. The idea of a radiologist occupying the central role in your treatment would never occur to you. Compare *interventional radiologist* with the word *surgeon* or *cardiologist*. You can conjure a mental image and easily imagine one of these doctors solving your problem. You may even know the cardiologist uses balloons and stents to treat arterial problems. But you cannot even remember the term *interventional radiologist*. Hearing it, you are able to conjure nothing.

For these reasons, in my 1999 Dotter Lecture (14) I suggested we undertake a prime-time national television advertising campaign to let the public know who we are and what we do. But I now believe that our name is an obstacle insurmountable even with a massive public relations campaign—at least one that we could afford. Nothing short of a name change will work. In a recent editorial in the *American Journal of Roentgenology* (15), Haaga suggested the name *image-guided microsurgery*. Certainly not succinct, but vastly more descriptive of what we do than *interventional radiology*. Last March, Frederick S. Keller, MD (16), devoted a third of his Dotter Lecture to this problem. His favorite subspecialty names are *image-guided surgery* and *minimally invasive surgery;* mine is *radiologic surgery*.

This problem is old news. Here are




**a.** **b.**

**Figure 5.** Enlarging abdominal aortic and bilateral iliac artery aneurysms. **(a)** Anterior view of a three-dimensional shaded-surface display of a pretreatment contrast agent–enhanced CT scan delineates the aneurysms (arrowheads). **(b)** Posteroanterior aortogram obtained after placement of a bifurcated endograft (Excluder; W. L. Gore & Associates, Flagstaff, Ariz) and embolization of the left iliac artery with Gianturco coils (Cook, Bloomington, Ind). Arrows delineate upper (aortic) end and lower (iliac) ends of the endograft. Note that there is no flow seen outside of the endograft within the aortic aneurysm (ie, no endoleak), the upper end of the graft is well positioned in the upper aortic "neck" just below the renal arteries, and the embolization coils in the left internal iliac artery trunk are seen just below and medial to the left distal endograft attachment. Although the right internal iliac artery is patent and provides flow across the pelvis (depicted on later arteriographic frames, not shown), the coils prevent retrograde filling of aneurysms.

**TABLE 2**
**Proposed 6-year Interventional Clinical Training Pathway**

| Postgraduate Year | Description | Duration (mo) |
|---|---|---|
| 1 | Transitional clinical | 12 |
| 2, 3, 5 | Clinical radiology, including 3 mo vascular and interventional during clinical years 2 and 3 | 32 |
| 4 | Vascular and interventional | 9 |
| 2–5 | Clinical training and research, with at least 3 mo for research training | 7 |
| 6 | Vascular and interventional fellowship | 12 |
| Total training | . . . | 72 |

