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It is with pleasure and pride that the Department of Radiology presents its 2006-2007 Annual Report & Newsletter, once again showing continued growth and exciting new directions in clinical care, education, and research. This report provides depth and detail on the department activities but as Chair I would like to highlight some of the activities of the Department.

Clinical Service

The Department faculty provides clinical radiology services at two locations, the University of Chicago Medical Center (UCMC) on the University campus and at Weiss Hospital on the northside of Chicago. Continued growth of clinical services was met at both facilities without expanding the faculty size. At the UCMC the department performed 281,217 examinations, increasing from prior years. As with most medical centers, overall procedural volume does not adequately describe the growth in complex imaging examinations.

While general plain radiography has declined slightly, CT and MRI procedures, the backbone of medical imaging diagnosis, have continued to increase substantially as shown in the accompanying graphs (see figures 1 and 2).

The excellence of the department’s administrative and technical staff is put in perspective when one realizes that the department accomplished this procedural growth during a time of keen budget oversight that consolidated and eliminated some positions in the department. Once again the department of radiology was among the UCMC’s best performing departments among hospital budget areas, finishing the year with hospital revenues exceeding budget and expenses below budget.

After several years of dramatic growth in new capital equipment for the hospitals, this past year was a relatively quiet one. Major upgrades were accomplished to two of the MR magnets at the Duchossois Center for Advanced Medicine over a three week period. Delays in hospital renovation construction gave the department a breather from continued new technology implementation and we will be ready for the next generation CT scanners and MR scanners that we will be installing early in the next academic year.
Teaching Programs

Throughout this report you will see the contributions of our trainees from the radiology residency and the medical physics programs towards all of our missions. We are in the third year of our radiology residency expansion to seven incoming residents per year and next year will reach the full approved complement of 28 residents. Our medical physics program, in conjunction with faculty from Radiation Oncology through the Committee on Medical Physics had 29 doctoral students during the year. Our department has always been very popular with medical students not just for clinical elective rotations, but we have always had large numbers of students working in our research programs. This year a medical student working with our research team first authored a publication in Radiology, the field’s highest rated clinical radiology journal. All of our trainees continue to bring vitality and new ideas to our department.

Research Programs

This was an exciting year for our research programs. Through a NIH shared instrumentation grant (Dr. Karczmar) and the generosity of the Florsheim family, we were able to install a new 9.4T MR scanner for small animals in the Lynn S. Florsheim Magnetic Resonance Imaging and Spectroscopy Laboratory. Dr. Jia-Hong Gao’s successful $2 million NIH large instrumentation grant received during the year has allowed the University to plan for a new and enlarged MR Research Center with new 3T and 1.5T magnets, to be completed during the next academic year. While all investigators nationwide, including ours, are impacted by the increasingly difficult NIH funding lines, this past year was an exceptional one for the Department of Radiology. The accompanying graphs show that during this academic year the Department expenditures reflected about $6 million (direct and indirect) of NIH funding, the highest level the department has ever experienced, and once again among the upper echelons of academic radiology departments (see figures 3 & 4).

Faculty Appointments and Promotions

The primary resource in the Department of Radiology has always been our faculty. During 2006-2007 we were able to strengthen our faculty and augment staffing in many divisions through faculty recruitments, and reward faculty with promotions. I am proud and pleased to welcome new faculty and congratulate promoted faculty from the past year listed below:

- Kenji Suzuki, PhD joined the Department in July as assistant professor in the basic science section. Dr. Suzuki received his doctorate in medical physics from the Nagoya University in Japan and since 2001 has been on our staff as a research associate with research focused on CAD. His appointment as assistant professor recognizes the contributions he has made to our research program in computer aided diagnosis specializing in artificial neural networks with applications in CAD to chest, breast and GI tract.
Paul Chang, MD joined the Department in October as professor in the abdominal imaging section and serves as Vice Chair of the Department for Radiology Informatics. He comes to us most recently from the University of Pittsburgh where he developed one of the country’s most productive and premier imaging informatics groups. He has a joint appointment here in pathology and serves as the Director of Pathology Informatics as well. A national leader in informatics, Dr. Chang will be a resource throughout the University for innovative informatics development and also a resource for industry to work with our department in novel developments.

Aytekin Oto, MD joined the Department in June as associate professor in the abdominal imaging section. Dr. Oto will also serve as the Chief of Body MR. A native of Turkey, Dr. Oto attended Hacettepe University in Turkey for his medical degree and radiology residency and received further subspecialty radiology training at the Cleveland Clinic. He has served on the radiology faculty at Hacettepe University, and at the University of Texas Medical Branch in Galveston where he served as vice chair of the department for research affairs.

Gillian Newstead, MD was promoted to professor of radiology. Dr. Newstead is an internationally recognized leader in breast imaging. By working closely with colleagues in radiology basic science, surgery and oncology, she has developed one of the country’s leading clinical investigative breast imaging programs.

Samuel Armato, PhD was promoted to associate professor of radiology with tenure. Dr. Armato has focused his research on CAD of the chest and most recently on developing semiautomated methods of assessing mesothelioma patients response to treatment as measured on CT.

Yulei Jiang, PhD was promoted to associate professor of radiology with tenure. Dr. Jiang has focused his research on CAD of the breast and is developing new programs in prostate diagnosis.

Scott Stacy, MD was promoted to associate professor of radiology. Dr. Stacy specializes in musculoskeletal radiology and has been a frequent annual honoree by radiology residents for excellence in teaching.

Thuong Van Ha, MD was promoted to associate professor of radiology. Dr. Van Ha specializes in vascular/interventional radiology. His research interests include liver interventions and inferior vena caval and peripheral interventions.

Mario Zaritzky, MD was promoted to assistant professor of radiology. Dr. Zaritzky specializes in pediatric radiology. His prior training as a surgeon has contributed to his ability to gain skills as a pediatric interventional radiologist.

I am very proud of the many accomplishments of our faculty and staff described in this report. These accomplishments demonstrate the Department and its faculty/staff commitment to the missions of the University of Chicago. We continue to build a solid foundation for the Department and the institution to continue to be a leader in the medical imaging arena for years to come.

**Department News**

**Radiology Installs New 9.4 Tesla Magnet**

Summer 2007 brought the eagerly awaited arrival of a new 9.4 Tesla magnet with a 30 cm bore, which was installed in the University’s Magnetic Resonance Imaging and Spectroscopy (MRIS) Laboratory. The magnet was purchased in part with a generous donation from Mrs. Nancy Florsheim, in memory of her daughter Lynn S. Florsheim with the UCCRC. Additional funding came from an NIH Shared Instrumentation Grant and the Radiology Department. In recognition of Mrs. Florsheim’s generous gift, the laboratory has been renamed the ‘Lynn S. Florsheim Magnetic Resonance Imaging and Spectroscopy Laboratory’. As part of the magnet installation the laboratory was completely renovated to accommodate the larger scanner and ancillary equipment and to improve electronic and acoustical noise suppression.

The Lynn S. Florsheim MRIS laboratory is part of a Core Research Facility of the University of Chicago Cancer Research Center and the Biological Sciences Division. The overall goal of the facility is to support the work of the University of Chicago scientists by allowing non-invasive, high resolution imaging of animal models of disease, tissues, materials, and clinical research studies involving new applications of MRI.
A primary goal of research in the laboratory is to develop improved imaging methods for early detection of breast cancer. Other cancers are also studied. The scanner will provide new insights into the etiology and response to therapy of heart disease, diabetes, and Alzheimer’s. In addition the scanner will be used to study the biology, physiology, and anatomy of normal tissues and organs. The new magnet will produce in vivo and in vitro images of small animals, tissues, cells, and materials. Spatial resolution for routine imaging will be on the order of 100 microns in-plane in 300 micron slices. This significant increase in resolution will lead to new insights into early events in the initiation and development of disease and response to therapy.

One of the first experiments performed on the new scanner provides an exciting example of research in the laboratory. The 9.4T magnet was used to detect very early pre-invasive mammary/breast cancers in mice. This is the first demonstration of pre-clinical detection of early breast cancer with MRI and required the development of a specialized detector and experimental protocols. The work was performed by Ms. Sunaz Arkani Jansen (Graduate Student in Medical Physics), Mr. Sean Foxley (Graduate Student in Medical Physics), Drs. Greg Karczmar, Gillian Newstead, and Xiaobing Fan (Radiology), Dr. Suzanne Conzen (Hematology and Oncology), Dr. Thomas Krausz (Pathology) and other colleagues. This is an important advance in breast imaging, because it will allow researchers to develop new imaging methods and therapies that target early non-invasive cancers and pre-cancerous conditions before they become dangerous. In addition, it will provide new insights into how early cancers develop and progress to invasive cancer. The pre-clinical research in the MRIS lab is closely linked to clinical research so that knowledge gained from studies of animal models and cells is directly ‘translated’ to clinical research, and then to clinical practice. For example, new methods developed by Dr. Brian Roman’s group for the evaluation of beta islet function require high resolution imaging on the 9.4T magnets and will lead to the development of improved methods for preparing islets for transplantation.

The 9.4T research scanner is part of a dramatic expansion of research resources for MRI at the University of Chicago. Other imminent improvements include installation of a new 3 Tesla magnet for research – funded by a $2,000,000 NIH grant to Dr. Gao, and a 1.5 Tesla research scanner equipped with MRI-guided HIFU (high intensity focused ultrasound) capability that will allow non-invasive treatment of cancer and other pathologies.

This state-of-the-art equipment for imaging and image-guided therapy and will allow Radiology researchers to work with collaborators in other Departments to pioneer new approaches to diagnosis and treatment.

The National Cancer Institute (NCI) recently awarded a breast SPORE to the University of Chicago. One of the most competitive and prestigious research grants offered by the National Institutes of Health (NIH), this award of $11.5 million over five years will enable physicians and physicists to implement a multi-faceted strategy of translational research. This program is designed to focus on developing genetic-based and imaging-based approaches to the treatment, prevention, and detection of breast cancers in women who are at risk of developing an aggressive form of the malignancy at a young age. The goal is to reduce the death and morbidity caused by breast cancer worldwide.
This major research initiative, led by PIs/co-PIs Olufunmilayo Olopade MBBS, Maryellen Giger, PhD, and Gini Fleming, MD, seeks to explore genomic and imaging strategies for reducing breast cancer mortality in women less than 40 years of age. This is a particular problem for young women of African ancestry, because this type of breast cancer affects them disproportionately. The team’s goal is to gain greater understanding of cellular dynamics in order to create more effective, less invasive, ways to prevent, screen, diagnose, and treat breast cancer in all women.

The Breast SPORE has four main project components; two of these are imaged based. These projects will bring together clinicians and basic scientists for a collaborative translational effort.

**Project One**, led by Maryellen Giger, PhD, Gillian Newstead, MD, and Charlene Sennett, MD, focuses on developing markers using advanced imaging techniques, which assess breast density and parenchymal structure. Preliminary work already performed in the department on mammographic density assessment on mammograms and parenchymal enhancement on breast MRI, formed the foundation for this new research. In collaboration with Dr. Olopade and the UC Cancer Risk Clinic, Dr. Giger’s lab has shown that the quantitative analyses of mammographic parenchymal patterns of women at high risk for breast cancer tend to have dense breasts with coarse and low-contrast texture patterns. The general hypothesis of project one is that by combining automated image-based analyses of the parenchyma and biomarkers, there will be an improvement in the assessment of breast cancer risk. Medical physicists Drs. Giger and Li, and radiologists Drs. Schmidt, Newstead, Abe and Sennett, are experts in computer aided diagnosis (CAD) applications that assist radiologists in interpreting medical images. Integration of CAD and biomarkers into a reliable inexpensive diagnostic system would allow more accurate screening of young women and identify those at high risk.

**Project Two**, led by Greg Karczmar, PhD, is designed to investigate new ways to use magnetic resonance imaging (MRI) to detect pre-cancerous or cancerous lesions in their earliest stages of development. This project combines expertise of radiologists Gillian Newstead and Hiro Abe, surgeon Nora Jaskowiak, and physicists Gregory Karczmar and colleagues. MRI has been shown to be excellent for the detection of potential malignancies before they become invasive. In this project they will be testing innovative MRI techniques to find very small lesions, which could be destroyed safely, using MRI-directed, minimally invasive procedures, such as high frequency ultrasound ablation. The researchers hope that by limiting risks they might move to a day when high-risk patients could make routine visits to their physicians to have all suspicious lesions removed before treatment becomes problematical and more invasive.

The University of Chicago has received a $2 million High-End Instrumentation (HEI) grant from the National Center for Research Resources (NCRR) to fund the purchase of a state-of-the-art 3 Tesla human Magnetic Resonance (MR) imaging and spectroscopy system that will facilitate ultra-high resolution studies of brain function, psychiatric and neurological disease, cardiac imaging and diagnostic of breast cancers.

Under this HEI program, the NCRR makes one-time awards to support the purchase of sophisticated instruments costing more than $750,000 to advance biomedical research and increase knowledge of the underlying causes of human disease.

Dr. Jia-Hong Gao, Professor of Radiology and Co-Director of the Brain Research Imaging Center, is the Principal Investigator on this project. The success in winning this highly-competitive HEI grant award indicates the national recognition of the achievements and strength of the imaging science and technology at The University of Chicago. The MR system will be a shared resource and all NIH funded imaging research projects in our campus will benefit from the access to this cutting edge imaging technology.

The anticipated installation of the system is March 2008 and it is expected to achieve full operation by May 2008.

**Radiology & Patient Satisfaction**

When it comes to patient satisfaction, the Department of Radiology faces more challenges – and has a broader impact – than most departments at the University of Chicago Medical Center. Nonetheless, Radiology has successfully raised its patient satisfaction scores over the past two years by embracing the Achieving Breakthroughs Initiative.

