Editorial

Biomedical Imaging Research Opportunities Workshop II: A Summary of Findings and Recommendations*

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INTRODUCTION

The second Biomedical Imaging Research Opportunities Workshop (BIROW II) was held on February 25–26, 2004 in Bethesda, Maryland. BIROW II was sponsored by the Academy of Radiology Research (ARR), American Association of Physicists of Medicine (AAPM), American Institute for Medical and Biological Engineering (AIMBE), Biomedical Engineering Society (BMES), and the Radiological Society of North America (RSNA), and co-sponsored by 15 other medical imaging societies. The purpose of BIROW II (similar to the purpose of BIROW I held a year earlier) was to identify and characterize opportunities for scientific research and engineering development in biomedical imaging. This paper presents a summary of the findings and recommendations of BIROW II; a full report of BIROW II is available in Radiology (August, 2005). Information about BIROW I and II, and the program for BIROW III (March 11–12, 2005, Bethesda, Maryland) are available at http://www.birow.org. The proceedings of BIROW III will be reported in a future issue the Annals of Biomedical Engineering.

BIROW II focused on four areas of imaging that present a spectrum of opportunities for scientific research and engineering development. These areas are as follows:

- Optical Imaging
- Computer-Aided Detection and Diagnosis
- Imaging Gene Expression
- Image-Guided Vascular Interventions

Each of the areas was addressed in a plenary session in which three leaders in the field summarized the state-of-the-art science and presented a view of research opportunities.

OPTICAL IMAGING

Current applications of optical imaging range from fluorescence techniques to identify molecular distributions within cells, to micrometer-scale imaging of the retina, and on to imaging and selective treatment of tumors. Nonlinear microscopy employs nonlinear optical methods, such as multiphoton molecular excitation, optical harmonic generation, and depletion of stimulated emission, to image subcellular morphology and trace molecular dynamics at sub-nanometer resolution up to depths of a fraction of a millimeter in living tissue. Optical coherence techniques, such as optical coherence tomography and phase-resolved microscopy, permit real-time, micrometer-scale imaging and ultrasensitive display of cellular dynamics to millimeter-scale depths in tissues. Diffuse optical tomography provides measurements of hemodynamics and neural activation at depths of several centimeters in tissue. These and other advances employ luminescent or fluorescent genetically expressible markers in combination with advanced photonic sensors to overcome the challenges and exploit the opportunities of molecular imaging with optical imaging methods.

Discussion of optical imaging at BIROW II identified the need for an enhanced commitment to translational research as a major challenge to optical imaging, where translational research is interpreted as the validation of the usefulness of new technologies in biomedical research laboratories and in clinical settings. This commitment must include collaboration among scientists, engineers and clinicians; additional funding resources in support of translational research; development of multimodality imaging approaches...
that provide a structural and functional context for optical signals; and extension of the validation process beyond academic institutions and into the community of clinical practice.

Several research opportunities were emphasized for optical imaging, including the following:

- Expand development of in vivo imaging at the cellular level
- Apply optical imaging to assess early neoplastic changes
- Use optical techniques to enhance the venue for molecular imaging
- Improve resolution of in vivo molecular imaging
- Devise novel imaging devices such as guided biopsy probes, smart interventional devices, and methods for imaging inside the body
- Develop optical imaging technologies for analyzing cognition and brain function, including low-cost, portable devices

These and other research opportunities require that engineers are educated in basic and clinical science, and that medical students are exposed to basic science and engineering research during their medical school training.

**COMPUTER-AIDED DETECTION AND DIAGNOSIS**

Over the past few years there has been a massive increase in the amount of information produced during individual imaging examinations, as well as in the number of examinations performed in hospitals and clinics. These increases have created a data logjam in clinical facilities that can be approached best through deployment of digital imaging systems, high bandwidth networks to transport images between acquisition, interpretation, consultation and storage sites, and algorithms for computer recognition of image features for computer-aided detection (CAD) and diagnosis (CADx). Computerized image analysis is currently used in mammography, and other applications (e.g., lung and colon cancer) are on the horizon. This approach to image screening and interpretation promises not only to improve accuracy, but also to expedite the processing of the burgeoning quantity of images confronting every radiologist today.

The BIROW working group on CAD and CADx identified five major areas of research opportunities, with several specific recommendations in each area. The five general areas of research opportunities are as follows:

- Establish a shared database of imaging studies amenable to CAD/CADx algorithm development and validation, and for use by experts in computer vision and similar fields who do not have direct access to patient images.
- Develop a standardized method of reporting CAD/CADx results that would facilitate comparison of methods and results and yield better studies.
- Foster interdisciplinary collaboration and a national “bulletin board” of “who is doing what” in CAD/CADx.
- Encourage innovative trends in CAD/CADx.
- Evaluate various CAD/CADx approaches through accepted statistical approaches.

Discussion of this subject at BIROW II yielded the conclusion that attention to these five recommendations would facilitate major advances in CAD/CADx over the next decade.

**IMAGING GENE EXPRESSION**

Molecular imaging approaches to understanding gene expression is making rapid progress, in part through the formation of multidisciplinary and multi-institutional teams of investigators to provide productive research interactions. Examples of such synergistic teams are the In vivo Cellular and Molecular Imaging Centers created in several institutions by the National Cancer Institute. The contribution of imaging techniques to understanding biological processes at the cellular, subcellular and molecular levels could be enhanced through several recommendations offered by the workshop on Imaging Gene Expression. These recommendations include the following:

- Establish Education Centers and Networks in Molecular Imaging to train pre- and post- doctoral students and to offer career-development pathways for new and established investigators.
- Develop large animal and small animal multimodality imaging facilities and bench-top optical imaging systems.
- Encourage the integration of gene expression imaging with genomic, proteomic, morphological (e.g., tissue banks) and functional databases for comprehensive analysis.
- Deploy clinically applicable/translatable multimodality imaging approaches and probes for monitoring gene and cellular therapies (e.g., stem cell trafficking, engraftment and tissue-specific differentiation and/or function).
- Support translational and Phase 1 (IND) studies to validate imaging of genetic and cellular tracers with reporter gene imaging tracers.
- Implement image-based navigation of image-guided biopsies for in situ molecular-biological validation of noninvasive imaging for target expression and activity.

Through support of these recommendations, multidisciplinary interactions would be encouraged among