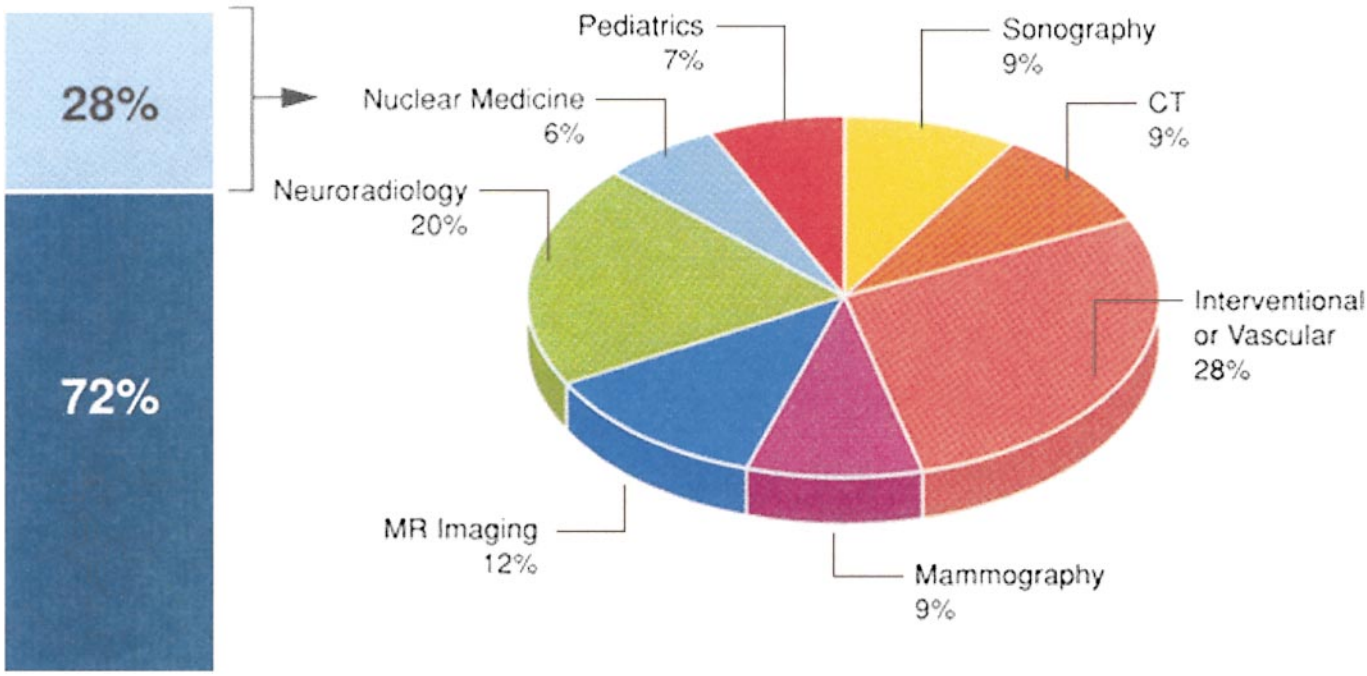



**Figure 6.** Pie chart shows distribution of specialization and subspecialization in radiology. Note that only 7.8% of radiologists (28% of the 28% who subspecialize) are interventional radiologists. (Adapted and reprinted, with permission, from reference 12.)

some comments of past SCVIR presidents from an unpublished history of interventional radiology supplied by Patricia E. McClenny, Associate Executive Director of SCVIR: "Ask an obstetrician or a dermatologist what they think we do," said Eric Martin in 1990, "and you will get some pretty blank looks." "During discussions about relative values," said Arina van Breda in 1992, "[the Health Care Financing Administration's] carrier medical directors were outspoken in denying that interventionalists ever took care of patients." In 1989, Ernest Ring lamented the unfortunate appellation "skivver" that the SCVIR had acquired, evidently through a combination of bad taste on the one hand and physicians' insatiable proclivity for acronyms on the other. He asked, "Who would refer a patient to a specialty that sounds like a brand of long underwear?" His favorite name was *endosurgery*. The point is that the name *interventional radiology* must change.

### Interventional Radiologists in the Radiology Group Practice

If you think that interventionalists are unknown to the public or misunderstood by other physicians, consider our own groups. The cultures of interventional radiologists and noninterventionalists are worlds apart. We interventional radiologists are aggressive, enjoy patient contact, seek new therapeutic procedures, and try to position ourselves as caregivers who bring patients into the system. Most diagnostic radiologists do not understand why we do this. As a result, we disagree on concepts of productivity and practice building. Our departments are not configured to examine and care for patients, and the clinical duty schedules do not accommodate these needs. No value is placed on the clinical activity we interventional radiologists know to be vital. And how many of us, interventionalists and noninterventionalists alike, still use the word "clinician" to refer to nonradiologists but not to radiologists? The latter has always been one of Dr Robert White's pet peeves that I came to understand many years ago. I have grown to despise the very sound of the word *clinician.*

Breaking out of the mold of diagnostic imager and trying on for size the self image of capable physician and caretaker of patients are important first steps in the maturation of a successful interventional radiologist. Interventionalists who accept referrals and assume responsibility for the management of specific clinical problems are regarded favorably and rewarded by the referral system. Unfortunately, this style of practice is uncommon. In most places, we are still regarded not as providers of patient care but as takers from the system and not givers. Moreover, our knowledge, skill, work ethic, and practice philosophy are misunderstood.

Inexplicably, many radiology groups still adhere to the loss-leader concept of interventional radiology and, therefore, require trained interventionalists to spend their nonprocedure time in the reading room "pulling their weight." If practice revenues are the concern, perhaps these individuals should keep in mind that in a university practice, while interventional radiology may account for only 1.5% of all procedures, it may also account for a full one-third of practice revenues. I am not so naive as to believe that these numbers are applicable to all departments in the nation. I am fully aware of the impact of managed health care in some heavily penetrated regions. Regardless of the revenue mix, however, the idea of forcing an interventional radiologist into the reading room at the expense of outpatient consultations, ward consultations, rounds, and conferences with other specialists is flawed because, ultimately, it dooms the group to forfeiture of its interventional work. Also, take a moment to consider the viewpoint of the referring physician. If you had angina, would your primary doctor select a specialist for you who practices cardiology only 30% of the

time? Clearly not. The same concept applies to interventional radiology.

In his Dotter Lecture, Dr Keller (16) called for a separation of diagnostic and interventional departments. Drawing on history, he stated that neither radiology nor radiation oncology would have flourished had that separation not occurred. He considered the current situation with interventional radiology to be similar and said that the separation was overdue. In my opinion, however, less drastic solutions can work. For openers, we should all heed the American College of Radiology policy statement passed in 1999 entitled "Support of Clinical Patient Management by Vascular and Interventional Radiologists" (17). In it, the American College of Radiology recognized the importance of clinical service development by interventional radiologists, opposed attempts at prohibiting this, affirmed the importance of patient-physician relationships to interventional radiologists, and encouraged the development of clinical services in interventional radiology, including the required infrastructure (Figure 7). Diagnostic radiologists really must embrace the dedicated interventionalist or risk losing interventional radiology.