Achieving Breakthroughs began in 2004 as part of a systematic approach to making UCMC the provider of choice for patients, physicians, and employees. Key elements of the overall initiative include AIDET, rounding, and management development.
“AIDET” is an acronym that stands for Acknowledge, Introduce, Duration, Explanation and Thank You. It represents a communication model designed to communicate with patients who may feel nervous, anxious, or vulnerable. AIDET allows our trained professionals to share their experience and knowledge, and results in reduced patient anxiety, increased patient compliance, improved clinical outcomes, and increased patient satisfaction. Under AIDET, the Hospitals or BSD representative must Acknowledge the patient by name, Introduce him- or herself, tell the patient how long a wait or procedure will take (the Duration), Explain what is going to happen, and Thank the patient for using UCMC Radiology services.

Integration and communication with internal customers have been essential to the department’s success. All managers “round” every month with several of their internal customers (nurse managers on the many units, physicians in the emergency room, surgeons, and others) for feedback on how Radiology can better meet the “customer’s” needs. Likewise, every month rounding with all employees on all shifts is required. Each manager meets face-to-face with every employee that he or she supervises. Rounding provides a forum for employees to voice their concerns and for managers to understand what is working well, how they can assist employees to do the best job possible, and who to recognize for exceeding employee or patient expectations.

The last key element is management development, which focuses on specific actions that lead to growth and professional development. Many of the managers in Radiology have strong technical skills, but are less experienced in leading staff. All participate in in-services and other programs aimed at honing their management skills and meeting clearly defined objectives for performance.

The result of these three key elements of Achieving Breakthroughs has been substantial progress in Radiology’s patient satisfaction scores in a short time. In January 2005, the department’s Press-Ganey scores were in the 2nd percentile compared to more than 1,000+ hospitals nationwide. (Press-Ganey is the health care industry’s leading independent vendor of satisfaction measurement scores.) This meant that – based on patients’ “likelihood to recommend” the department to others – the University of Chicago Medical Center Radiology Department scored lower than 98% of hospitals surveyed – despite the fact that 88-92% of UCMC patients rated Radiology “good” or “very good.” To rank in the 50th percentile of Press-Ganey scores, a hospital needs about 96% of its patients to evaluate it as “very good.”

By implementing the key processes described above, Radiology achieved a score in the 61st percentile in July 2006 in the “likelihood to recommend” category (see figure 6). Although scores have taken a dip at times since the July 2006 high, the Department believes that while they have a few issues remaining to focus upon, the trend is generally moving in a positive direction.

Awardees of the 2006 Radiology “Patient’s First Award” for outstanding customer service. Seated: Theresa Howard, Yolanda Owens, Executive Administrator Edward Smith; Standing: Deborah Williams, Kathleen Douglass, Sharice Davis, Brian Tymkiv, Danny Valdivieso, Caroline Gaiter, and Rita Fagan. Also honored were Anthony DeFily and Cynthia Sacramento.

Managers assess employees’ AIDET techniques in Radiology on a regular basis. Employees find patients are much more satisfied and cooperative when AIDET is used on a consistent basis. Shown are Yolanda Owen and Theresa Howard, Breast Imaging staff members, along with Milton Griffin, Assistant Director, Radiology General Imaging Services.

DEPARTMENT OF RADIOLOGY
PRESS GANEY PATIENT SATISFACTION SCORES
FY06-FY07

Figure 6
The 2007 academic year was productive for the Section of Abdominal Imaging in all aspects, including clinical evolution, teaching, research and continuous quality improvement. Clinically, the Section participated in the revamping of ultrasound, with new leadership, technologists, protocols and equipment. CT continued to grow, both in volume and exam complexity, a trend that should continue in the coming year with the addition of a Beta scanner in conjunction with Philips Medical. It is expected that the offerings in the realm of body MR and associated volumes will increase significantly in the near future, with the addition of Dr. Aytekin Oto from the University of Texas system as the new Director of body MR. GI Radiology expansion during the past year was completed with the addition of a fluoroscopic unit and revision of the clinical reading and educational areas.

The Section’s commitment to education was solidified in the past year with several enhancements to the educational program. A dedicated orientation session was added to clarify goals and expectations for residents on CT, ultrasound, MR and GI radiology. In addition, mid-rotation feedback has been provided to allow the residents to more quickly adapt to Faculty observations. Daily teaching conferences have remained strong, and Section faculty provides two didactic conferences per week as well. Dr. Michael Vannier expanded on-line educational resources for residents and fellows, and in the 2008 academic year, more focused reading lists will be provided and post-testing will be initiated in all modalities to provide structure to the current rotations. In addition to this focus on resident education, the Section is participating in the restructuring of the Medical Student experience within the Department, again to provide more structure to the rotation and enhance the educational experience.

The Abdominal Imaging fellowship program had a robust year under the direction of Dr. Abraham Dachman, with the completion of a highly successful year by Dr. Adnan Qalbani. Adnan participated in all facets of the Section, including teaching and research with a resulting publication in *The Radiologic Clinics of North America*. The fellowship continues to evolve and is currently filled until 2009. Dr. Kurti Kulkarni will begin her fellowship in July of 2007 after completing a strong fellowship experience in the Section of Breast Imaging.

The Section actively participated in the Department’s continuous quality improvement program with its project “Results of Imaging-Guided Biopsy” which has changed prior practice among the Faculty. Adequacy of tissue obtained from biopsies far exceeded national benchmarks when cytologic analysis guided resampling for optimal results. This process was streamlined by the creation of an on-line, pre-populated biopsy database, devised by Dr. Paul Chang, a new section member and Vice Chair of Informatics, and members of the Information Technology group. In addition, quality improvement folders were incorporated into the Stentor PACS system, allowing faculty to provide constructive feedback to managers and technologists in all modalities. Finally, the creation of an on-line peer review system for the entire Department by Dr. Chang and IT members has greatly simplified the peer review process and has provided immediate feedback to all faculty.
Section members represented the Department and their peers at the national level in all major allied societies. Dr. Richard Baron, Departmental Chair, served on the Board of Directors of the Society of Gastrointestinal Radiologists (SGR), and as the Secretary-Treasurer. In addition, he was Vice-Chair of the Educational Exhibits Committee of the Radiological Society of North America (RSNA), and Council member as well as Program Committee Chair of the American Roentgen Ray Society (ARRS). Dr. David Paushter, Section Head and Vice Chair of Operations, was appointed to Chair the Examination Documentation Subcommittee of the Clinical Standards Committee of the American Institute of Ultrasound in Medicine and was named an ultrasound site reviewer by the American College of Radiology (ACR). Dr. Abraham Dachman served on multiple committees for the ACR, the RSNA, the ARRS and the SGR, and continued with significant appointments in conjunction with his work on virtual colonography for the National Institutes of Health (NIH). Dr. Michael Vannier, Vice Chair of Research, was appointed to a 5 year term as a member of the NIH/NCI Parent Committee for Programs and Centers, and participated as an external advisor to multiple health care systems. Dr. Paul Chang provided service to multiple societies in key roles, including the Society for Computer Applications in Radiology, the Association of University Radiologists, the National Library of Medicine of the NIH and the RSNA.

All section members contributed their expertise as manuscript reviewers and editorial board members for such journals as Radiology, the American Journal of Roentgenology, Radiographics, the Journal of Computer Assisted Tomography, Computerized Medical Imaging and Graphics, and the American Journal of Orthopedics. Dr. Michael Vannier served as Editor-in-Chief of the International Journal of Computer Assisted Radiology and Surgery and Automedica, and sat on the editorial board of The American Journal of Orthopedics, Medical Image Analysis and Computerized Medical Imaging and Graphics.

Dr. Richard Baron was an Associate Editor for Liver Transplantation. Dr. Paul Chang served as Associate Editor for Computers in Radiology, and has participated on the editorial board of Radiology and Imaging Letter, the Journal of Digital Imaging and Cancer Informatics.

Dr. Abraham Dachman has continued as Managing Editor of the Radiology content of the eMedicine project, sat on the Publications Committee for the Rockey Trial of the NIH and received the Editor’s Award from Radiology.

The Section’s active involvement in research resulted in a number of scientific publications as well as invited publications and presentations. Section members presented nine times at the RSNA 2006 annual meeting and participated in five exhibits, including two by Drs. Aytekin Oto and Abraham Dachman that were granted the prestigious Cum Laude award. In addition, Dr. Myrosia Mitchell was a co-author on a paper that received the ASCO Merit Award at the 2007 American Society of Clinical Oncology Meeting, utilizing dynamic contrast-enhanced MR in a pharmacologic study of metastatic renal cell carcinoma. Dr. Abraham Dachman, through his research on virtual colonography, was involved in eight funded projects during the academic year.

It is expected that the Section’s academic focus will continue to grow in the coming year with the addition of Drs. Chang and Oto, both successful researchers and leaders in their fields.

Breast Imaging

The clinical programs in breast imaging have continued to flourish and the expanded MRI volume and its offshoots such as “second look” ultrasounds and interventional procedures have increased the complexity of patient care. There are increasing numbers of outside proven breast cancer cases that choose to come to The University of Chicago Medical Center for definitive work up and treatment. These patients receive sophisticated assessment of disease extent. Treatment options for all new breast cancer cases are discussed at a weekly interdisciplinary conference. Breast MRI in particular has been a major draw, and the complexity / difficulty of procedures has increased significantly in recent years, with many more patients having multiple biopsies, and multiple wires placed at needle localization. Axillary lymph nodes are routinely biopsied when abnormal at ultrasound, providing important pre-surgical staging information for many patients. Breast conference has blossomed to an average of 15 to 20 patients reviewed each week. The faculty, Hiroyuki Abe, Gillian Newstead, Robert Schmidt and Charlene Sennett provide clinical...
other colleagues, they have published eight manuscripts with four more in press, and four more submitted. The Section has received funding from an NIH Specialized Programs of Research Excellence (SPORE), in Breast Cancer. This award of $11.5 million over five years has four major projects, two of which are imaging programs. The effort focuses on developing genetic-based approaches to the treatment, prevention, and detection of breast cancers in women who are at risk of developing an aggressive form of the malignancy at a young age. A primary goal is to conduct translational research, with the aim of improving understanding of the pathophysiology of DCIS lesions. Sunny Jansen, a physics graduate student, who works closely with faculty, clinical fellows, and research fellow Akiko Shimauchi, presented her prize-winning paper on MR findings in DCIS, at RSNA 2006.

The Section of Breast Imaging (left to right): Dr. Charlene Sennett, Dr. Shital Makim (Clinical Fellow), Dr. Gillian Newstead, Dr. Robert Schmidt, Dr. Akiko Shimauchi (Research Fellow), Dr. Hiroyuki Abe, Dr. Kirti Kulkarni (Clinical Fellow).

The major sectional research interests this past year have focused on multimodality assessment of lymph nodes for detection of metastases, development of new breast MR protocols for improved cancer detection and analysis, functional assessment of normal breast tissue, computer-aided visualization and analysis (CAVA) of breast lesions and the study of DCIS and high-risk lesions using MRI and mouse models. The Section has been the recipient of a variety of NIH, industry and philanthropic funding. Working closely with physicists, residents and other colleagues, they have published eight manuscripts with four more in press, and four more submitted. The Section has received funding from an NIH Specialized Programs of Research Excellence (SPORE), in Breast Cancer. This award of $11.5 million over five years has four major projects, two of which are imaging programs. The effort focuses on developing genetic-based approaches to the treatment, prevention, and detection of breast cancers in women who are at risk of developing an aggressive form of the malignancy at a young age. A primary goal is to conduct translational research, with the aim of improving understanding of the pathophysiology of DCIS lesions. Sunny Jansen, a physics graduate student, who works closely with faculty, clinical fellows, and research fellow Akiko Shimauchi, presented her prize-winning paper on MR findings in DCIS, at RSNA 2006; this work will also be presented in the journal Radiology.

The establishment of the Translational Laboratory, VyTL, named after Dr. Carl Vyborny, has proved to be successful in promoting collaboration between the clinicians and physicists. Drs. Giger, Nishikawa, and colleagues have initiated multiple collaborative research projects with our section. The reading room in DCAM now hums quietly, with radiologists and physicists working side by side.
The past year has been an eventful one for the section of Neuroradiology. After a long wait, the new biplane angiographic room was finally completed, allowing additional interventional procedures to be performed. The interventional program continued the growth begun last year but then hit a small speed bump with the unexpected departure of Drs. Aletich and Mazumdar in December of 2006. A more limited interventional program has continued under Drs. Mojtahedi and Rosenblum.

New programs in tumor and white matter imaging have been initiated and new faculty is expected with interests in these areas in the near future. Clinical turnaround remains excellent even with the loss of two faculty members and at the end of the year, 12

Academically, the Section maintains a national presence with publication in *Radiographics* and presentations at the Society of Skeletal Radiology. Cooperation with the basic science group has resulted in an abstract on particle wear osteolysis that will be presented at the Radiological Society of North America in the fall. The Section is also active in other research projects involving MRI analysis of both benign and malignant primary tumors of bone and soft tissue.

Teaching residents has always been a high priority for the section, and this past year Dr. Stacy was given an award from the senior residents for his efforts in oral boards preparation. Medical student education has also blossomed, with dedicated musculoskeletal imaging lectures given during the Gross Anatomy and Human Morphology courses for first-year students, as well as an arthritis review as part of the Physical Diagnosis Course for second-year students. The medical student course in MSK Radiology continues to be popular with fourth year medical students, especially those pursuing residencies in orthopedics or radiology.

