The reformation that has characterized diagnostic imaging over the past twenty years is far from over. However, future advances are likely to emphasize functional mapping and software development. Current frontiers in MRI include fast-scan pulse sequences, angiographic, diffusion/perfusion, chemical shift and fat suppression studies, and 3-dimensional, in vivo and interventional imaging. Dramatic reductions in CT scan times have been achieved by cine-CT and spiral scanning, yielding remarkable improvements in temporal and volume resolution. New radiopharmaceuticals are enhancing the value of SPECT studies and adding to the promise of clinical applications of PET. Miniaturization of ultrasound transducers, and Doppler techniques and waveform analysis offer new horizons for ultrasonography, and efforts continue to bring computed radiography into the mainstream of x-ray imaging. New technologies with promise for anatomic imaging and functional mapping include magnetic source, light and possibly electrical impedance imaging. With the plethora of imaging data already available about patients, and the additional informations contributed by new developments, information management will be a major factor in the future success of diagnostic imaging.

INTRODUCTION

As with any reformation, the evolution of diagnostic imaging over the past two decades is easy to appreciate. The extent of additional changes over the emission tomography, grayscale, next few years is more difficult to predict. However, it appears self-evident that the reformation is far from over, and that additional significant advances are destined to occur. In addition to anatomic information, these advances will provide quantitative data related to physiology and metabolism that yields insight into the functional status of patients. Imaging information will increasingly be collected from microdetectors positioned inside the body, and computer-based techniques will permit correlation of data from different imaging methods. These and other possibilities present exciting challenges to physicians and scientists working today in diagnostic imaging. The challenges extend beyond overcoming technical barriers to evaluating applications of new imaging developments and to verification of their clinical usefulness and cost-effectiveness.
Magnetic Resonance

Since its introduction a decade ago, magnetic resonance imaging (MRI) has experienced extra-ordinary changes. These changes include reductions in scan times from minutes to seconds and decreases in slice thickness to a few millimeters. Ultrafast gradient-echo and echo-planar pulse sequences are opening opportunities for magnetic resonance angiography, diffusion/perfusion studies, and 3 dimensional imaging that seemed unachievable a few years ago. Chemical shift and fat-suppression sequences promise to extend MRI's applications in the spine and open opportunities for MRI in other areas, including breast imaging. Miniaturization yields the possibility of in vivo MRI coils, and discussions are focusing on the use of realtime magnetic resonance to guide interventional procedures using radiofrequency, laser and other sources.

Computed Tomography

Superior soft-tissue resolution yields an advantage of MRI over computed tomography (CT) for many applications in the central nervous system. However, an increased volume of body CT studies more than compensates for a continuing shift of CNS studies towards MRI. Slip-ring technology and cine-CT have dramatically reduced CT scan times, and spiral (helical) scanning permits data acquisition over a volume of tissue during a single patient breath-hold. This technique provides superior temporal and volume resolution, and offers significant advantages for 3-dimensional imaging. The increased price of spiral CT systems may be partially offset by increased patient throughput.

Nuclear Medicine

The acquisition of functional information about patients is most advanced in the imaging specialty of nuclear medicine. Three- and four-detector single photon emission computed tomography (SPECT) units are rapidly gaining in popularity, and one manufacturer has designed a ring geometry of SPECT detectors. These devices are being used with technetium-labeled pharmaceuticals for improved studies of the brain and heart. Positron emission tomography (PET) continues to evolve as a research tool, but its clinical applications are impeded by high costs and a reluctance of third parties to reimburse clinical studies. Less expensive positron-emitting tracers are needed, and rubidium 82 and copper-62 are candidates for heart and blood flow studies, respectively. Another possibility is development of a relatively inexpensive linear accelerator to replace the cyclotron currently needed to produce positron-emitting isotopes.

Ultrasound

Ultrasonography is an area of expected technical growth over the next decade. Catheter mounted transducers and ultrasound contrast agents are rapidly evolving, and pulsed and color Doppler techniques have potential clinical applications that have barely been tapped. Three-dimensional volume imaging appears feasible, although much development work remains. Ultrasound tissue characterization and Doppler waveform analysis promise to yield quantitative data to supplement ultrasonographic imaging. Corrections for beam distortions caused by tissue inhomogeneities ultimately could greatly improve the spatial resolution of ultrasound images.

Computed Radiography

The replacement of conventional radiographic units with digital detection systems has been an uphill struggle. Major difficulties include the cost of digital systems and the exquisite resolution of images from conventional units. Charge coupled devices offer superb resolution, but so far have been limited to relatively small areas. Phosphor storage plates are gaining popularity, and yield a spatial resolution of 2000 x 2000 pixels, with a 3000 x 3000 matrix not wholly unimaginable.

Magnetic Source Imaging

External detectors employing superconducting quantum interference
devices (SQUIDS) can detect the tiny magnetic fields associated with electrical activity occurring in the brain, heart and musculoskeletal system. Systems currently under development employ up to 37 detectors to construct biomagnetic maps of nerve activity associated with functional conditions such as epilepsy, migraine headache and diabetic coma. These studies are promising, but their clinical utility remains unproven and their cost is high. Under the present atmosphere of disinclination to reimburse new technologies, and the technical challenges of accurately producing, displaying and interpreting biomagnetic maps, magnetic source imaging is developing rather slowly.

**Light Imaging**

The use of transmitted light to depict abnormalities in tissue, especially breast cancer, has been frustrated over the years by the propensity of visible light to scatter extensively as it traverses a medium. Recent efforts to circumvent this problem include the time-of-flight measurement of focused pulses of laser light.

An alternate approach, termed diffused tomography, reconstructs the tissue substrate that gives rise to patterns of scattered light. Free-electron lasers are possible sources of variable wavelength light useful for the spectral analysis of tissues. These lasers require a high-energy accelerator such as a synchrotron to produce the free electrons. To date none of these light-imaging techniques has yielded a clinically useful technology for medical imaging.

Other Technologies Several other approaches to anatomic and functional imaging are being explored. Electrical impedance imaging (EEI) employs surface potential measurements obtained by impressing radiofrequency currents into tissues. The spatial resolution of EEI is rather coarse, but the temporal resolution is reasonably good, and the technique might eventually be useful for selected monitoring applications. Infrared thermography has been discredited as an ancillary technique for breast imaging, but some clinicians believe the technique is useful for analysis of selected musculoskeletal conditions, in spite of formidable skepticism.

**Information Management**

Information overload is a major problem in radiology. A substantial effort is underway to develop and implement

However, definite shifts are noticeable from anatomic functional imaging, and from hardware to software development, as the primary avenues of evolution. If the rate of progress is retarded in the future, its efficient systems for information cause will probably be growing handling in radiology.

These systems are known as Picture Archiving and Communications (PACS), Digital Imaging Networks (DIN), and Information Management, Archiving and Communications Systems (IMACS). Several barriers remain to be surmounted before IMACS become widely useful, including cost, inter-face standards, efficient data storage, workstation design, and changes in workstyle necessitated by the systems. These barriers undoubtedly will be reduced over the next few years, leading eventually to more efficient and effective methods for handling and using radiologic information.

**Summary**

Diagnostic imaging represents a major frontier of new developments in medical diagnosis. It continues to attract bright young physicians and scientists interested in research and clinical applications of emerging technologies. The reformation of diagnostic imaging begun two decades ago shows no signs of diminution.

However, definite shifts are noticeable from anatomic functional imaging, and from hardware to software development, as the primary avenues of evolution. If the rate of progress is retarded in the future, its cause will probably be growing disincentives for reimbursement of new technologies rather than fundamental limitations in new ideas and imaging techniques.