**Key Elements of the ACR Policy Statement "Support of Clinical Management by Vascular and Interventional Radiologists" Adopted September, 1999**

- Recognized importance of clinical service development
- Opposed attempts to prohibit clinical privileges
- Affirmed importance of physician-patient relationships
- Encouraged/ supported establishment of clinical services

*-Clinical Team* *-Clinic Space* *-Time*
*-Admitting Service* *-Noninvasive Lab* *-Services*

**Figure 7.** Key elements of the American College of Radiology *(ACR)* policy statement (17).

### Workforce and Graduate Medical Education Funding Considerations

Advances in the number and types of interventional procedures create workforce needs. Some procedures are unique; others supplant surgical ones. Evidence-based medicine will help determine which procedures survive the test of time. All of this change occurs against a background of encroachment by other disciplines and legislation affecting graduate medical education funding and reimbursement. So the ascertainment of true workforce needs has become frustrating. Which procedures will be performed, for what indications, and by whom? The answers have far-reaching workforce implications.

One thing is clear: There are not enough radiologists or interventionalists today. Lee Rogers, MD, was correct to point out that the Graduate Medical Education National Advisory Committee report of 1980 (18), in which a 34% oversupply of radiologists by the year 2000 was predicted, was way off the mark. Today, we have 7% fewer radiology training positions than we had just a few years ago, in part because in anticipation of graduate medical education funding reductions following the Balanced Budget Act of 1997, our programs voluntarily reduced the number of slots (19). Also, the use of radiology services was expected to decline as managed health care grew, but the former grew instead and so did the demand for radiologists. A 1-year 75% increase in advertised radiology positions from 1998 to 1999 is unequivocal evidence of a shortage of radiologists so serious that immediate corrective action is needed. And for interventional radiology, the proportion of positions available today is double that of graduating interventional trainees among all radiology graduates (13). Accurate ongoing workforce assessment, with regular reporting, is a critical need.

### Interspecialty Turf Battles

In the past decade, the mix of specialists involved in vascular intervention has changed drastically. To maintain a stake, our trainees must be able to compete in the community with cardiologists, surgeons, and now even other specialists such as nephrologists—and competition is not our long suit. Surely you have noticed that we radiologists are great at developing techniques but not so great at hanging onto them. Our creativity is legendary, but when we succeed in providing a valuable service, others take notice. If our procedure competes with alternative therapies, involves new technology, or is financially rewarding, the battle begins. For PTA and stent placement, we fight endless battles to maintain a share; and our share is declining. Market study results have shown that, in 1988, radiologists performed more than 80% of noncoronary angioplasty procedures. In 1998, the percentage for PTA and stent placement was 70%–75% and declining (20). Now it is closer to 60% and still decreasing. Our peripheral angioplasty is being replaced by central venous access and other procedures inescapable to the hospital-based interventionalist, such as paracentesis and peripherally inserted central catheter placement.

I like to read the medical device industry market analysis reports (20–23). They provide a window on the world we do not ordinarily see. Through it we can see a future predicted by experts paid to know and advise institutional investors. These quotes are from one report (20): "Interventional cardiologists are repositioning themselves as vascular disease management specialists; market expansion will result," and "cardiologists control the patient." In a particularly telling section of the same 1998 report to prospective investors, one analyst describes a medical device company and its field personnel as "particularly well positioned to teach interventional cardiologists peripheral techniques, vascular surgeons interventional procedures, and interventional radiologists methods to cope with a rapidly changing environment." So, influential sectors of the business world consider coping, taught to us by industry, to be the future of vascular and interventional radiology.

Why does industry "bank on" cardiologists? There are several reasons: *(a)* Cardiologists treat a large number of patients, *(b)* they are aggressive, and *(c)* the numbers. Let us look at the numbers (Table 3). There are 101 interventional radiology training programs in North America, 89% of which are accredited, with

**TABLE 3**
**Distribution of Numbers of Programs, Positions, and Graduates according to Specialty**

| Specialty | No. of Programs | No. of Positions | No. of Graduates per Year |
|---|---|---|---|
| Vascular surgery | 82 | 102 | 85 |
| Interventional radiology | 101 | 228 | 200 |
| Adult cardiology | 177 | 2,173 | 750 |
| Specific peripheral arterial disease training | 18 | 390 | 130 |

228 total positions. Since not all available positions are filled, about 200 trainees graduate per year. Accredited vascular surgery programs number 82, with 102 training positions. In adult cardiology, there are 177 accredited programs with a total of 2,173 positions (24), more than the combined total of interventional radiology certificates of added qualification that have been awarded since the inception of examinations in the subspecialty 6 years ago. The average cardiology training program is 3 years in duration; so, about 750 trainees graduate each year. At its Web site, the American College of Cardiology lists 18 programs (10.2%) with training in peripheral vascular disease. These 18 programs have a total of 390 (17.9%) of the training slots, however, which means the large influential programs are teaching peripheral vascular disease management, so the trend will likely continue.