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quality was again reviewed. Follow-up survey demonstrated a significant decrease in the number of examinations that were felt to be of non-diagnostic quality as well as significant improvement in overall examination standardization. As a result of the project a new protocol sheet was also devised to allow continued use of one standard protocol.

In other news, Dr. Jeff Ho finished his fellowship at the end of the year and entered private practice in the Detroit area. Dr. Cheng Hong joined the Section as a clinical fellow, while Dr. Fang Zhu joined as a research associate.

The past year, the section of nuclear medicine has undertaken significant and long awaited structural improvements on several fronts. The general nuclear department is currently undergoing a complete renovation of its facility, including the patient consultation, injection and imaging rooms, radiopharmacy laboratory, technologist processing and physician reading rooms. The renovation is expected to reach completion in fall 2007. This new, state-of-the-art facility will, among other additions, welcome a newly released dual-headed gamma camera, the BrightView from Philips, making them one of the very first centers nationwide to upgrade to this SPECT camera. On the cardiac nuclear side, additional significant renovations have recently been approved and are scheduled to commence shortly. These will include remodeled imaging rooms and an entirely new patient waiting area. Two new cardiac gamma cameras are anticipated, including a Philips Forte with its new gamma based attenuation correction. These significant structural improvements will allow the Section to continue to be a national leader in innovative and high-quality patient care.

Despite the expected chaos inherent in such improvement projects, the Section ambitiously embarked upon, and completed, a major clinical quality assurance initiative: certification by the Intersocietal Commission for the Accreditation of Nuclear Medicine Laboratories (ICANL). ICANL certification results only after a comprehensive review of all clinical policies and procedures, images and interpretations and documents that the

**Nuclear Medicine**

The Section of Nuclear Medicine (left to right): Dr. Yonglin Pu, Dr. Daniel Appelbaum, Dr. Christopher Straus, Dr. Bill O’Brien-Penney.
highest quality standards are met on all fronts. As a result of this review, all subsections of nuclear medicine: general, cardiac, and PET are now fully ICANL certified.

In addition to addressing quality assurance globally, the Section targeted a more specific area for a continuous quality improvement project within cardiac nuclear medicine. Noting that inpatient bed turnover is an increasingly important issue to avoid unnecessary patient costs and time, the Section embarked on an initiative to identify patients who can be discharged pending a negative nuclear stress result (“conditional discharge” patients), and to decrease their exam performance and reporting times. As a result of this CQI initiative, such patients were completed and discharged much sooner, significantly decreasing wasted inpatient time.

On the educational front, the Section has modified its teaching format and with great success. Noon conferences are now primarily reserved for a revamped lecture series, while case-taking approaches are reviewed during daily board-side sessions on rotations as well as during new, resident level-specific end-of-rotation exams. Also, for the second straight year a member of the Section was awarded the Marc Tetalman Teacher of the Year Award (Dr. Appelbaum 2006-7, Dr. Pu 2005-6). Dr. Straus is spearheading the Department’s overhaul of medical student education, including the design of a new lecture series that will enrich students’ exposure to nuclear and molecular imaging at an early level.

Academic output continues to be prodigious as a number of publications, presentations, and abstracts have been accepted and honored in a number of major journals and meetings. For examples, two abstracts presented at the SNM 2007 annual meeting describing novel computer aided diagnostic techniques for bone scintigraphy and PET were included in the Henry N. Wagner highlight lecture at the conclusion of the national meeting. Additionally, CAD research on pulmonary nodule characterization with PET/CT published in the JNM this past year was selected for inclusion in the 2007 Year Book of Nuclear Medicine. Additional research on temporal subtraction and bone scintigraphy was awarded a certificate of merit at RSNA 2006. Clinical research at the University of Chicago, in partnership with referring physicians continues, with emphasis on PET. For example, Dr. Pu is a co-investigator on an NIH grant looking at pathways linking reduced sleep duration and quality to obesity risk with FDG-PET.

These continued commitments to clinical, educational, and academic excellence have manifested in further regional, national, and international recognition for the Section and its members. For examples, this year Dr. Appelbaum was asked to deliver the annual bone scintigraphy review lecture at the national SNM meeting in DC. He has also agreed to join the national SNM Education Committee. Dr. Pu was invited to be a visiting professor to Zhejiang University in China where he delivered a number of lectures to the medical center and several nearby institutions. Dr. O’Brien-Penney continues to be active at the national level as Secretary for the Computer and Instrumentation Council of the SNM.

And so, as the dust begins to settle on their renovation projects, the Section emerges even stronger and more energized than before. The nearly completed new infrastructure will provide a tremendous platform as they continue to build their high-quality educational, research, and patient care initiatives to even greater heights in the coming year.
The Section of Pediatric Radiology remains dedicated to the care of neighborhood children as well as those from around the world. The Section’s patient population is ever increasing due to the recent opening of the state-of-the-art Comer Emergency Department, with its 24 beds and two trauma bays, and from recruitment of faculty in the Section of Pediatric Hematology-Oncology and their expanding bone marrow transplant program. The University of Chicago Medical Center has resumed its pediatric liver transplant program with more referrals from this group, also. The pediatric sedation service based in the Comer radiology department, under the medical direction of the pediatric intensivists, has enhanced care for children who require MR imaging and complex CT examinations. Motion degradation of examination is rare and hospitalized patients needing exams frequently have them within 24 hours of the request. All of the staff, comprising technologists, nurses, child-life experts, and clinic coordinators, are dedicated pediatric care professionals who are instrumental in the efficient, safe, and sympathetic function of the radiology department.

As a result of the restructuring of the pediatric radiology curriculum, the radiology residents have a greater grasp of the essentials of the subspecialty. They work alongside the pediatric radiologists and receive detailed training in caring for spectrum of patients seen, from the youngest preterm patients, who frequently weigh one pound or less, to young adult patients who are making the transition from pediatrician to internist. Pediatric residents and medical students are actively involved in the educational program in the Section. Each week, a member of the faculty is assigned as the teaching attending and reviews the reading assignments with the residents. Due to curriculum redesign, in addition to increased competency in clinical practice, the residents have also improved their test results in national standardized exams (in-service and written boards) and now score well above the 75th percentile in pediatric radiology.

Notable publications and presentations for the past academic year include the normal and enlarged vestibular aqueduct, ultrasonographic evaluation of cartilage in the growing skeleton, management of fluid collections of the pancreas, and multidetector CT evaluation of congenital heart disease.

During 2006-2007 the chest section made further improvements in productivity and turn around time. In spite of having the highest volume of exams, many of which are performed after hours, they have been one of the leading sections in terms of time from exam performance to report sign-off.

The Section has also updated their CT protocols to provide uniformity between the different scanners, and to take full advantage of their reconstruction capabilities. The Section has the most comprehensive and advanced reconstruction protocols for routine thoracic imaging of any institution in the country. They have identified issues with contrast delivery and timing that formed the basis for our QA project this year.

The educational component of the rotation has been enhanced during the past year by increasing the number of daily conferences, and by improving their quality, and by tracking and following up on interesting cases. The Section plans to follow-up on all cases for which further imaging is recommended during the next year, in order to identify cases that may not have received appropriate
follow-up, and also as a QA mechanism to keep track of true and false positive diagnoses.

For the first time, a resident was selected to receive the John Fennessy Award for Academic Achievement in Thoracic Imaging. This award was presented to Monica Harish at the resident dinner in June.

Recruitment of a junior faculty member remains a high priority in the coming year as volumes are expected to increase further, while teaching and research initiatives are expanded.

The Radiology residency now includes a rotation in cardiac imaging. The American Board of Radiology (ABR) written and oral exams include cardiac function, morphology and physiology. Beyond imaging physics, these exams emphasize knowledge of cardiac anatomy, coronary artery disease, cardiomyopathy and congenital structural heart disease. Expertise in image acquisition of CT and MR exams is required for the physics component of the ABR exam.

They have developed a comprehensive cardiovascular CT and MR imaging curriculum to train the residents and fellows for clinical practice and to meet all examination requirements. This curriculum is complemented by an extensive electronic on-line resource available in the Radiology intranet environment. There are lecture videos, simulators, case archives, tutorials, and an extensive collection of current medical literature which are organized to facilitate intensive training. This is complemented by a cardiovascular imaging wikipedia, developed by Drs. Bardo and Vannier that is available on the internet. To view the scope and details of cardiac imaging from the perspective of Philips cardiac CT/MR users, please visit our independent CV WIKI website at http://cvwiki.merseine.nu/mediawiki-1.5.8/index.php/Main_Page.

Future development of cardiac imaging requires continued support, cooperation and collaboration of the Radiology and Internal medicine departments. Together, radiologists and cardiologists are working to develop an Adult Cardiac Imaging center at The University of Chicago Medical Center, which will coordinate all cardiac imaging modalities.

Cardiac Imaging

Cardiac MR and CT imaging services have been offered by the Department of Radiology, and a joint service managed by the Division of Cardiology in the Department of Medicine (which includes echocardiography and cardiac nuclear medicine in addition to CT and MR) is planned.

Drs. Dianna Bardo and Michael Vannier work together to design imaging protocols and with the expertise of Barbara Newby, RT (CT), Bruce Jameson, RT (MR) and Diana Saldana, RT (MR) examine the heart using CT and MR. Drs. Bardo and Vannier have primary appointments in Radiology and joint appointments in Internal Medicine (Cardiology).

The Section currently uses two 64 channel Philips Brilliance CT scanners and four MR scanners (two Philips Achieva 1.5T and two GE Signa HDX 1.5T magnets) for cardiac imaging. All of these scanners have the full complement of upgrades, including cardiac imaging workstations, needed to provide state-of-the-art clinical cardiac imaging at the University of Chicago.

Patients with atypical chest pain, those with prior coronary artery bypass grafts (CABG) or stent placement, and those with suspected anomalous origin of the coronary arteries are ideal patients for coronary artery CT angiogram (CCTA). Cardiac CT is also performed to evaluate pulmonary vein anatomy prior to ablation procedures which aim to stop arrhythmias such as atrial fibrillation.

Cardiac CT

This 3 dimensional surface rendered image of the heart shows normal caliber left anterior descending (LAD) and left circumflex (LCx) arteries. The vessels are tortuous, perhaps due to hypertension.
MR is the ideal imaging modality to image patients with cardiomyopathy or structural heart disease (adults and children with congenital heart disease), and allows the operator to estimate functional measurements such as ejection fraction, cardiac output, blood flow through shunts and across the valves.

**Cardiac MR**

This is a short axis image of the heart, a slice of the heart, looking from the apex toward the base of the heart. The patient was given gadolinium contrast approximately 10 minutes before this image was acquired. The crescent of high signal (arrows) is abnormally enhancing tissue, indicating myocarditis.

MR is the ideal imaging modality to image patients with cardiomyopathy or structural heart disease (adults and children with congenital heart disease), and allows the operator to estimate functional measurements such as ejection fraction, cardiac output, blood flow through shunts and across the valves.

**Vascular and Interventional Radiology**

The Vascular and Interventional Radiology section continued to thrive in 2006-7 despite many challenges. The completion of a new interventional radiology suite and combined holding and clinic area provided much needed facilities to meet the ever expanding demand for services. The Section has been able to provide prompt service with most procedural requests addressed within 24 hours. Their role in evaluation and management continues to expand as they continue to provide the entire gamut of diagnostic and therapeutic Vascular and Interventional Radiology procedures.

As a continuing quality improvement program, the Section initiated a pilot program of pre-procedural consultations for patients undergoing subcutaneous chest port implantation. Both nurses and physicians participated in this program. The group found that this visit helped to alleviate anxiety for many patients who were unfamiliar with the procedure and enabled them to streamline care on the day of the procedure by ensuring all pre-procedural criteria were fulfilled. Overall, patients were very satisfied with this new service and the Section plans to continue it as a permanent program.

3D reconstruction of right pulmonary artery shows pulmonary arteriovenous malformation.

Selective pulmonary angiogram shows multiple arteriovenous malformations.

Fluoroscopic image shows embolization of malformation.
Jia-Hong Gao, PhD, is developing a functional MRI (fMRI) research program at the University of Chicago. The mission of the BRIC is to enhance the development and application of magnetic resonance imaging techniques to neuroscience as well as a broad range of other medical research disciplines. In May 2007, NIH awarded $2M to Dr. Gao for the purchase of a research dedicated 3T MRI scanner. This state-of-the-art scanner will replace the outdated GE 3T MR system that is currently operating in BRIC and the new scanner will be used to support all cutting-edge NIH funded imaging projects at The University of Chicago. Presently, Dr. Gao’s research activities are focused on several areas: (1) development of a novel fMRI technique, termed neuronal current MRI, that allows for substantial enhancement in the detection of brain activity in terms of both spatial and temporal resolution; (2) study of the biophysical mechanism of the homodynamic-based fMRI signal, and exploring the relationship between cerebral blood flow and oxygen metabolism during neuronal stimulation; (3) MRI measurements of the current density distribution in a body when an external current source is applied; (4) mapping of brain activation in the actions of glucose and alcohol. The neuroimaging techniques developed in BRIC will greatly improve understanding of the nature of normal brain function and help in the treatment of neurological disorders.
**Imaging the Activation of Pancreatic Islets**

Dr. Brian Roman’s lab is interested in imaging the activation of pancreatic islets in vitro and in vivo as a way to understand diabetes. It is well established that diabetes is of critical importance in the world as the number of people affected increases globally. A recent survey by the Centers for Disease Control and Prevention showed that from 1980 through 2005 the number of Americans with diabetes increased from 5.6 million to 15.8 million.

