Since the beginning of the 20th century, medical imaging has evolved into an essential component of modern cardiovascular management (Figure 1). In the early 2000s, the editors of the New England Journal of Medicine named medical imaging one of the most important medical developments of the past millennium (1). Cardiovascular imaging plays a significant role in the current era by improving our clinical ability to diagnose, stratify, and treat heart disease; however, its lack of clinically measurable outcomes has made its use a hot topic within the last decade among clinicians, health policy officials, and payers.

The rapid growth of imaging services, especially in cardiology, is no secret to any trainee. From 2000 through 2006, Medicare spending for imaging services under the Part B physician fee schedule more than doubled to about $14 billion. This increase is particularly significant in cardiac imaging examinations such as nuclear imaging, cardiovascular computed tomography (CT), and cardiac magnetic resonance (CMR) imaging, which account for approximately one-third of the total imaging services (2). In a recent study to evaluate decision making and trends in the use of cardiac stress testing, Ladapo et al. (3) found that the average annual rate of ambulatory visits resulting in cardiac stress test with imaging increased from 59% in 1993 to 1995 to 87% in 2001 to 2003. This trend was not explained by population growth or risk factors, suggesting that less-than-appropriate indications might play a more significant role than initially thought. The uncontrolled rate of growth in imaging services was recognized by Medicare and private insurers very quickly by the start of the new millennium. As a result, Congress passed into law the Deficit Reduction Act (DRA) of 2005 in an effort to control this exponential growth by limiting the reimbursement for the technical component of imaging services provided in the office setting. Later in 2007, hundreds of current procedure terminology codes were revised and bundled together reducing payment reimbursement, which affected every cardiac imaging modality by 2012 (4). As a consequence, the American College of Cardiology and other cardiac imaging societies developed appropriate use criteria guidelines for the use of multimodality imaging services in different conditions (5). In addition, by January 1, 2017, physicians will be required by the Centers for Medicare & Medicaid Services to consult the appropriate use criteria document for advanced diagnostic testing (nuclear, CT, and CMR) to be fully reimbursed (6).

The outcome is not surprising: medical imaging growth has declined steadily since 2006, a trend that will most likely continue. Recent reports found that the spending on imaging services per Medicare beneficiary has decreased by >15% from 2006 to 2011. Cardiovascular imaging has seen similar trends, except in cardiac CT and CMR, which continue to grow (7). Guidelines may help to control the growth of imaging services; however, increased regulations along with decreased reimbursement may potentially cause underutilization of imaging services in scenarios where it could have a meaningful effect.

To overcome these difficulties, there is a great need for cardiovascular-trained imaging specialists who could serve as the link between traditional noninvasive cardiologists and referral physicians to promote appropriate use of multimodality cardiac imaging in the management of patients with cardiovascular disease. The traditional cardiovascular training structure allows fellows to achieve level 2 expertise most commonly in 2 imaging modalities (e.g., echocardiography and nuclear imaging). However, the options are
FIGURE 1  Imaging Time Line: A Century of Medical Imaging Progress

*Nonpublic domain photos (Hal Anger, CT-FFR, and Regadenoson): permission granted by Roy Kalschmidt and Pamela Patterson (University of California Berkeley), Michael Smith (Heartflow, Inc.), and Christina Noland (Astellas US LLC). CT perfusion image courtesy of Amit Patel, MD (University of Chicago), and PET/CMR image courtesy of Felix Nensa, MD (Essen University Hospital, Germany). 2-D = two-dimensional; 3-D = three-dimensional; CMR = cardiac magnetic resonance; CT = computed tomography; FFR = fractional flow reserve; NMR = nuclear magnetic resonance; PET = positron emission tomography; SPECT = single photon emission computed tomography; SSFP = steady state free precession.
not the same for fellows trying to gain clinical competence in advanced modalities like cardiovascular CT or CMR. Under the prior American College of Cardiology Core Cardiovascular Training Statement (COCATS 3) published in 2008, to become a level 3 expert in the 4 imaging modalities a fellow would require 42 consecutive months in just echocardiography, nuclear, CT, and CMR training without including any other clinical rotations (8). Early this year, the COCATS 4 guidelines highlighted the fact that multimodality expert seekers will need further training beyond the traditional 3 years of general fellowship to achieve expertise in the different modalities (9). Thus, training opportunities in advanced cardiovascular imaging should be promoted, and those programs supported by the National Institutes of Health (NIH) should continue to be funded. Among the many U.S. centers that offer opportunities in pursuing advanced cardiac imaging training (Figure 2), 6 offer positions in advanced imaging sponsored by an NIH-T32 program (Brigham and Women’s Hospital, Massachusetts General Hospital, Stanford, Wake Forest, University of Virginia, and Yale). Our training program at the University of Virginia has high-level clinical, physics, engineering, and molecular expertise in all cardiovascular modalities, as well as a long track record of training physicians in research. Trainees interact with physicists, engineers, and radiologists, seeking improvements in both the clinical applications of newer technologies and further development of and applications of translational imaging.