The problem is not cardiology alone. It is vascular surgery, too. Until the late 1980s, when iliac stents were introduced into U.S. clinical trials, vascular surgeons considered angioplasty to be experimental or, at best, a partial solution for a few patients who were not ideal candidates for surgery. However, as the new technologies began to proliferate and a new generation of vascular surgical leadership matured, the surgeons turned their attention to new technologies. At the Society for Vascular Surgery meeting in Chicago (Ill) in 1988, all of PTA and stent placement procedures were declared "the new endovascular surgery." Understandably, they want to maintain their stake in the future. But many of them now believe the best way is to obtain, without delay, the skills required to perform endovascular procedures independently. A recent mail survey of Society for Vascular Surgery members revealed that 78% of them think they should be performing all of the catheter work in their patients.

We know, of course, that formal training is required for optimal care, just as it would be for us to perform bypass operations. We do not wish to fight with or exclude the surgeons. We would, however, prefer to shift the focus away from wholesale surrender and toward long-term collaborations, including multispecialty group practice, joint ventures, cross training in various procedures, and, perhaps ultimately, a hybridization of formal training and certification. Impatient with the long view and sensing that they cannot afford delays, however, several surgeons have started their own training and influenced the Society for Vascular Surgery to undertake more aggressive measures. These include a standing committee on "endovascular issues," a formal liaison with the American College of Cardiology to discuss training, and the publication in 1999 in the *Journal of Vascular Surgery* of their own credentialing document for endovascular procedures (25). The more time that passes without a solution, the less inclined they are to work with us.

More recently, vascular surgery programs have incorporated catheter procedures into their training requirements. The following ACGME-approved modified "Program Requirements for Residency Education in Vascular Surgery" went into effect in January 2000 (26): "It is essential that residents have an acquaintance with the methods and techniques of angiography and competence in the interpretation of angiographic findings." Also, "Residents must be afforded the opportunity to have chief or senior resident responsibility in the operative management of patients who require a wide range of reconstructive and non-reconstructive vascular procedures within the scope of vascular surgery. This must include experience in endovascular procedures."

The message is that we cannot stand by and hope for change. We must explore new practice models and permutations of training. Vascular centers are a beginning. Several such private and AHCs are already in operation around the country.

Despite all these threats, remember the difference between the modern interventionalist and the angiographers of old. I do not mean anything disparaging or disrespectful when I say that today's breed is different—tougher, more aggressive, and less likely to lose out entirely to others the way that radiology lost out to cardiology in the cardiac catheterization laboratories 20 years ago (27,28). There will be no complete forfeitures. Tomorrow's vascular interventionalists will be a heterogeneous bunch with varied backgrounds and specialty board certifications. Radiologists will be among them.

A key to future success for interventional radiology is involvement in innovation, laboratory research, and clinical investigation. Several years ago when William Casarella, MD, gave the RSNA Annual Oration in Diagnostic Radiology (Casarella W, oral communication, 1989), he chided us for a lack of involvement in angioplasty research and publication. He cited statistics from a literature search of the term *angioplasty* and shocked us with the staggeringly high proportion of articles written by cardiologists. Today, I am happy to say that in two new areas, transluminal endograft treatment for abdominal aortic aneurysms and carotid bifurcation stent placement, interventional radiologists have remained involved. For several reasons, vascular surgeons have the dominant role in aneurysm treatment. First, they view aortic repair as the quintessential vascular operation, any threat to which is construed as an assault. Second, the graft manufacturers, who are historically allied with vascular surgeons, have kept the surgeons involved and worked with them since the beginning of endograft research. Finally, vascular surgeons have been the major players in aortic aneurysm repair, so referral patterns are set. It is a credit to interventional radiologists that despite all this, we have managed to get involved at all.

Traditionally, radiology's role in abdominal aortic aneurysm management has been limited to diagnosis. However, the interventional skill requirements for endograft repair have thrust interventional radiologists into a key role in therapy. For many, the new high level of clinical involvement has required a "crash-course" approach. Specific information has been published about converting an angiography laboratory to an endovascular suite for abdominal aortic aneurysm repair (29). Those who have acted on these opportunities are building their services. Others will now find it difficult to get involved unless they work in communities where endograft treatment has not yet started. Finally, let us not forget the

cardiologists, who are already in leadership positions in some of the aneurysm repair clinical trials.