Diabetes is characterized by insufficient release of insulin by the pancreas or poor utilization of it. Its complications can lead to diseases such as retinopathy, neuropathy, nephropathy and arteriosclerosis. Presently pancreatic endocrine function is assessed using biochemical tests of insulin release or serum glucose. Knowing the functional efficiency of the pancreas would be beneficial in the development of novel therapies aimed at maintaining or increasing endocrine function particularly during progressive pathologies. Although several animal models of diabetes exist direct monitoring of pancreatic function has not been achieved. Imaging modalities have been used with limited success due to the morphology, location, motion, and tissue density of the rodent pancreas.

Previously the lab has successfully implemented a µMRI technique to assess functionality of isolated human and rodent pancreatic islets via manganese (Mn²⁺) enhanced MRI (MEMRI) in response to glucose stimulation. Figure 30 illustrates the increase in image contrast associated with stimulation. Over the past year they have made good progress in applying these techniques in vivo application to the rodent pancreas using a novel application of Magnetization Prepared RApid Gradient Echo (MP-RAGE) imaging to achieve significant T1 weighting and motion limited images. The results demonstrate significant change in image contrast as a result of dynamic effects of glucose in the pancreas and liver regions and demonstrate that glucose stimulated MEMRI of the rodent pancreas can be used to monitor pancreatic function in vivo.

Experiments are currently underway using this imaging approach to understand the onset and development of diabetes in the hopes that a similar approach can be used to detect pancreatic cancer as well.

![Figure 30: Two microcapillary NMR tubes filled with human islets incubated in low glucose (left control tube) and high glucose (right activated tube).](image)

The figure below illustrates the highlighted pancreatic region pre- and post glucose activation indicating an overall (entire highlighted area) SNR increase of 20 to 26% activation.

![Figure 31: Functional MRI of the rodent pancreas shown in color - (a) control (b) activated pancreas (c) subtracted image (b-a).](image)

**Analysis of dynamic contrast enhanced MRI data to assess tumor response to therapy**

Dynamic contrast enhanced MRI (DCEMRI) is increasingly a critical component of the evaluation of response to experimental cancer therapies. DCEMRI data has the potential to greatly shorten the time required to test new therapy, reduce costs, and more effectively identify useful drugs. We have continued our work on a number of innovative approaches to dynamic contrast enhanced MRI. These new methods include reference tissue methods for measurement of the arterial input function (AIF), methods for measurement of contrast media concentration, and new approaches to modeling MRI data. These new methods are used to evaluate changes in tumor blood flow during therapy.

For example, figure 32a shows the arterial input function calculated using ‘Reference Tissue Methods’ developed by Dr. Cheng Yang and co-workers. This arterial input function was used to produce the maps in figure 32(b-c) showing that Ktrans (a measure of tumor blood flow and capillary permeability) in a liver metastasis decreased dramatically after treatment with a renal cancer drug sorafenib. The red color in figure 32b and c indicates high values of Ktrans, while a blue color indicates low Ktrans (see Yang et al, MRM, 2006).
Development and testing of new spectral/spatial imaging methods to image tumor vasculature

Figure 33 shows co-registered MRI and micro-CT data. The 3D high resolution micro-CT image was acquired in vitro from a tumor bearing leg (tumor is indicated by the white circle; the femoral bone is indicated by arrows) after I.V. injection of a barium solution. The animal is sacrificed immediately after barium injection, and the barium forms a vascular cast that can be detected with high contrast by micro-CT. Therefore the micro-CT image shows bone and tumor vasculature at high resolution. The micro-CT image is fused to corresponding MRI data using in-house methods developed by Pelizzari and Haney. The red and blue colors show vascular regions that can be detected on MRI following injection of superparamagnetic particles. The results of this work suggest that high spectral and spatial resolution imaging allows reliable detection and evaluation of tumor vasculature both before and after contrast injection.

Development of vanadyl-based contrast agents that are sensitive to tumor metabolism

Dr. Devkumar Mustafi and co-workers in the MRIS laboratory have developed a novel class of contrast agents that contain VO²⁺-chelated organic ligands for magnetic resonance imaging (MRI). These contrast agents provided excellent T1 and T2* contrasts compared to that of Gd-DTPA in high-resolution MR images of rodent tumors. The major objective of this study was to demonstrate that these contrast agents are taken up by highly glycolytic colon cancer cells and target intracellular signaling pathways. Cells were pretreated with VO²⁺-chelates and experiments were carried out to measure activations of intracellular kinases. Dr. Mustafi demonstrated that VO²⁺-chelates activate kinases involved in glycolysis. Furthermore, MRI and atomic absorption studies of the soluble portion of cell extracts provided unambiguous evidence that VO⁴⁺-chelates are taken up by cancer cells. Finally – MRI experiments demonstrated preferential and persistent uptake of the VO²⁺-chelates in some tumor regions – particularly near the tumor rim. Figure 34 shows two representative time courses for the contrast agent in tumor (blue) and muscle (red). Arbitrary signal intensity is plotted vs. time after I.V. injection (time is given as image #, but representative times are indicated). In the initial rapid enhancement phase, Vanadyl behaves as a blood pool agent because it binds tightly to albumin in the blood. Subsequently it leaks out of tumor blood vessels and the continued increase in enhancement over 2 hrs is consistent with intracellular accumulation of Vanadyl. In muscle the contrast agent washes out rapidly. These results suggest that Vanadyl may be effective as a contrast agent that is specific and sensitive for tumor metabolism.

MRI methods for early detection of breast cancer including improved spectral, spatial, and temporal sampling methods

In collaboration with Dr. Gillian Newstead and the mammography group, we are evaluating high spectral and spatial resolution (HiSS) imaging combined with high temporal resolution imaging as a new approach for early and accurate detection of breast cancer. Unlike conventional MRI, HiSS MRI acquires the entire water proton spectrum associated with each small image voxel, with a spectral resolution of 2 – 10 Hz, and spatial resolution equal to or better than that of conventional anatomic MRI. The water resonance is easily separated from the fat resonance in each voxel to produce a completely fat suppressed image. The details of the water resonance are analyzed to produce a variety of images including water peak height images, water integral images, and images with intensity proportional to various Fourier Components of the water resonance. Images derived from HiSS datasets especially water peak height images - have been demonstrated quantitatively to have improved fat suppression, contrast, and texture, and sensitivity to contrast agents compared to conventional images. Over the last year Dr. Milica Medved and Ms. Abbie Wood a GPMP student have developed multislice HiSS methods that produce 3D data sets such as those used to produce the left
image in figure 35. These methods provide whole breast HiSS images that are very useful for detecting lesions and evaluating lesions pre-contrast. Figure 35 shows two maximum intensity projection images calculated from multi-slice HiSS datasets. The breasts shown in figure 35 contain invasive cancer and DCIS (indicated by arrows). HiSS shows the lesions clearly before contrast agent is injected.

**Dynamic Contrast Enhanced MRI**

**Pharmacodynamic Study of Sorafenib in Metastatic Renal Cell Cancer: Preliminary results of a Randomized, Phase II trial**

In collaboration with Dr. Walter Stadler, Dr. Cheng Yang, and Dr. Olwen Han, we have used DCEMRI to evaluate response of patients to a new antiangiogenic drug, Sorafenib is an oral antiangiogenic agent with activity in renal cell cancer. We conducted a randomized, placebo control trial to investigate if dynamic contrast MRI (DCE-MRI) is a pharmacodynamic marker for Sorafenib. Patients were randomized to placebo, 200 or 400 mg bid Sorafenib.

The results show that tumor blood flow before the beginning of therapy, measured by DCEMRI, may predict response to therapy. This is illustrated in the Kaplan-Meier plot below – showing progression free survival for patients with low and high initial values of Ktrans. This finding suggests an important clinical role for DCEMRI in terms of designing therapy for individual patients.

These are the first results demonstrating in vivo, high resolution, functional and anatomic MRI of orthotopic early mammary cancers in mice. Cancers were detected with high sensitivity and specificity. The discovery that murine DCIS can be imaged is particularly important. This is an important step towards the more effective use of non-invasive imaging in pre-clinical models of breast cancer. Mice could be used as a ‘test bed’ for development of imaging methods with improved sensitivity and specificity. In addition, MRI could be used to evaluate effects of new therapies that specifically target early cancers. MRI could also be used to follow the natural history of pre-cancers and early cancers to determine the characteristics of those that become invasive cancers compared to those that do not.
Molecular Imaging: PET, SPECT, and Optical Imaging

Improvement of Quantitative Accuracy and Scanning Efficiency in SPECT

Chin-Tu Chen, PhD is working with Christian Wietholt, PhD, of the National Health Research Institutes in Taiwan, to develop new methods for improving the quantitative accuracy of SPECT imaging at a reduced scanning time or with fewer projection views. By modeling the collimator response functions more completely and precisely, the accuracy of derived quantitative measurements can be improved substantially. They have also devised reconstruction approaches that can reduce the required projection views to 15-20% of those previously used, without hindering the resulting SPECT image quality. These are important issues in routine clinical imaging studies since many patients with abnormalities such as Parkinson's and Alzheimer's diseases cannot tolerate lengthy scanning time, thus demanding novel efficient scanning methods; however, strategies to maintain or even improve quantitative accuracy remain essential in these clinical applications. Their goal is to achieve high accuracy with very efficient scanning methods.

Development of Ultra-High Resolution SPEM with CT Capability

Graduate students Xiao Han and Erik Pearson, and Chin-Tu Chen, PhD, have been collaborating with Dr. Ling-Jian Meng from the University of Illinois at Urbana-Champaign (UIUC) on developing ultra-high resolution single-photon emission microscope (SPEM) that can achieve a spatial resolution better than 80 microns. This SPEM system design utilizes I-EMCCD (intensified electron-multiplying charged couple device) as a photon sensor with a scintillation crystal for detection. This same I-EMCCD can be used for X-ray detection as well, thus providing the CT capability. We are building a 4-head system with special multi-pinhole collimators that can provide reasonably high system sensitivity. Applications to brain imaging and bone imaging, in which ultra-high spatial resolution can facilitate new findings unattainable previously, are also in progress.

Development of Multi-Modality Probes for Molecular Imaging and Therapy

Chin-Tu Chen, PhD, is involved in two collaborations in developing novel molecular probes that are capable of carrying different agents to be used for many different imaging modalities or therapeutic approaches. Working with Dr. Laiohai Chen in the Bioscience Division at Argonne National Laboratory, they are designing and developing novel molecular probes using ghost T7 phage as templates to construct nano-particles that can incorporate various imaging tracers or therapeutic agents. The work has demonstrated imaging capabilities for optical imaging, ultrasound, X-ray, CT, PET, SPECT, and MRI. In collaboration with Kurt M. Lin of the National Health Research Institutes in Taiwan, the team is developing fusion reporters (EGFP-HSV1TK, enhanced green fluorescent protein and herpes simplex virus thymidine kinase) suitable for optical, PET, SPECT and MRI imaging. This multi-modality reporter gene has been tested in breast tumor xenograft models which has proven that this method can provide sensitive and specific imaging of breast tumors by SPECT/CT imaging. They are also expanding the reporter genes to MRI and have tested the MRI reporter gene in vitro and showed that cells express the reporter gene have shorter T2 than those in the group. Finally, they have created the adenovirus expressing MRI reporter genes and RFP fusion proteins so that they can analyze this new reporter in animal models in vivo.

Dual-Head Small-Animal PET

Chien-Min Kao, PhD and colleagues are developing a dual-head small-animal PET scanner (DHAPEM), which has generated first phantom and rat images, showing ~2.2 mm spatial resolution (figure 38). Advanced image reconstruction techniques that can improve the resolution toward ~1.2 mm are under development and testing (figure 39). The DHAPEM can reach a ~20% sensitivity, compared to ~4% sensitivity available with most existing small-animal PET scanners. This high sensitivity can reduce radiation dose or the scan time, and improve the temporal resolution in dynamic studies. The group is also studying the new Silicon Photomultiplier (SiPM) photo-detector for PET imaging, investigating time-of-flight (TOF) PET imaging, and developing new reconstruction techniques for TOF-PET.

Quantitative Methodologies for In Vivo Optical Imaging Using Surgically-Implanted, Flexible Peritoneal Windows

Jeffrey Souris, PhD, and Chin-Tu Chen, PhD, have been
developing quantitative methodologies for in vivo fluorescence and bioluminescence imaging, especially novel approaches to circumvent their intrinsic limitation: the significant reduction in signal due to anisotropic scattering and absorption of light by tissues. One such approach they have been developing is to utilize surgically-implanted, flexible peritoneal windows to improve imaging sensitivity and quantification. In addition to substantial improvement of detection, these flexible windows permit in situ correlation of anatomy to pathology, enable visualization of larger areas than afforded by glass windows, and do not impair animal ambulation. Working with Jonathan A. Hickson, PhD, Lambda Msezane, MD, and Carrie Rinker-Schaeffer, PhD of the Department of Surgery, they have been applying this novel technique to investigate ovarian cancer metastases in mice. To evaluate the performance of the flexible peritoneal window technique, they excised the skin and peritoneum of over 40 nude female mice and intra-abdominally implanted sterile 16-gauge poly-vinyl chloride windows of 2cm x 1.5cm extent, using horizontally-run, 5-0 uninterrupted mattress sutures. After a 5-7 day post-op recovery period, each animal was intraperitoneally injected with 500 microliters of PBS containing 103, 104, 105 or 106 SKOV3ip.1 human ovarian cancer cells that express luciferase. Torsos of window-implanted animals were circumferentially wrapped biweekly and, along with positive/negative controls and shams, imaged for bioluminescence at least weekly for up to 8 weeks. Spectroscopic analysis of excised windows, at various time points, revealed no significant extracellular matrix or fibroblast accumulation. Similarly, postmortem comparison of fenestrated and non-fenestrated mice revealed no apparent differences in metastases location, number, or size distribution. Results from the group’s preliminary studies indicate that this new flexible window approach can become a very useful tool in quantitative measurements of in vivo optical signals from live animal models.