The success of cardiology as a subspecialty over the years has been thanks to the vast resources that the NIH and National Heart, Lung, and Blood Institute

![Figure 2: Advanced Cardiovascular Imaging Fellowships Across the United States](image-url)

Data obtained from the American College of Cardiology Imaging Training Program Database, Society of Cardiac Magnetic Resonance, and Society of Cardiovascular Computed Tomography. EVMS = Eastern Virginia Medical School; NIH = National Institutes of Health; UC = University of California; UCLA = University of California, Los Angeles; UCSF = University of California, San Francisco.
invested in research. Unfortunately, due to shrinking budgets after the economic recession of 2009, the growth of cardiovascular disease research has slowed, and its stagnation threatens the progress made thus far. This is particularly visible in cardiovascular imaging, where U.S. publications in this area have decreased by 20% in 2010 to 2011, compared with 1991 to 1992 (10). Also, NIH funding continues to decrease year by year, and the projected budget for 2019 is <50% of the pre-2008 budget analysis (11).

However, the future still looks promising for those who seek further advanced training as imagers. Perhaps the time could not be better. The era of conscious spending has promoted the search for quality, excellence, accurate diagnosis, prognosis, and clinical outcomes. The use of CMR, positron emission tomography (PET), and CT have gained popularity among U.S. cardiologists. Research opportunities in CMR and CT have actually grown 5- to 7-fold during the last decade within many academic centers (10). Several imaging trials with outcomes as endpoints are under way that should have a significant clinical effect in the near future. The potential for growth in CMR is immense when compared with its utilization in Europe, where it is widely accepted and utilized. Under the current economic system, more nonacademic centers are adapting new technologies faster than ever before to attract patients and avoid losing them to the large academic medical centers that are equipped with advanced imaging technologies.

Cardiology-trained imagers should lead the movement toward a rational utilization of diagnostic cardiac studies. Imagers have a unique knowledge of each individual cardiac imaging test performed within the specialty; they understand how to perform, generate, troubleshoot, and interpret the image. They also acquire the clinical expertise that allows them to choose the safest, most accurate, efficient, and cost-effective imaging test for our patients by knowing the strengths and weaknesses of each modality. They should carry the duty to educate referring physicians, health care workers, and patients about appropriate use for different cardiac tests, thereby reducing cost and maintaining a significant clinical effect in our patients. Cardiology-trained imaging specialists who undergo combined training under the supervision of cardiologists and radiologists are in a privileged position to overcome some of the traditional territorial battles among these 2 specialties that may cause underutilization of cardiac imaging services. This will affect the health care system as a whole but also, more importantly, the patient. We need to start showing improved clinical outcomes through imaging and apply the most appropriate test tailored to individual patients and not use repetitive tests that do not add further clinical benefit. The imager should help to become the gatekeeper into this new array of diagnostic options, to choose wisely on the basis of the individual patient’s problem, and to interpret the test critically and translate it into clinical decision-making to achieve the best benefit/cost ratio possible. Only in this way will we be able to continue the innovation we have been fortunate to witness over the last 100 years.