In the earliest days of carotid stent placement, many radiologists, myself included, adopted a cautious conservative approach (30,31). Our rationale was that carotid endarterectomy is a good operation with low morbidity and mortality and that stent placement was likely too risky and unnecessary. After all, results from the North American Symptomatic Carotid Endarterectomy Trial (32) in patients with symptomatic stenoses of more than 70% revealed a 17% reduction in absolute risk of any ipsilateral stroke at 2 years in the surgically treated group versus that in the aspirin-only group (9% vs 26%; $P < .001$); a perioperative stroke plus mortality rate of 5.8%; and a reduction in risk of fatal or major ipsilateral stroke at 2 years, from 13.1% in the aspirin-only group to 2.5% in the surgical group.

For several reasons, however, our approach to carotid stent placement was too conservative. First, most of the endarterectomy reports published in the past 2 decades underreported complications. Most postoperative neurologic assessments in these studies were performed by the surgeons themselves (33), and as many as one-half of surgical services do not monitor endarterectomy complications systematically. It has now been shown that when a neurologist is involved in the patient's care, the likelihood of finding and reporting neurologic complications is threefold higher than that when a neurologist is not involved (34). Study results (34–37) have also shown differences in patient selection and a high major complication rate for carotid endarterectomy in the community. Cranial nerve palsies total 6%–9% in most series (7.6% in the North American Symptomatic Carotid Endarterectomy Trial [32]), and to these complications are added wound hematomas, wound infections, and cardiac and other nonneurologic complications that occur. So there is a sound medical-scientific reason for the study of alternative therapies like carotid stent placement.

Also, remember the market-driving factor, cardiology. Cardiologists are pushing the development of carotid stent placement, so it will happen. We can stand by and let it happen or participate and play a role in making it better. I believe it is our duty to participate and to make these interventions better. Also, many patients "surf" the Internet and become informed and are making their own choices to be treated nonsurgically.

The trial that will prove most important is the Carotid Revascularization by Endarterectomy versus Stenting Trial, or CREST. It is a multicenter, National Institutes of Health–funded, prospective, randomized study of carotid endarterectomy versus stent placement that will take several years to complete. It is well designed, and the neurologic scrutiny in this trial will apply to both carotid endarterectomy and stent placement. With selection of interventional investigators over one-half complete, 38% of investigators are vascular interventionalists or neuroradiologists, 46% are cardiologists, and the remaining 16% are vascular surgeons or neurosurgeons, a mix that, in my opinion, exemplifies the future in vascular intervention.

Finally, with respect to turf, we should keep in mind that the following commonly used strategies do not work when new technologies are involved and emotions are running high: exclusive contracts, credentials documents, practice standards, optimal imaging environment, and control of equipment. Strategies that do work in turf battles over new technologies are active clinical involvement, relationship with hospital administration, creative partnerships with other specialties, revenue sharing, and the support of radiology partners.

## The Population Is Aging

If you feel beleaguered, brace yourselves. Population experts consider the nation to be on the verge of a shortage of cardiologists! I am not kidding. In a compelling demographic study published last year in the *Journal of the American College of Cardiology,* Foot and colleagues (38) considered population trends, aging "baby boomers," children of those baby boomers (the so-called baby boomer echo generation), and projections about heart disease. The authors then predicted the workforce needs for the next 50 years (Table 4). The U.S. population is about 275 million people. The percentage of those over 65 years old is 12.6% and increasing. Baby boomers reach age 65 years during the years 2011–2030. In 2030, 20% of the population will be over 65 years, and by 2050, with a U.S. population of 394 million, it will still be 20%. Although the death rate due to heart disease is declining, because the population is aging and mortality due to heart disease is a problem of older persons the absolute number of cardiac deaths will increase by 112.7% in the same period, during which the population will increase by 43.4%. Adding a few assumptions about use, prevalence of coronary disease, and a trend to keep workloads per cardiologist constant, the authors claim that the number of cardiologists in the United States must double within 20–30 years. Do not worry. Noncardiac vascular diseases and cancer in the aging population will keep interventional radiologists busy for a long time to come—and require additional workers, too.

**TABLE 4**
**The Aging U.S. Population**

| Year | Population | Aged 65 Years or Older (%) |
|---|---|---|
| 2000 | 275 million | 12.6 |
| 2030 | 340 million | 20.0 |
| 2050* | 394 million | 20.0 |

* By 2050, the population will have increased 43.4%. The prevalence of heart disease is increased in the aging population, and the death rate for coronary arterial disease will have increased 113% (2.5 times the rate of the population increase).

## Access to Care Will Improve in the United States

From 1993 to 1998, the number of nonelderly uninsured in our country increased by 13% (39), even though at the same time the proportion of employed adults increased by 9% and per capita income increased by 13%. One-fifth of the uninsured failed to enroll in available plans, in part because of rising premiums and employers covering a smaller portion of the cost (40).