The molecular probe has been designed to shift its absorption spectrum when cleaved by specific proteases. This would allow the cleaved and uncleaved probes to be distinguished by the optoacoustic signal at different wavelengths. Typical absorption spectra of the cleaved and uncleaved probes are shown in figure 41. The imaging system will comprise a conventional ultrasonic transducer with a coupled optical fiber to deliver the stimulating near-infrared pulse. This will enable interlaced anatomical and molecular images to be acquired and superimposed. Substantial progress has been made in the past year in the synthesis of the molecule and in the design of the instrument.  

**Developing Molecular Imaging Agents and Image Reconstruction Strategies for Optoacoustic Tomography**

Patrick La Riviere, PhD, and graduate student Dimple Modgil are working with James Norris, Professor of Chemistry, and Anthony Green, graduate student in Chemistry, to develop imaging agents and imaging systems that allow for visualization of protease activity in vivo by stimulation and detection of optoacoustic signals. Proteases are overexpressed in a number of pathologies, including cancers and vascular disease. In optoacoustic imaging, the tissue of interest is exposed to pulsed near-infrared laser light, as in optical imaging, but the image is formed by measuring the acoustic signal engendered by the absorption of optical energy in the tissue or by a molecular probe. This optoacoustic approach will offer advantages in terms of resolution, sensitivity, and depth penetration over the purely optical approaches to protease imaging that have been developed previously.

**X-Ray Fluorescence Imaging of Pancreatic Islets**

Brian Roman, PhD, Patrick La Riviere, PhD, and Research Associate Lara Leoni, PhD, are using the scanning x-ray fluorescence microprobe at Sector 2 of the Advanced Photon Source to image the spatial distribution of exogeneous manganese that has been introduced into islets of Langerhans as a contrast agent for magnetic resonance imaging (MRI). The islets of Langerhans comprise the hormone-secreting cells in the pancreas, including the insulin-secreting beta cells whose dysfunction is a major cause of diabetes. The ability to assess the function of beta cells through in-vivo imaging would aid in assessing the progression and severity of diabetes as well as the success of therapies based on islet...
transplantation. Recently, Dr. Roman and his collaborators have shown that manganese can be employed as an MRI contrast agent for islet imaging since it is taken up through the calcium channels of functional, glucose-stimulated beta cells. However, the ability to draw quantitative conclusions about beta-cell functionality from manganese-enhanced MRI is limited by a lack of knowledge of how the manganese is actually distributed in the islets: how much of it is actually taken up by beta cells versus how much remains in the extracellular space. X-ray fluorescence imaging is an ideal tool for producing a map of exogenous manganese, as well as endogenous elements such as calcium and zinc, in isolated, intact islets. Typical images are shown in figure 42.

**Figure 42:** Multi-elemental images of pancreatic islets obtained by use of X-ray fluorescence microscopy performed at the Advanced Photon Source.

**Improved Image Reconstruction in X-Ray Fluorescence Computed Tomography (XFCT)**

XFCT is an emerging imaging modality that allows for the reconstruction of the distribution of nonradioactive elements within a sample from measurements of fluorescence x-rays produced by irradiation of the sample with synchrotron radiation. The ability to map elemental distributions within a sample has many potential biomedical applications, including mapping of iodine distributions in the thyroid, detection of heavy metals in the bones, and mapping of cisplatin distribution in cancer cells. This year, Patrick La Riviere, PhD and Phillip Vargas, in collaboration with scientists at the Advanced Photon Source, have demonstrated that new concepts in image reconstruction developed by Xiaochnuan Pan, PhD, can be used to perform region-of-interest image reconstruction in XFCT, substantially reducing data acquisition times. An example is shown in figure 43.

**Figure 43:** XFCT reconstruction of a portion of a leaf of the plant “Kotodesh,” a nickel hyperaccumulator employed in environmental remediation. The images were reconstructed from a minimal, truncated dataset by use of novel algorithms developed in the department.

**Advanced Cone-Beam CT**

Graduate students Dan Xia, Sengryong Cho, Junguo Bian, Xiao Han, Research Associate (Assistant Professor) Emil Sidky, PhD, and Xiaochnuan Pan, PhD are performing research on advanced CT imaging. CT remains one of the dominant medical imaging techniques. In particular, the research on helical cone-beam CT has been extremely active because of its high volume-scanning speed and temporal resolution. Indeed, helical cone-beam CT would allow for new imaging protocols that were not possible with conventional CT. They have made significant breakthroughs in CT research and enjoy a leading status in this area. Specifically, they have developed computationally efficient and numerically stable algorithms for obtaining images in helical cone-beam CT; have designed innovative scanning strategies and algorithms for obtaining images with improved resolution properties; and have developed the new strategy and algorithms for reconstructing images within regions of interest (ROIs) from much reduced data. Most importantly, the team has developed and refined new concepts and algorithms that would allow the design of innovative imaging protocols that may have significant clinical implications, e.g., breast imaging, liver imaging, and cardiac imaging. One of the important advances made in the past year was the development of algorithms for image reconstruction from highly incomplete data, which are expected to find significant applications to a wide variety imaging problems in medicine, security scan, and other areas.

**System and Algorithm Development of Micro-CT and its Applications**

Graduate students Sengryong Cho, Junguo Bian, Charles Pelizzari, PhD (Department of Radiation and Cell Oncology) have been collaborating with Chin-Tu Chen, PhD, and Xiaochnuan Pan, PhD to develop micro-CT and its applications to small animal imaging. Micro-CT plays an important role in animal and molecular imaging. In the past year, they have developed the first micro-CT system for animal imaging on the campus. This system can provide 3D images with isotropic resolution at 30µm to 50µm. They are using this system to perform imaging studies of lung cancer, bone cancer, and vascular vessels in small animals from various laboratories in the Biological Sciences Division. This system is also being used to perform a wide variety of studies aimed at understanding the physical properties of the system and reconstruction algorithms. They expect that a large number of studies on small animal imaging and on imaging physics and algorithms will be conducted on this system and that a large amount of data and results will be generated, which can form the basis for the development of advanced micro-CT with the capability of performing innovative scanning tasks. In the past year, more than 150 mice have been scanned using our laboratory-made micro-CT.
**Single-Photon Emission Computed Tomography (SPECT)**

Bill O'Brien-Penny, PhD, Chien-Min Kao, PhD, Charles Metz, PhD, and XiaoChuan Pan, PhD have been investigating single-photon emission computed tomography (SPECT) imaging. Radionuclide imaging is an important research and clinical tool that can provide in vivo quantitative information at molecular level concerning functional and physiologic processes within organs of interest. One of their research programs in this area has focused on SPECT and, more recently, with clinical emphasis on its application to prostate cancer and Parkinson’s diseases. The group has made significant progress on the development of algorithms that reconstruct quantitatively accurate SPECT images by compensating adequately for the effect of photon attenuation and other physical factors.

**Comparison of Reconstruction Algorithms for Breast Tomosynthesis**

Ingrid Reiser, PhD and Robert Nishikawa, PhD, working together with graduate student Junguo Bian, MS, Emil Sidky, PhD, and XiaoChuan Pan, PhD, are evaluating a new reconstruction technique for digital breast tomosynthesis. Digital breast tomosynthesis (DBT) is an emerging modality for breast imaging. A typical DBT image is reconstructed from projection data acquired over a limited number of views from a limited angular range, i.e., compared to CT, the scanning of the breast is incomplete. In general, the quantitative accuracy of the image can be significantly compromised by severe artifacts and non-isotropic resolution resulting from the incomplete data. Nevertheless, it has been demonstrated that DBT may yield useful information for clinical tasks and is currently undergoing pre-clinical evaluation trials in breast imaging.

The purpose of this study was to conduct a preliminary, but systematic, investigation and evaluation of the properties of reconstruction algorithms that have been proposed for DBT. A breast phantom designed for DBT evaluation was used to generate analytic projection data for a typical DBT configuration. The reconstruction algorithms in this comparison include (i) filtered back projection (FBP), (ii) expectation maximization (EM) and (iii) total variation minimization (TV), a new technique.

The results of their study indicates that FBP reconstructed images are generally noisier and demonstrate lower in-depth resolution than those obtained through iterative reconstruction (EM and TV) and that the TV-minimization reconstruction yields images with reduced artifacts as compared to that obtained with other algorithms under study. In collaboration with Dr. Nishikawa, they are investigating and evaluating algorithms for image reconstruction in tomosynthesis breast imaging. Such an investigation constitutes an important component of the foundation for the development of CAD-based tomosynthesis breast imaging.

**New Innovative Imaging Techniques**

**Diffraction Tomography (DT), Reflectivity Tomography, and other Wave Imaging Techniques**

Samuel LaRoque, PhD, Emil Sidky, PhD, and XiaoChuan Pan, PhD are investigating innovative imaging techniques such as diffraction tomography (DT), reflectivity tomography, and other wave imaging. In recent years, innovative imaging techniques have becoming increasingly important for studying physiological processes as well as anatomic structures in small animals. They have made considerable impact on the algorithm development for these imaging techniques. For example, they have shown that reflectivity tomography can be related to the emerging imaging techniques such as opt-acoustic tomography, thus allowing the direct application of algorithms developed for the former to the latter. The group has proposed short-scan and half-time imaging strategies in these unconventional imaging modalities for reduction of scanning time and image artifacts. In recent years, much effort has been devoted to developing imaging techniques that rely upon contrast mechanisms other than absorption. Phase-contrast imaging is one such technique that exploits differences in the real part of the refractive index distribution of an object to form an
image using spatially coherent source. The group is developing algorithms to reconstruct and process phase-contrast images from the acquired data by use of the third-generation synchrotron at Advance Photon Source at Argonne National Laboratory. Recent research results seem to suggest that tomosynthesis breast imaging may yield more detailed information than does the mammography.

**Spin Resonance Imaging**

Samuel LaRoque PhD, Emil Sidky, PhD, Xiaochuan Pan, PhD, Gregory Karczmar, PhD, and Howard Halpern, PhD, are conducting spin-resonance-based imaging. Nuclear magnetic resonance imaging (MRI) has become one of the dominant clinical and research imaging techniques. They have been investigating, developing, and evaluating a variety of efficient and accurate sampling schemes such as the spiral sampling schemes for fast spatial-spectral MRI and are also developing algorithms for optimal suppression of data noise and other artifacts that are likely to be contained in rapidly acquired data. Unlike MRI that is based upon nuclear spin resonances, which are generally in high abundance in biological samples, electron paramagnetic resonance imaging (EPRI) detects spin resonances of unpaired electrons of free radicals in samples and determines the spatial distributions of parameters of physiologic significance. The researchers are particularly interested in estimating oxygen concentration within tumors because such information is important for detection, assessment, and monitoring of cancer status. Collaborating with Dr. Halpern of the Department of Radiation and Cellular Oncology allows the investigation of innovative sampling schemes for efficient and complete acquisition of EPRI data and the development of algorithms for optimally processing the acquired data and for accurately reconstructing EPRI images. One of the important breakthroughs that the group has made in the area is that they have proposed algorithms for exact reconstruction of ROI images from reduced EPRI data.

**Applications of Imaging Techniques to Radiation Therapy**

Graduate student’s Seungryong Cho, Xiao Han, and Erik Pearson, along with Charles Pelizzari, PhD, and Xiaochuan Pan, PhD are performing research on image-guide radiation therapy. Radiation therapy remains one of the most important procedures for treating cancer. The goal of conformal radiation therapy is to deliver a high radiation dose to the tumor volume, while minimizing the radiation exposure of healthy tissues that surround this volume. Therefore, treatment planning is a critical step for accurate and effective radiation therapy. Because treatment planning is conceptually related to a reverse process of SPECT imaging the insights and techniques attained in their research on SPECT can shed the light on the development of effective methods for accurate treatment planning in radiation therapy. In collaborating with Dr. Pelizzari of the Department of Radiation and Cellular Oncology, the team has been investigating and developing dose-efficient image guided treatment methods for detecting patient positioning errors in conformal radiation therapy treatments. Unlike previously proposed approaches, their methods will be based upon the theory of local tomography, and, consequently, will only utilize treatment radiation that passes through or very near the tumor volume to form the reconstructed image of the tumor volume. Also, their ROI imaging strategy provides an excellent opportunity for imaging the targeted tumor region with considerably reduced radiation dose.

**A New Approach to Digital Breast Tomosynthesis for Breast Cancer Screening**

Digital breast tomosynthesis (DBT) is being proposed as a replacement for conventional mammography for breast cancer screening. However, there are limitations to DBT that reduce its effectiveness for screening, principally the difficulty in imaging microcalcifications and the increased radiologists’ reading times.

Robert Nishikawa, PhD, and Ingrid Reiser, PhD have proposed a new method to overcome these limitations. Their proposed method is to divide the total dose given to the patient unequally such that one projection uses at least half of the dose and the remaining dose is divided over the remaining projections. It is assumed that in screening with DBT, only a single view is obtained using twice the dose of a conventional mammogram. All the projection images are used in the reconstruction. The 2D projection image that received the highest dose is analyzed by a computer-aided detection (CADe) scheme for microcalcifications. The radiologist views the 3D image set, with mass CADe, principally to search for masses. The 2D image that received the highest dose is subjected to CADe for clustered microcalcifications. Since the 3D image set is for mass detection, the image can be reconstructed using larger sized pixels. This will reduce computation time and image noise. In principle, radiologists can review the tomosynthesis slices faster since they do not have to search for microcalcifications. By producing a high resolution, “standard” dose 2D image and a lower resolution 3D image set, both calcifications and masses can be optimally imaged and detected in a time efficient manner. This novel scanning method is currently being tested in one commercial prototype.