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REFERENCES
**RESPONSE: Value-Based Cardiac Imaging and the Imaging Expert**

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The field of cardiac imaging, long a mainstay for diagnosis and patient management, offers great, future opportunities for current cardiology trainees. Each of the 4 main imaging modalities—echocardiography, nuclear cardiology, cardiac computed tomography, and cardiovascular magnetic resonance—has evolved dramatically over the past decades to provide increasingly precise definition of cardiac pathology and patient risk. At the same time, economic imperatives have created an environment in which these powerful modalities will be used only in circumstances where they provide value—improving outcomes or decreasing costs. To provide value, imaging studies must be well-performed and interpreted with accuracy, and then be appropriately utilized to optimize patient therapies. With the consolidation of hospital systems, the increasing prevalence of large, multisubspecialty cardiology groups, and the development of electronic image transfer from multiple institutions to an imaging expert, imaging services will be increasingly provided by imaging experts in each modality. The practice of having performance and interpretation of imaging services by cardiologists whose imaging training was merely that of performance and interpretation of imaging services by imaging experts in each modality. The practice of having expert, imaging services will be increasingly provided by images transfer from multiple institutions to an imaging ecardiology groups, and the development of electronic systems, the increasing prevalence of large, multisubspecialty patient therapies. With the consolidation of hospital sys-
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tems, the increasing prevalence of large, multisubspecialty cardiology groups, and the development of electronic image transfer from multiple institutions to an imaging expert, imaging services will be increasingly provided by imaging experts in each modality. The practice of having performance and interpretation of imaging services by cardiologists whose imaging training was merely that of the current “Level 2” is likely to decline. Such trends are leading to a critical analysis of the future of cardiac imaging, such as that recently developed at an American College of Cardiology Think Tank, now in the process of publication. We address below some of the cogent points raised by Drs. Gonzalez, Balfour, and Shaw.

**TRAINING OPPORTUNITIES IN ADVANCED CARDIOVASCULAR IMAGING SHOULD BE PROMOTED**

Given the increasing complexity of each imaging field, becoming an expert in a given specialty now requires a minimum of 1 year of training. The training of an expert in 1 of the imaging fields during a 3-year training program could be facilitated by altering current fellowship training requirements. For example, given the growth of noninvasive imaging and the decrease in need for cardiologists to provide standard diagnostic invasive procedures—distinct from interventional procedures—the need for extensive hands-on training in coronary angiography is diminishing; noninvasive diagnostic coronary angiography will increasingly become the norm. By reducing the time requirements for cardiac catheterization, it could become possible to spend sufficient time to become an expert in 1 cardiac imaging field during cardiology fellowship.

**ARE THERE ADEQUATE NUMBERS OF PROGRAMS TO PROVIDE TRAINING OF THE IMAGING EXPERT AT THE PRESENT TIME?**

For a cardiologist to be a cardiac imaging expert in more than 1 field, or for him or her to become a leader, teacher, or researcher in an imaging field, advanced imaging fellowship training will be requisite. Due to multiple obstacles, accreditation for such programs is unlikely in the near future. Nonetheless, various funding sources currently exist. The fellows-in-training section of the ACC website lists 38 currently available programs offering 1- to 2-year advanced imaging fellowship programs—clinical, research, or both—with approximately 70 fellows-in-training. The numbers of these programs are underestimated, as they are not all listed. However, the total is inadequate to meet the need for training the numbers of the cardiac imaging experts who will be required in the future across the United States.

Optimally, 2-year imaging fellowships are most likely to produce the true leaders and productive
researchers of the future. Our experience demonstrates that research productivity and clinical excellence of cardiac imaging fellows grow exponentially during the second year of advanced training. Programs that provide such fellowships often depend on research grants. As suggested by Gonzalez and colleagues, advocacy for increased National Institutes of Health funding for training of cardiac imaging experts is clearly needed.

“THE IMAGER SHOULD BE INVOLVED IN BECOMING THE GATEKEEPER INTO THIS NEW ARRAY OF DIAGNOSTIC OPTIONS”

Drs. Gonzalez, Balfour, and Shaw note that the cardiac imaging expert is in a position and has the responsibility to allow for the development of and implementation of practices that result in choosing the right test for the right patient. However, although imaging experts may become experts in more than 1 imaging field, it will be rare that they would be an expert in all 4 fields. Rather, achieving optimal gatekeeping could be facilitated by the development of cardiac imaging service lines within health care systems, with the mandate to develop the most cost-effective strategies for imaging test utilization. Setting up systems of compensation for cardiac imaging specialists that are not related to the volume of services they provide would encourage this development. The creation of an imaging service line could also help lead to more effective collaboration between cardiologists, radiologists, and the clinical “consumers” of imaging information—ranging from those involved in preventive medicine to interventionists and cardiovascular surgeons. Ultimately, fostering such collaboration is the most important link for achieving true value-based cardiac imaging.