Despite these facts, there is universal agreement that access to care will improve. Leaders in both major political parties agree that the federal government must and will take steps to improve coverage for low-income and uninsured persons (41). In the absence of specific new federal initiatives, communities across the nation, including Boston (Mass), Indianapolis (Ind), Lansing (Mich), northern New Jersey, and Orange County (Calif), have already begun to address the plight of the nation's 44 million uninsured (42). As access increases, so will the demand for radiologic and interventional radiologic services. In diagnostic radiology, part of the increase will be handled without an increase in workforce by means of improved efficiency and image-transfer technologies. With the ability to deliver accurate timely diagnoses to underserved rural and remote areas, however, the demand for interventional radiologists will increase.

### Web-empowered People Will Increasingly Make Their Own Health Care Choices

Today's consumers access the Internet with home computers in search of health care information. Physicians may have difficulty staying a step ahead of their patients. Why do we interventionalists consider this a positive change? The answer is simple: Informed patients choose solutions that are less invasive; uninformed ones choose what their doctors advise. In the past, a physician explaining options to a patient had great latitude. A vascular surgeon who did not particularly believe in PTA as an alternative to bypass surgery but who felt some obligation to mention it to the patient, might say, "They can balloon it or we can just fix it." This, of course, gave the impression that PTA was only a stopgap measure and that bypass surgery was definitive. Today, however, determined and curious baby boomers surf the Web for the best solutions to the problems of their ailing parents. And tomorrow's surfers will be more computer savvy. So, physicians are confronted by patients or families armed with articles from the Web. They (we) must be prepared to discuss everything or risk losing the trust and confidence of the patient. If you think that because physician time per office visit is shrinking under managed health care and that there is no time for discussion, think again. It is precisely because of time limits that patients are doing their homework before the appointment. Today, Web-based practice management companies are changing the way patients interact with their doctors. They can access prescription renewal services, appointment-making services, and disease-specific educational materials online through secure pathways. From now on, the average patient will be far better prepared for an office visit or procedure.

In a retrospective review of new patients with uterine fibroleiomyomas examined at our office for possible embolization, 68% had reached us by way of the Internet, print media, or unconventional means; only 32% had arrived by way of traditional referral. Many expressed dissatisfaction with their gynecologist for not thoroughly reviewing alternatives to hysterectomy. We have heard similar complaints from some new patients with aortic aneurysm whose initial surgical consultation failed to satisfy their curiosity about endografts or to address their concerns about the risks of conventional surgery.

So what does health care seeking on the Internet really mean to interventional radiology? Nothing less than unprecedented involvement in and responsibility for the care of motivated patients. We must understand the diseases amenable to our treatments, know the outcomes of treatment, the risks and benefits, and all the therapeutic alternatives. If nothing has yet impelled us to be complete physicians and trustworthy sources of information, then the intelligent empowered patient will.

### Reform of Managed Health Care Organizations

For 2 years, a public backlash against managed health care organizations (MCOs) has started to result in reform. Concerns have been that these organizations usurp the professional decision-making authority of physicians, impose financial disincentives for appropriate specialty referrals and testing, limit the choice of and access to specialists, fail to address grievances, impose "gag rules," and fail to improve quality of care. Some have also illegally denied coverage, delayed payments, and deliberately and automatically "down-coded" services to improve their bottom line. At this moment in Florida alone, there are five companies, including two of the state's largest, under investigation by the attorney general's office due to an extraordinary number of complaints received by the Department of Insurance (43).

Although a national patients' bill of rights has been highly politicized and slow in coming, the American Medical Association clarified its support for specific minimum rights, and public pressure and state legislative initiatives have yielded changes for the better, including broader choice of physicians, more direct access to specialists, better appeal mechanisms, and, in some cases, a backpedaling to physician-determined hospital admission without preauthorization. The authors of one study (44) supported by the Agency for Healthcare Research and Quality and conducted by investigators from the RAND Health Program compared gatekeeping, liberal coverage, and self-referral to specialists and found no difference in cost of physician services. Such studies have enormous potential implications for radiology, especially interventional radiology. Liberalization of specialist access for patients covered by MCOs is a vital concern, particularly to patients who are candidates for novel investigational interventional therapies.

A positive aspect of managed health care is its emphasis on outcomes. We interventional radiologists have known for years that our therapies are effective, are less invasive, have few complications, and involve short lengths of hospital stay. Now we must prove it.