**Figure 46: A slice through a reconstruction of simulated projection images of a 3D breast phantom.** The image on the left is from a DBT technique that distributes the dose equally to all projections. The image on the right is from the projection that received half the total dose give in the full scan. There is more noise in the image on the right, but they do not adversely affect the detectability of the simulated masses.
Computer-Aided Diagnosis In Chest Radiography

CAD for Improved Detection of Lung Nodules by use of Posterior-Anterior and Lateral Chest Radiographs

Junji Shirashi, PhD, Feng Li, MD, PhD, and Kunio Doi, PhD have developed a computerized scheme for detection of lung nodules in the lateral views of chest radiographs, in order to improve the overall performance in combination with the CAD scheme for posterior-anterior (PA) views. In this study, 106 pairs of PA and lateral views of chest radiographs (122 lung nodules) were used for development of the CAD scheme. In the CAD scheme for lateral views, initial candidates of lung nodules were identified by use of a nodule enhancement filter based on the edge gradients. Thirty-four image features extracted from the original and the nodule-enhanced images were used for the rule-based scheme and for artificial neural networks (ANNs) for removal of some false-positive candidates. The computer performance was evaluated with a leave-one-case-out test method for ANNs. For PA views, the existing CAD scheme was trained with one-half of 924 chest images and then tested with the remaining images. When the CAD scheme was applied only to PA views, the sensitivity in the detection of lung nodules was 70.5%, with 4.9 false positives per image. Although the performance of the computerized scheme for lateral views was relatively low (60.7% sensitivity with 1.7 false positives per image), the overall sensitivity (86.9%) was improved (6.6 false positives per two views), because 20% (16.4%) of the 122 nodules were detected only on lateral views. In conclusion, the CAD scheme by use of lateral-view images has the potential to improve the overall performance for detection of lung nodules on chest radiographs when combined with a conventional CAD scheme for standard PA views.

Computer-Aided Nodule Detection on Digital Chest Radiography: Validation Test on Consecutive T1 Cases of Resectable Lung Cancer

Shuji Sakai, MD, PhD, Kunio Doi, PhD, and their colleagues evaluated the usefulness of a commercially available CAD system on operable T1 cases of lung cancer by use of digital chest radiography equipment. Fifty consecutive patients underwent surgery for primary lung cancer, and 50 normal cases were selected. All cancer cases were histopathologically confirmed T1 cases. All normal individuals were selected on the basis of chest CT confirmation and were matched with cancer cases in terms of the age and gender distributions. All chest radiographs were obtained with one computed radiography or two flat-panel detector systems. Eight radiologists (four chest radiologists and four residents) participated in observer tests and interpreted soft copy images by using an exclusive display system without and with CAD output. When radiologists diagnosed cases as positives, the locations of lesions were recorded on hard copies. The observer’s performance was evaluated by receiver operating characteristic analysis. The overall detectability of lung cancer cases with CAD system was 75% (37/50), and the false-positive rate was 2.28 (114/50) false positives per case for normal cases. The mean Az value increased significantly from 0.896 without CAD output to 0.923 with CAD output (P = 0.018). The main cause of the improvement in performance is attributable to changes from false negatives without CAD to true positives with CAD (19/31, 65%). Moreover, improvement in the location of the tumor was observed in 1.5 cases, on average, for radiology residents. This CAD system for digital chest radiographs is thus useful in assisting radiologists in the detection of early respectable lung cancer.

Effect of Temporal Subtraction Technique on Interpretation Time and Diagnostic Accuracy of Chest Radiography

Shingo Kakeda, MD, Kunio Doi, PhD, and their colleagues compared reviewing time and diagnostic accuracy in the interpretation of radiographs without and with subtraction images and to examine whether this temporal subtraction technique can contribute to improving radiologists’ performance. Thirty cases with newly developed chest abnormalities on chest radiographs and 90 negative cases were selected. All chest radiographs were obtained with a computed radiography system. For the 90 negative cases, subtraction images were classified into two groups: 33 clean images without misregistration artifacts and 57 images with some misregistration artifacts. Eight radiologists (four board-certified radiologists and four radiology residents) participated in observer tests and interpreted the original radiographs without and with subtraction images using an independent test method. The reviewing time for each radiologist was recorded in each case. The observers’ performance was evaluated by use of receiver operating characteristic (ROC) analysis. When subtraction images were available, the mean reviewing time per case was reduced significantly from 13.6 to 10.8 seconds for the cases with newly developed abnormalities (p<0.001) and from 29.8 to 14.1 seconds for negative cases (p<0.001). The reduction in the mean reviewing time with subtraction images was greater for clean images than for images with artifacts (17.7 vs. 14.5 seconds, p<0.001). The average mean area under the ROC curve value increased significantly from 0.942 without subtraction images to 0.988 with subtraction images (p=0.025). There were significant differences in the sensitivity (0.963 vs. 0.888) and specificities (0.976 vs. 0.899) without subtraction images) and with subtraction images (p=0.001). In conclusion, the temporal subtraction technique can reduce reviewing time and also improve diagnostic accuracy in the interpretation of chest radiographs.
Computerized Image Analysis of CT Examinations

Improving Radiologists’ Recommendations with Computer-Aided Diagnosis for Management of Small Nodules Detected by CT

Feng Li, MD, PhD, Qiang Li, PhD, Heber MacMahon, MD, and Kunio Doi, PhD, evaluated how CAD can improve radiologists’ recommendations for management of possible early lung cancers on CT. Twenty-eight lung cancers and 28 benign lesions were employed. Each group of 28 lesions was classified into subgroups of two sizes (9 between 6 and 10 mm and 19 between 11 and 20 mm) and three patterns (8 with pure ground glass opacity [GGO], 12 with mixed GGO and 8 solid lesions). Sixteen radiologists participated in the observer study, first without and then with CAD. Radiologists’ recommendations, including (1) follow-up in 12 months, (2) in 6 months, (3) in 3 months, or (4) biopsy, were compared at three levels of their malignancy probability ratings (low: 1%-33%; medium: 34%-66%; high: 67%-99%) for 896 observations (56 lesions by the 16 radiologists) in the two size subgroups and three patterns. The number of recommendations changed by radiologists by use of CAD was 163 (18%) among all 896 observations. Among these changed recommendations, the fraction showing a beneficial effect from CAD was 68% (111/163), and the fraction showing a beneficial effect regarding biopsy recommendations was 69% (48/70). With CAD, the radiologists’ performance regarding biopsy recommendations was significantly improved for 43 lung cancers (31 changed to biopsy versus 12 changed away from biopsy; P = .003) and was also improved for 27 benign lesions (10 changed to biopsy versus 17 changed away from biopsy; P = .18). Most of the cancers with improved recommendations were solid lesions or mixed GGO and relatively large. Therefore, CAD has the potential to improve the appropriateness of radiologists’ recommendations for small malignant and benign lesions on CT scans.

Radiologist Agreement in the Identification of Lung Nodules on CT Scans

Samuel Armato III, PhD and Heber MacMahon, MD are the local Principal Investigators of the NCI-sponsored Lung Image Database Consortium (LIDC), which is developing a public database of thoracic computed tomography (CT) scans as a medical imaging research resource. A key aspect of this database is the annotations assigned by LIDC radiologists to indicate lung nodules in the scans. These annotations provide an opportunity to investigate the consistency of lung nodule identification by radiologists. 130 CT scans were reviewed by one radiologist at each of four LIDC sites through a two-phase process. During the initial “blinded read,” radiologists independently annotated lesions they identified as “nodule > 3mm (diameter),” “nodule < 3mm,” or “non-nodule > 3mm.” During the subsequent “unblinded read,” the blinded read results of all radiologists were revealed to each of the 4 radiologists, who then independently reviewed their annotations along with those of their colleagues; a radiologist’s own annotations then could be deleted, added, or left unchanged. This approach was developed to identify, as completely as possible, all nodules in a scan without requiring forced consensus. After the initial blinded reads of the first 30 cases, 71 lesions received “nodule > 3mm” annotations from at least one radiologist; however, all 4 radiologists assigned such annotations to only 24 (34%) of these lesions. Following the unblinded reads, a total of 59 lesions were so annotated by at least one radiologist, with 27 (46%) of these lesions receiving such annotations from all 4 radiologists. Considering the complete read of all 130 cases, 285 lesions received “nodule > 3mm” annotations from at least one radiologist, of which 55 (19%) were identified as such by all 4 radiologists and 82 (29%) were identified by only one radiologist. The two-phase reading approach improves radiologist agreement for nodules > 3mm. Even with this approach, however, substantial variability remains across radiologists in the task of lung nodule identification.

Evolution of Adrenal Gland Perfusion with Anti-Angiogenic Therapy

Samuel Armato III, PhD, Heber MacMahon, MD, Michael Maitland, MD, PhD, and colleagues have been investigating the pharmacodynamic effects of sorafenib on normal vasculature. In the radiologic monitoring of therapy, it is important to recognize changes to normal anatomy that may result from the treatment. Many anticancer agents affect both the growth of tumor vasculature and the growth of vessels in normal organs. Monitoring these effects with imaging may be useful to guide selection and dosing of different treatments.
Substantial changes in perfusion over time may suggest a decrease in normal vessel growth as a result of therapy. Patients receiving the VEGF-inhibitor sorafenib underwent CT imaging every six weeks, beginning with a baseline study prior to treatment. A “jog scan” was used to track perfusion through the adrenal glands (the normal organ of interest) over a period of 150 seconds. Sixteen pairs of adrenal images were obtained per jog scan and manually contoured. The mean pixel value of each gland was obtained, and these values were compared over time for any significant changes in pixel value that would represent change in vascular perfusion. The average change in maximum pixel value from baseline to six weeks after treatment initiation was an increase of 4.6% in peak pixel value for both adrenal glands. The manual contouring of adrenal glands in conjunction with calculated maximum pixel values demonstrated change in adrenal perfusion between baseline and the first cycle of therapy. The continued monitoring of perfusion could prove beneficial to the radiologic diagnosis of significant anatomical changes as a result of targeted therapies.

Assessment of Mesothelioma Tumor Response Based on Correlation of Tumor Thickness and Tumor Area

Samuel Armato III, PhD, Heber MacMahon, MD, Philip Caligiuri, MD, Hedy Kindler, MD, and colleagues have been investigating the quantitative assessment of pleural mesothelioma tumor extent, which is necessary to evaluate the efficacy of clinical trials. The manual acquisition of linear tumor thickness measurements across a series of computed tomography (CT) scans is the current standard for tumor response assessment. The purpose of this study was to determine the correlation of response based on linear tumor thickness measurements and response based on tumor area in individual CT sections. Two CT scans from each of 22 mesothelioma patients were collected. Linear tumor thickness measurements were obtained through a computer interface on each patient’s baseline and follow-up scans. These linear measurements provided the standard for comparison with area measurements. A computer interface was used to delineate the tumor border in the same CT scans to obtain tumor area and changes in tumor area between the baseline and follow-up scans of each patient. A comparison of the sum of tumor thickness measurements and tumor area yielded a correlation coefficient of 0.59. With regard to tumor response, a comparison of change in the sum of tumor thickness measurements and change in the total tumor area between the baseline and follow-up scans of the 22 patients yielded a correlation coefficient of 0.83. This relatively high correlation, however, does not capture the extent of variability in the data. For example, among patients with “stable disease,” change in tumor area ranged from a decrease of 58% to an increase of 89%. Although measurements of tumor thickness and tumor area demonstrated moderate correlation, variability in this association requires further investigation.

Evaluation of a CAD Scheme for Polyp Detection Incorporating 3D MTANNs with False-Negative CT Colonography Cases

Kenji Suzuki, PhD, Abraham Dachman, MD, and their colleagues are developing a computer-aided diagnostic (CAD) scheme for detection of polyps in CT colonography (CTC) and evaluating their CAD scheme with false-negative polyps in a large multicenter clinical trial in collaboration with Don C. Rockey, MD, the Southwest Medical Center at the University of Texas. A major challenge in CAD schemes for detection of polyps in
CTC is the detection of “difficult” polyps which radiologists are likely to miss. The purpose was to develop a CAD scheme incorporating 3D massive-training artificial neural networks (3D MTANNs) and to evaluate its performance on false-negative (“missed”) cases in a large multicenter clinical trial. The researchers developed an initial CAD scheme consisting of colon segmentation based on mathematical morphology, detection of polyp candidates based on intensity-based and morphologic feature analysis, and linear discriminant analysis for classification. For reduction of false-positive (FP) detections, they developed a “mixture” of seven expert 3D MTANNs designed to differentiate between polyps and seven types of non-polyps, including folds, stool, the ileocecal valve, and rectal tubes. An independent database that consisted of CTC scans of 614 patients obtained from a large multicenter clinical trial in which 15 institutions participated nationwide was used. Each patient was scanned in the supine and prone positions with collimations of 1.0-2.5 mm and reconstruction intervals of 1.0-2.5 mm. All patients underwent “reference-standard” optical colonoscopy. One hundred fifty-five patients had clinically significant polyps. Among them, about 45% patients received false-negative interpretations in CTC. For testing of the groups CAD scheme with 3D MTANNs, 14 cases with 14 polyps/masses were randomly selected from the false-negative cases where lesions were visible in both supine and prone scans retrospectively. Lesion sizes ranged from 6-35 mm, with an average of 10 mm. The initial CAD scheme detected 71.4% (12/14) of “missed” polyps, including sessile polyps and polyps on folds, with 18.9 (264/14) FP per patient. The 3D MTANNs removed 75% (197/264) of the FPs without loss of any true positives; thus, the performance of the team’s CAD scheme was improved to 4.8 (67/14) FPs per patient. Using the CAD scheme incorporating 3D MTANNs, 71.4% of polyps “missed” by radiologists in the trial were detected correctly, with a reasonable number of FPs. Thus, the CAD scheme would be useful for detecting “difficult” polyps which radiologists are likely to miss, thus potentially improving radiologists’ sensitivity in their detection of polyps in CTC.

