Chapter XXXV
Imaging Technologies and their Applications in Biomedicine and Bioengineering

Nikolaos Giannakakis
National and Kapodistrian University of Athens, Greece

Efstratios Poravas
National and Kapodistrian University of Athens, Greece

ABSTRACT

New developments are making the technology faster, more powerful, less invasive, and less expensive. While the technology evolves, new devices are developed, in purpose to be used in the hospitals. Many new imaging methods are used in biomedical applications today and can predict the growth of a tumor or detect a disease. The advantages are numerous, but the problems, during the acquisition and use by the staff, are also remarkable.

INTRODUCTION

We have come from the family doctor's signature black bag in the first half of the 20th century to the powerful scanning equipment of the modern medical center, from tens of thousands dying in influenza epidemics to hundreds of thousands of seniors receiving their annual flu shots, and from an average life expectancy of about 50 years to our present expectancy of 75 years. The biomedical community is taking advantage of the power of computing and technology so as to manage and analyse data. Imaging technologies save day to day more and more people.

X-rays, endoscopes, CT (computed tomography) scans, MRI (magnetic resonance imaging), digital mammography—these imaging technologies make it possible for medical scientists to peer into the body without cutting through the skin. With video monitors and robotic equipment, surgery becomes less invasive and less traumatic to the body (Sawchuck, 2000). Noninvasive means of looking into the human body are now being used to diagnose a wide variety of diseases, including cancer, Alzheimer's disease, stroke, heart failure, and vascular disease (President's Committee of Advisors on Science and Technology, 2000). The first imaging technologies, the X-ray (discovered by W. K. Roentgen) and EEG (electroencephalogram), were primitive by today's standards, but both have been considerably improved and provided the conceptual base of the other amazing imaging technologies that have recently emerged.

The most common, CAT (computer-assisted tomography) scans, combine X-rays with computer technology to create cross-sectional images of the patient's body, which are then assembled into a three-dimensional picture that displays organs, bones, and tissues in great detail. MRI scanners use magnets and radio waves instead of X-rays to generate images that provide an even better view of soft tissues, such as the brain or spinal cord (President's Committee of Advisors on Science and Technology, 2000).

Much of today's imaging technology relies on microprocessors and software. In addition, the great advances in noninvasive sensing, tomography, and imaging technologies now allow repeated studies with minimal stress and damage (National Research Council, & Institute for Laboratory Animal Research, 2002).

Medical imaging is often thought of as a way of viewing anatomical structures of the body. Indeed, X-ray computed tomography and magnetic resonance imaging yield exquisitely detailed images of such structures. It is often useful, however, to acquire images of physiologic function rather than of anatomy. Such images can be acquired by imaging the decay of radioisotopes bound to molecules with known biological properties. This class of imaging techniques is known as nuclear medicine imaging.

Although the mathematical sciences were used in a general way for image processing, they were of little importance in biomedical work until the development in the 1970s of computed tomography for the imaging of X-rays (leading to the CAT scan) and isotope-emission tomography (leading to positron-emission tomography [PET] scans and single-photon-emission computed tomography [SPECT] scans). In the 1980s, MRI eclipsed the other modalities in many ways as the most informative medical imaging methodology (Webb, 1988).

Table 1 summarises some of the imaging methods used in biomedical applications.

Technologies such as those in Table 1 are all being investigated in small-animal models. The goal is to marry fundamental advances in molecular and cell biology with those in biomedical imaging to advance the field of molecular imaging (TA-Datenbank-Nachrichten, 2001). The two basic starting points in evaluating the overall utility of a medical technology are efficacy and safety. If a technology is not efficacious, it should not be used. In addition, efficacy and safety data are needed to evaluate the cost

Table 1. Imaging methods used in biomedical applications

X-ray projection imaging (discovered in 1895)
X-ray CT (1972)
MRI (1980)
Magnetic resonance spectroscopy (MRS)
SPECT
PET (1974)
Gamma camera (1958)
Nuclear magnetic resonance (NMR, 1946)
Ultrasonics
Electrical source imaging (ESI)
Electrical impedance tomography (EIT)
Magnetic source imaging (MSI)
Medical optical imaging
Micro computerised axial tomography (MicroCAT)
Optical and thermal diagnostic imaging (OCT, DOT)

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