### AHCs Strain to Compete

In the 1980s and 1990s, health care became unaffordable; so, for 2 decades MCOs saw unprecedented growth. In mature markets, the biggest and strongest of such organizations consolidated and began exerting downward pressure on reimbursement to physicians and institutions. The trends continue today in maturing markets across the nation. The results have been catastrophic for AHCs for several reasons. First, AHCs have always pursued the missions of *(a)* teaching physicians and health care professionals, *(b)* discovering new knowledge through basic and clinical research, and *(c)* (for many) shouldering the burden of caring for a disproportionate percentage of the nation's medically indigent population, so their cost of doing business is higher.

AHCs require a patient base to accomplish their missions; with managed care, however, the tertiary referrals have dried up. So, the AHCs must compete. Because of their costs, they do not compete well, and competing has not been altogether comfortable. It is an unfamiliar and, many think, unbecoming activity for AHCs, given their academic mission and public support. Dean Allen Lichter, MD, of the University of Michigan Medical School (Ann Arbor) said in May at an American Medical Association news briefing on the plight of AHCs, "We have a responsibility to educate tomorrow's physicians and to do research that improves clinical medicine. Effective teaching takes time and patience, and that clashes with the challenge to provide efficient and cost-effective care" (45).

At the same news conference, Catherine DeAngelis, MD, MPH, editor of the *Journal of the American Medical Association,* once again asserted her stance, articulated in a May 10, 2000, editorial (46), that the ethics of business in a capitalist society should not apply to the ethics of health care. The American Medical Association called for a freeze on Medicare cutbacks in the balanced budget; an all-payer system to support patient care, education, and research; and universal health insurance. Naturally, the all-payer proposal is strongly supported by the As-

sociation of American Medical Colleges, whose member representatives are the deans of U.S. medical schools (47). They believe, and I strongly agree, that MCOs reap the benefits of medical education and research while pretending that these valuable resources grow on trees. The deans would like to see the playing field leveled. In disagreement, the insurance industry opposes the all-payer concept and claims that MCOs have flourished by bringing accountability to an industry where there has been none (47). Academic and other opponents say that for 10–20 years, physicians have embraced cost consciousness and that today MCOs cannot justify their profits, executive salaries, or existence in a nation with more than 44 million uninsured.

Average AHC margins are approaching 0%. More than 30% are operating at a deficit, and several have closed (48). As for AHC mergers with community hospitals, thus far the anticipated savings due to streamlining, service consolidation, capital equipment savings, and general economies of scale have not been realized (49). Inertia, resistance to change, geographic separation, and the culture and income gaps between academic and private community physicians explain why such changes occur not in years or even in a decade, but in generations. Even when AHCs develop a plan that seems to work, such as the Partners Healthcare System in Massachusetts, clinical duties of the faculty make them less available for teaching and research, so the academic missions are constantly threatened (47,50).

Why dwell on AHCs? Simple: They are the lifeblood of medicine, radiology, and interventional radiology. Although AHCs compose only 5.5% of the nation's 5,000 hospitals, they provide 44% of all care to the nation's poor; they produce our doctors, nurses, and allied health professionals; and they are responsible for most major advances that improve health, reduce mortality, and increase longevity (51). So, the threat to AHCs is a threat to interventional radiology. I believe that good sense and fairness will ultimately prevail and that an all-payer solution will save most remaining AHCs. We must support all efforts directed toward this end.

### Public Demand for Accountability, Competence

Last year's Institute of Medicine report, "To Err is Human: Building a Safer Health System" (52), riveted the public's attention by describing how as many as 44,000–98,000 deaths per year may be attributed to medical errors due to flaws in the organization of health care systems. The report called for establishment of a center for patient safety within the Agency for Healthcare Research and Quality and a mandatory nationwide reporting system for tracking serious errors. President Clinton's quick response endorsed the report and set a goal of reducing medical errors by 50% over 5 years. In their response to the President's plan, the American Medical Association objected to the "culture of blame" being established and pointed to a much-preferred "culture of safety," which has proved to be effective in the airline industry (53,54). In the latter system, opportunities to learn from errors are emphasized. For a system like that to work in health care, providers would need assurances that information would not be used as evidence in malpractice suits. Whatever happens, this issue is not going away.

Even before the Institute of Medicine report, the public had unprecedented access online to detailed disclosure of outcomes, including coronary bypass mortalities by hospital and by operator. Information about physician experience with arteriography, cardiac catheterization, endarterectomy, and other procedures is also available. However, public access to data such as these and to the National Practitioner Data Bank, or NPDB, is a hotly contested issue (55,56). The NPDB, established a decade ago, contains information on nearly a quarter of a million medical malpractice payments and adverse actions taken in the areas of licensure, professional society membership, and clinical privileges. To date, the NPDB has received more than 20 million requests for information. A concern is that raw statistics in public view without risk adjustment will be misinterpreted and misused. Nevertheless, certain trends are being established. For instance, in several reports the relationship between high procedure volumes and low death rates has been documented (57). Since more and more data will reach the public, we must be prepared in our individual practices and institutions. Obviously, this topic will affect interventional radiology.