**Figure 50:** A patient with a small (7 mm) sessile polyp (one of the major sources of false-negative interpretations by radiologists) that was “missed” in a clinical trial. (a) our CAD scheme incorporating 3D MTANNs correctly detected the polyp and pointed it by an arrow in an axial CTC image, (b) the polyp in the 3D endoluminal view, and (c) 3D volume rendering of the colon with three computer outputs indicated by yellow circles (one in the rectum is a true-positive detection and the other two are FP detections).

**Figure 51:** Free-response receiver-operating-characteristic (FROC) curves for the mixture of expert 3D MTANNs obtained with ensemble training and the mixture of expert 3D MTANNs obtained with standard training for 26 polyps and 489 non-polyps (FPs). The FROC curve for the mixture of expert 3D MTANNs indicates a reduction in the FP rate from 4.9 to 2.2 per patient at a 96% by-polyp sensitivity level (100% by-patient sensitivity).
into several segments, and ten non-polyps were sampled from the center of each segment so that sets of non-polyp samples covered diverse difficulties. The colleagues trained several 3D MTANNs with several sets of non-polyps so that each 3D MTANN became an expert for the non-polyps at a certain level of difficulty and then combined expert 3D MTANNs with a mixing artificial neural network (ANN) to form a “mixture of expert” 3D MTANNs. The database consisted of CTC datasets acquired from 100 patients, including 26 polyps. The initial CAD scheme was applied to this CTC database. FP sources included haustral folds, stool, colonic walls, the ileocecal valves, and rectal tubes. The mixture of expert 3D MTANNs distinguished all polyps correctly from more than 50% of the non-polyps. Thus, the mixture of expert 3D MTANNs was able reduce one half of the FPs generated by a computerized polyp detection scheme while the original sensitivity was maintained. The group then compared the effectiveness of ensemble training with that of training with manually selected cases. The performance of the 3D MTANNs with ensemble training was superior to that of the 3D MTANNs trained with manually selected cases.

**Usefulness of Artificial Neural Network for Differential Diagnosis of Hepatic Masses on CT Images**

Kunishige Matake, MD, Kunio Doi, PhD, and their colleagues applied an artificial neural network (ANN) for differential diagnosis of certain hepatic masses on CT images and evaluated the effect of ANN output on radiologist diagnostic performance. Clinical cases included 120 cases of hepatic disease. The ANN is designed to differentiate four hepatic masses (hepatocellular carcinoma, intra-hepatic peripheral cholangiocarcinoma, hemangioma, and metastasis) by using nine clinical parameters and 24 radiological findings in dual-phase contrast-enhanced CT images. Thus, the ANN consisted of 33 input units and four output units. Subjective ratings for the 24 radiological findings were provided independently by two attending radiologists. All clinical cases were used for training and testing of the ANN by implementation of a round-robin technique. In the observer tests, CT images of all 120 cases (30 cases for each disease) were used. CT images were viewed by seven radiologists first without and then with ANN output. Radiologist performance was evaluated by using ROC analysis on a continuous rating scale. Averaged area under the ROC curve for ANN alone was 0.961. The diagnostic performance of seven radiologists increased from 0.888 to 0.934 (P < .02) when they used ANN output. The ANN can provide useful output as a second opinion to improve radiologist diagnostic performance in the differential diagnosis of hepatic masses seen on contrast-enhanced CT.

**Feature-Based Characterization of Motion-Contaminated Calcified Plaques in Cardiac Multidetector CT**

In coronary calcium scoring, motion artifacts affecting calcified plaques are commonly characterized using descriptive terms, which incorporate an element of subjectivity in their interpretations. Quantitative indices may improve the objective characterization of these motion artifacts. MSTP student Martin King, and Maryellen Giger, PhD, Kenji Suzuki, PhD, and Xiaochuan Pan, PhD are investigating an automated method for generating twelve quantitative indices, i.e. features that characterize the motion artifacts affecting calcified plaques, is presented. This method consists of using the rapid phase-correlated region-of-interest (RP-ROI) tracking algorithm for reconstructing ROI images of calcified plaques automatically from the projection data obtained during a cardiac scan, and applying methods for extracting features from these images. The twelve features include two dynamic, six morphological, and four intensity-based features. The two dynamic features are 3-D velocity and 3-D acceleration. The six morphological features include edge-based volume, threshold-based volume, sphericity, irregularity, average margin gradient, and variance of margin gradient. The four intensity-based features are maximum intensity, mean intensity, minimum intensity, and standard deviation of intensity. The twelve features were extracted from 54 reconstructed sets of simulated 4D images from the dynamic NCAT phantom involving six calcified plaques under nine heart rate/multi-sector gating combinations. In order to determine how well the twelve features correlated with a plaque motion index, which was derived from the trajectory of the plaque, partial correlation coefficients adjusted for heart rate, number of gated sectors, and mean feature values of the six plaques were calculated for all twelve features. Features exhibiting stronger correlations (|r| [0.60,1.00]) with the motion index were 3-D velocity, maximum intensity, and standard deviation of intensity. Features demonstrating stronger correlations (|r| [0.60,1.00]) with other features mostly involved intensity-based features. Edge-based volume/irregularity and average margin gradient/variance of margin gradient were the only two feature pairs out of twelve with stronger correlations that did not involve intensity-based features. Automatically extracted features of the motion artifacts affecting calcified plaques in cardiac CT images potentially can be used to develop models for predicting image assessibility with respect to motion artifacts.

**Computerized Assessment of Motion-Contaminated Calcified Plaques in Cardiac Multidetector CT**

MSTP student Martin King is working with Maryellen Giger, PhD, Kenji Suzuki, PhD, Xiaochuan Pan, PhD, Diana Bardo, MD and Brent Greenberg, MD to develop an automated method for evaluating the image quality
of calcified plaques with respect to motion artifacts in non-contrast-enhanced cardiac computed tomography (CT) images is introduced. This method involves using linear regression (LR) and artificial neural network (ANN) regression models for predicting two patient-specific, ROI-specific, reconstruction-specific and temporal phase-specific image quality indices. The first is a plaque motion index, which is derived from the actual trajectory of the calcified plaque and is represented on a continuous scale. The second is an assessability index, which reflects the degree to which a calcified plaque is affected by motion artifacts, and is represented on an ordinal five-point scale. Two sets of assessability indices were provided independently by two radiologists experienced in evaluating cardiac CT images. Inputs for the regression models were selected from twelve features characterizing the dynamic, morphological, and intensity-based properties of the calcified plaques. Whereas the LR-velocity (LR-V) model used only a single feature (3-D velocity), the LR-multiple (LR-M) and ANN regression models used the same subsets of these twelve features selected through stepwise regression. The regression models were parametrized and evaluated using a database of simulated calcified plaque images from the dynamic NCAT phantom involving nine heart rate/multi-sector gating combinations and forty cardiac phases covering two cardiac cycles. Six calcified plaques were used for the plaque motion indices and three calcified plaques were used for both sets of assessability indices. In one configuration, images from the second cardiac cycle were used for feature selection and regression model parametrization, whereas images from the first cardiac cycle were used for testing. With this configuration, repeated measures concordance correlation coefficients (CCC) and associated 95% confidence intervals for the LR-V, LR-M, and ANN models were $0.817 [0.785, 0.848]$, $0.894 [0.869, 0.916]$, and $0.917 [0.892, 0.936]$ for the plaque motion indices. For the two sets of assessability indices, CCC values for the ANN model were $0.843 [0.791, 0.877]$ and $0.793 [0.747, 0.828]$. Note that these two CCC values were statistically greater than the CCC value of $0.689 [0.648, 0.727]$ comparing the two sets of assessability indices with each other. These preliminary results suggest that the variabilities of assessability indices provided by regression models can lie within the variabilities of the indices assigned by independent observers. Thus, the potential exists for using regression models and assessability indices for determining optimal phases for cardiac CT image interpretation.

Figure 52. (a) Phase-correlated ROI reconstructions and (b) corresponding edge-based segmentation of a RCA calcified plaque. Cardiac phases average $\phi$ are specified for the first vertical column of images. Images within a horizontal row are reconstructed at phase intervals of approximately 0.01. For the reconstructions shown in (a) L: 50, W: 400 HU.

Figure 53. (top) shows the relationship between plaque motion indices and cardiac phase for RCA1 plaques (heart rate of 66 bpm), illustrating their phase correlation. The dark solid line represents the predicted values from the ANN regression model and the light dashed line represents the actual motion values (from the projection data of the NCAT phantom). Similarly (but for the human determined assessability index truth), the bottom shows the relationship between assessability indices and cardiac phase for RCA1 plaques (heart rate of 66 bpm). The dark solid line represents the predicted values from the ANN regression model, and the light dashed line represents the actual human-assigned assessability index.

Quantitative Analysis of Lesions in Breast Images

Comparison of CAD on Digitized Screen-Film Mammograms and Full-Field Digital Mammograms

As part of her doctoral dissertation, Laura Yarusso, BS, working in conjunction with Robert Nishikawa, PhD, Alexandra Edwards, MA, and John Papaioannou, MS, has compared the performance of different components of a computer-aided detection (CADe) scheme for clustered calcifications on mammograms. The goals of this research are to measure and compare image quality between full-field digital mammography (FFDM) and digitized screen-film mammography (dSFM), and to investigate the effect of image quality differences on the multiple components of the CADe scheme for the detection of clustered microcalcifications. The main hypothesis tested was that the superior image quality of FFDM
relative to dSFM would result in improvements to multiple aspects of CADE performance. Several image quality metrics were measured for FFDM and dSFM, including physical imaging characteristics and detector temporal stability. Although optimized for dSFM, all stages of their CADE scheme performed comparably or better when applied to FFDM compared with dSFM images. Among the results, the higher signal-to-noise-ratio (SNR) of FFDM led to improved computerized detection sensitivity, and the improved temporal stability offered by FFDM resulted in better CADE reproducibility. Computer-calculated features were robust in classifying true-positive and false-positive detections in FFDM compared with dSFM images. Their results indicate that extensive modifications might not be necessary to transition their CADE scheme to FFDM, except for classifier retraining with patient data. This was the first investigation to rigorously study the relationship between image quality and CADE performance, particularly for FFDM and dSFM. A long-term goal of this research is to develop a framework for modifying CADE schemes based on changes in the image acquisition system. Such a framework would benefit the CADE field by guiding initial modifications of CADE schemes for new imaging systems before large patient databases become available for complete reoptimization. The would facilitate the development of CADE schemes for next generation of mammography detectors.

**Simulated Mammograms**

Payam Seifi, MSc, Michael Chinander, PhD and Robert Nishikawa, PhD have developed a method to produce simulated mammograms. The method models the physics of the x-ray detector to convert a distribution of x-rays exiting from the breast into the final image. High fidelity images of cadaver breasts imaged directly on film with a geometric magnification factor of 2 are used as input to the model. Comparisons of the noise, contrast, and resolution properties of the simulated images match to within 5-10% the properties of an actual mammographic image of the same cadaver tissue. An observer study was performed to see if humans could distinguish real mammograms from the simulated images. Five readers, all experienced in looking at mammograms, read 130 images (half real and half simulated). For each image, the reader gave his or her confidence that the image was from a real mammogram (cadaver breasts were used in this experiment) on a 100-point scale. ROC analysis was used to test whether the readers could tell the difference between the real and simulated mammograms. The average area under the ROC curve (AUC) was 0.530 with a standard error of 0.042. In a ROC experiment a value of 0.5 means the reader was essentially guessing and a perfect score is 1.0. It was concluded, therefore, that the readers could not tell the difference between real and the simulated images.