Spurred in part by the Institute of Medicine report and in part for other reasons, the member boards of the American Board of Medical Specialties will implement changes in how physician candidates for certification are assessed. The changes, which will take years, emphasize not only cognitive knowledge and patient care, but also professionalism, interpersonal and communication skills, practice-based learning and improvement, and systems-based practice (58). Maintenance of certification will entail an assessment of continuing competence. The components are evidence of professional standing, commitment to lifelong learning and periodic self-assessment, cognitive expertise, and evaluation of performance in practice. Also, ACGME requirements are evolving along similar lines.

### Evidence-based Medicine Will Dominate the Clinical Arena

The future of vascular and interventional radiologic practice will be determined in large part by results of outcomes research. Hospitals have "care maps" for a variety of conditions. Many of us have participated in their development. On a larger scale, quality-of-life outcomes and health care econometrics will be with us forever. Health care and new technologies are simply too expensive to have it any other way. Health services research is a whole field of endeavor concerned with improving care by means of critical analyses of services. Organizations and consortia for evidence-based medicine are springing up and can be easily found on the web. The Society for Health Services Research in Radiology *(www.shsrr.org)* is a major organization that encourages and promotes health services research and education for radiology. The organization has an important future in fostering collaborative imaging research that will lead to rapid resolution of important clinical research questions. The American College of Radiology Imaging Network plays an important role of this type in cancer imaging. These same concepts should apply to vascular and interventional radiologic research. It is our responsibility to see that this happens.

### The Effect of the Age of Biology, Genetics, and New Cancer Therapies

"In 20 years, most human diseases will be understood at the fundamental level of molecules; knowledge about genetic control of cellular functions will underpin future strategies to prevent or treat disease phenotypes," predicted Francis Collins, MD, PhD, director of the national Human Genome Research Institute. Specific drug therapies for hypertension and diabetes will be prescribed only after genetic testing. Until that time, image-guided gene therapy will have a role, and it may continue to have a role even long into the future. For example, at

Stanford University (Calif), catheter-directed transarterial gene therapy is being used in patients with colon cancer metastatic to the liver (59). The same group in collaboration with industry is embarking on transarterial intrahepatic gene therapy for hemophilia (factor IX deficiency), and initial experiments have been started on the same approach for the treatment of hepatitis C.

Image-guided cancer therapies will become a huge growth area for interventional radiology and radiology, too. These will include embolization; chemoembolization; gene therapy; and direct tumor ablation by means of injection, radio frequency, and real-time MR-guided high-intensity focused ultrasound (Acker D, written communication, 2000). When these and other forms of completely noninvasive tumor ablation become available, it will be interesting to see who the primary operators are. In addition to the completely noninvasive approach, there will also be a variety of attacks on the angiogenic pathways involved in tumor growth.

## SUMMARY

Interventional radiology is a clinical discipline with imaging roots whose practitioners must accept responsibility for the care of patients with conditions amenable to interventional radiologic methods. Interventional radiology links the invasive past with the preventive future and is heavily dependent on innovation. A supply of innovators must be ensured, with funded research training. Training and certification of interventionalists has come a long way but is continuing to evolve toward a more clinical foundation. Interventional radiology has an image problem that can be addressed only with a name change. Radiology groups must embrace the concept of the dedicated interventionalist and support the American College of Radiology policy statement approved in September 1999. Today, interventional radiologists are in short supply. Ongoing workforce study and reporting are needed. Turf battles with cardiology and vascular surgery continue. Interventional radiologist involvement in endograft repair and carotid stent placement is essential. Also helpful are relationships with other specialists and with hospital administration, formulas for revenue sharing with other specialists, clinical involvement, and the support of diagnostic radiology group partners. The population is aging. Although this change will bring a need for more cardiologists, the high prevalence of noncoronary vascular disease and cancer will keep interventional radiologists busy for a long time to come. The demand for interventional radiology services will increase with access to care. Self-directed Web-surfing patients in search of the best in health care bring new opportunities but increased responsibilities to interventional radiologists. Managed health care reforms should result in increased use of interventional radiology. AHCs are the lifeblood of medicine, radiology, and interventional radiology. Their missions must be preserved. An all-payer system to support education, research, and care for the indigent is the best solution. Accountability to the public will continue to increase. Graduate medical education and certification will focus on competencies and their assessment. Evidence-based medicine will dominate in the future. New biologic and genetic approaches to disease will evolve more rapidly than ever before. Interventional radiology will maintain a role. Many new image-guided cancer therapies are in development. Some of them, such as real-time MR-guidd high-intensity focused ultrasound will be completely noninvasive. Time will tell which applications of the new methods are appropriate and, more than likely, who the practitioners of these new procedures will be.

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