**Computerized Identification of Clustered Calcifications for Breast Tomosynthesis**

Ingrid Reiser, PhD and Robert Nishikawa, PhD are developing a computer-aided detection (CADE) scheme to identify clustered calcifications in digital breast tomosynthesis images. Digital breast tomosynthesis (DBT) is a promising modality for breast imaging in which an anisotropic volume image of the breast is obtained. This algorithm operates on the projection views only. Therefore it does not depend on reconstruction, and is computationally efficient. Candidate signals are identified in each of the 11 projection images. These signals are then projected into a virtual breast volume. Each signal in the virtual breast volume is then re-projected into each of the 11 projections. The signals are then segmented and features were extracted. Because the projection images have high noise, accurate signal segmentation is very difficult. Therefore only intensity-based features, which are less dependent on accurate segmentation, were used. Linear-discriminant analysis was used to distinguish between actual calcifications and computer-detected false positives. In their preliminary work, the algorithm was developed using a database of 30 image sets with microcalcifications, and 30 normals. The patient data was acquired on the first DBT prototype at Massachusetts General Hospital. Algorithm sensitivity was estimated to be 86% at 1.3 false positive clusters per volume, which is below that of current microcalcification detection algorithms for full-field digital mammography. Because of the small number of patient cases, algorithm parameters were not optimized and one linear classifier was used. An actual limitation of their approach may be that the signal-to-noise ratio in the projection images is too low for microcalcification detection. This indicates that clustered microcalcifications may be more difficult to visualize in tomosynthesis images than in conventional mammograms.
Comparison of Softcopy and Hardcopy Reading of Full-Field Digital Mammograms

Robert Nishikawa, PhD, leads a multi-institutional study to compare radiologists’ performance in detecting breast cancer when reading full-field digital mammograms displayed either on softcopy monitors or printed on film. This study was part of the Digital Mammography Screening Trial (DMIST), which was conducted by the American College of Radiology Imaging Network (ACRIN). A reader study was conducted in which 30 radiologists read full-field digital screening mammograms displayed on high resolution monitors (softcopy digital) and printed on film (hardcopy digital). The study was approved by the local IRB at each participating site. Three hundred thirty-three cases were selected from the DMIST screening study (n=49,528). Of these, 117 cases were from patients who were diagnosed with breast cancer within 15 months of the screening mammogram. The digital mammograms were displayed on mammography workstations supplied by the manufacturer and printed on film to the manufacturer’s specifications. Readers read both hard and softcopy images six weeks apart. Each radiologist read a subset of the total images. The 30 readers were assigned to cases imaged from one of three different full-field digital mammography systems. Each radiologist assigned a malignancy score based on their overall impression, using a 7-point scale where 1=’definitely not malignant’ and 7=’definitely malignant’. There were no significant differences in the areas under the ROC curves (AUC) for the primary comparison. The AUC for softcopy was 0.75 and for hardcopy it was 0.76. The 95% CI for AUC difference was [-0.04, 0.01] and the p-value was 0.36. Secondary analyses showed no significant differences in AUC based on manufacturer type, lesion type, or breast density. It was concluded that softcopy reading does not provide an advantage in the interpretation of digital mammograms. Clinically, given the current softcopy workstations, reading digital mammograms on film or on monitors should not affect radiologists’ ability to detect breast cancer.

Experimental Determination of Subjective Similarity for Pairs of Clustered Microcalcifications on Mammograms

Presentation of images of lesions similar to that of an unknown lesion might be useful to radiologists in distinguishing between benign and malignant clustered microcalcifications on mammograms. Investigators have been developing computerized schemes to select similar images from large databases. However, whether selected images are really similar in appearance is not examined for most of the schemes. In order to retrieve images that are useful to radiologists, the selected images must be similar from radiologists’ diagnostic points of view. Therefore, graduate student Chisako Muramatsu, BS, Qiang Li, PhD, Robert Schmidt, MD, Gillian Newstead, MD, Kunio Doi, PhD, and their colleagues obtained the data of radiologists’ subjective similarity for pairs of clustered microcalcification images from a number of observers, and the intra- and inter-observer variations and the intergroup correlations were determined to investigate whether reliable similarity ratings by human observers can be determined. Nineteen images of clustered microcalcifications, each of which was paired with six other images, were selected for the observer study. Thus, subjective similarity ratings for 114 pairs of clustered microcalcifications were determined by each observer. Thirteen breast, ten general, and ten nonradiologists participated in the observer study; some of them completed the study multiple times. Although the intraobserver variations for the individual readings and the interobserver variations for pairs of observers were not small, the interobserver agreements were improved by taking the average of readings by the same observers. When the similarity ratings by a number of observers were averaged among the groups of breast, general, and nonradiologists, the mean differences of the ratings between the groups decreased, and good concordance correlations (0.846, 0.817, and 0.785) between the groups were obtained. The result indicates that reliable similarity ratings can be determined by use of this method, and the average similarity ratings by breast radiologists can be considered meaningful and useful for the development and evaluation of a computerized scheme for selection of similar images.

A Dual-Stage Method for Lesion Segmentation on Digital Mammograms

Mass lesion segmentation on mammograms is a challenging task since mass lesions are usually embedded and hidden in varying densities of parenchymal tissue structures. With graduate student Yading Yuan, Maryellen Giger, PhD, Kenji Suzuki, PhD, and Charlene Sennett, MD are developing a method for automatic delineation of lesion boundaries on digital mammograms. This method utilizes a geometric active contour model that minimizes an energy function based on the homogeneities inside and outside of the evolving contour. Prior to the application of the active contour model, a radial gradient index (RGI) based segmentation method is applied to yield an initial contour closer to the lesion boundary location in a computationally efficient manner. Based on the initial segmentation, an automatic background estimation method is applied to identify the effective circumstance of lesion, and a dynamic stopping criterion is implemented to terminate the contour evolution when it reaches the lesion boundary. By using a full-field digital mammography database with 739 images, they quantitatively compare the proposed algorithm with a conventional region-growing method and a RGI-based algorithm by use of the area overlap ratio between computer segmentation and manual segmentation by an expert radiologist. At an overlap threshold of 0.4, 85% of the images are correctly segmented with the proposed method, while only 69% and 73% of the images are...
correctly delineated by the previously developed region-growing and RGI methods, respectively. This resulting improvement in segmentation is statistically significant.

Evaluation of CADx on a Large Clinical Full-Field Digital Mammographic Dataset

Hui Li, PhD and Maryellen Giger, PhD are investigating methods to convert and optimize their previously developed computerized analysis methods for use with images from full-field digital mammography (FFDM) for breast mass classification in order to aid in the diagnosis of breast cancer. An institutional review board approved protocol was obtained, with waiver of consent for retrospective use of mammograms and pathology data. 739 full-field digital mammographic images, which contained 287 breast lesions, were retrospectively collected. Lesion margins were delineated by an expert breast radiologist as the truth for the evaluation. The computerized image analysis method consisted of several steps: 1) identified lesions were automatically extracted from the parenchymal background using computerized segmentation methods; 2) a total of 29 image characteristics (mathematical descriptors) were automatically extracted from image data of the lesions and surrounding tissues; and 3) selected features were merged into an estimate of the probability of malignancy using a Bayesian artificial neural network classifier. Performance of the analyses was evaluated at various stages of the conversion using receiver operating characteristic (ROC) analysis. An AUC value of 0.81 was obtained in the task of distinguishing between malignant and benign mass lesions in a round-robin by case evaluation on the entire FFDM dataset. They failed to show a statistically significant difference (P value=0.83) as compared with results from their previous study in which the classification was performed on digitized screen-film mammograms (SFMD). Thus, the computerized analysis methods developed on digitized screen-film mammography can be converted for use with FFDM. Results show that the computerized analysis methods for the diagnosis of breast mass lesions on FFDM are promising, and can potentially be used to aid clinicians in the diagnostic interpretation of FFDM.

Preliminary Studies on Grid-Based Optimization for Breast CAD

In recent years, datamining and data driven discovery has begun to be incorporated into research of many disciplines. The basic idea is that massive amounts of data may contain hidden structure and rich information, previously unavailable for characterization within smaller subgroups. The digital age of medical imaging provides an ever growing archive of data that potentially holds the key to advancing computerized detection and diagnosis. Graduate student Andrew Jamieson, along with Maryellen Giger, PhD, Lorenzo Pesce, PhD, and Ian Foster, PhD, is developing a stable Grid-based
computer-aided diagnosis method for breast mass lesions work-flow based off of previously generated and tested algorithms. The computing power of the Grid was used to conduct some sample large scale image analysis calculations. Specifically, they used 850 biopsy proven SFMD ROIs to compute the diagnostic performance of 15 and 29 individual mathematical descriptor features. In each instance, they also varied a parameter setting, Gaussian width, for the lesion segmentation algorithm (RGI) across 40 and 60 different increments. Additionally, borrowing from methods used in gene expression, they have begun to explore statistical methods capable of discerning the significance in differences between the large quantities of resulting output. This involves a bootstrap method of resampling from the original image set to characterize the error and variability of feature performance for different sample sizes. They found in their studies that Grid-based CAD holds strong potential for future development in many regards.

**Power Spectral Analysis of Mammographic Parenchymal Patterns for Breast Cancer Risk Assessment**

Hui Li, PhD and Maryellen Giger, PhD, in collaboration with Funmi Olopade, MD of the Department of Medicine are investigating the usefulness of power law spectrum analysis on mammographic parenchymal patterns in breast cancer risk assessment. Mammograms from 172 subjects: 30 women with the BRCA1 or BRCA2 gene mutation and 142 low-risk women were retrospectively collected and digitized. Since age is a very important risk factor, 60 low-risk women were randomly selected from the 142 low-risk subjects and were age-matched to the 30 gene mutation carriers at 5-year intervals. Regions-of-interest (ROIs) were manually selected from the central breast region behind the nipple of these digitized mammograms and subsequently used in power spectrum analysis. The output from power law analysis, in differentiating between gene mutation carriers and low-risk women was assessed using receiver operating characteristic (ROC) analysis. Power spectrum analysis of mammograms yielded in ROC analyses AUC values of 0.90 and 0.89 were achieved with this single feature in distinguishing between the gene-mutation carriers and the low-risk women, in the entire database and the age-matched group, respectively. The BRCA1/BRCA2 gene-mutation carriers and low-risk women have different mammographic parenchymal patterns. It is expected that women identified as high risk by computerized feature analyses might potentially be more aggressively screened for breast cancer.

**Breast Ultrasound Computer-Aided Diagnosis: Performance on a Large Clinical Diagnostic Population**

Karen Drukker, PhD, Charlene Sennett, MD, and Maryellen Giger, PhD are evaluating the performance of a computer-aided diagnosis (CADx) workstation in the task of classifying cancer in a realistic dataset representative of a clinical diagnostic breast ultrasound practice. The database in this study consisted of consecutive diagnostic breast ultrasound examinations acquired with a Philips HDI5000 scanner, and collected under IRB protocols and HIPAA constraints. 695 patients consented to participate in this study, of which 187 had no sonographic abnormality, while the remaining 508 presented with one or more lesions (a total of 1046 distinct abnormalities). Approximately 36% of the patients had been referred to biopsy and the clinical positive predictive value for biopsy was 40% (resulting in a 15% cancer prevalence). Only the image data of the group of patients presenting with lesions (508 patients) were used in the image analysis study. We present results both for patients for whom lesion pathology was proven by either biopsy or aspiration, and for all patients irrespective of biopsy-status. The ability of the CADx workstation to distinguish malignancies from benign lesions was evaluated with a leave-one-out-by-case analysis. In the task of distinguishing cancer from all other lesions sent to biopsy, the CADx workstation obtained an area under the ROC curve (AUC value) of 0.88, obtaining 100% sensitivity at 26% specificity. When analyzing all lesions irrespective of biopsy-status, more representative of actual clinical practice, the CADx scheme obtained an AUC of 0.90 and 100% sensitivity at 30% specificity. In conclusion, current levels of computer performance warrant a clinical evaluation of the potential of sonographic CADx.

**The Effect of Image Quality on the Appearance of Lesions on Breast Ultrasound – Implications for CADx**

With the emergence of recent technology in breast ultrasound, sonographic image quality has changed profoundly. Most notably, the technique of real-time spatial compounding impacts the appearance of lesions and parenchyma. During image acquisition, spatial compounding can be turned on or off at the discretion of the radiologist, but this information is not stored along with the image data. Karen Drukker, PhD, Charlene Sennett, MD, and Maryellen Giger, PhD are investigating the computer’s ability to distinguish between lesions imaged with and without spatial compounding - using either single image features or a Bayesian neural net (BNN) - was assessed using ROC analysis. Our database consisted of consecutively collected HDI5000 images of 129 lesions imaged without spatial compounding (357 images, cancer prevalence of 18%) and 370 lesions imaged with spatial compounding (965 images, cancer prevalence 15%). These were used in automated feature selection and BNN training. An additional 33 lesions were imaged for which identical views with and without spatial compounding were available (70 images, cancer prevalence 15%). These served as an independent test dataset. Lesions were outlined by a radiologist and
image features, mathematically describing lesion characteristics, were calculated. In feature selection, the 4 best performing features were related to gradient strength and entropy. The average gradient strength within a lesion obtained an area under the ROC curve (AUC) of 0.78 in the task of distinguishing lesions imaged with and without spatial compounding. The BNN - using 4 features - achieved an AUC on the independent test dataset of 0.98 in this task. The sonographic appearance of breast lesions is affected by spatial compound imaging and lesion features may be used to automatically separate images as obtained with or without this technique. In computer-aided diagnosis (CAD), it will likely be beneficial to separate images as such before using separate classifiers for assessment of malignancy.

Volumetric Texture Analysis of Breast Lesions on Contrast-Enhanced Magnetic Resonance Images

Weijie Chen, PhD and Maryellen Giger, PhD are investigating automated image analysis that aims to extract relevant information from contrast-enhanced magnetic resonance images (CE-MRI) of the breast and improve the accuracy and consistency of image interpretation. In this work, they extend the traditional 2D gray-level co-occurrence matrix (GLCM) method to investigate a volumetric texture analysis approach and apply it for the characterization of breast MR lesions. Our database of breast MR images was obtained using a T1-weighted 3D spoiled gradient echo sequence and consists of 121 biopsy-proven lesions (77 malignant and 44 benign). A fuzzy c-means clustering (FCM) based method is employed to automatically segment 3D breast lesions on CE-MRI images. For each 3D lesion, a nondirectional GLCM is then computed on the first postcontrast frame by summing 13 directional GLCMs. Texture features are extracted from the non-directional GLCMs and the performance of each texture feature in the task of distinguishing between malignant and benign breast lesions is assessed by receiver operating characteristics (ROC) analysis. Our results show that the classification performance of volumetric texture features is significantly better than that based on 2D analysis.

Joint Feature Selection and Classification using Bayesian Neural Networks with ARD Priors: Simulation Studies

A Bayesian neural network (BNN) with automatic relevance determination (ARD) priors has the ability to assess the relevance of each input feature while training the neural network. Weijie Chen, PhD, Richard Zur, and Maryellen Giger, PhD are investigating the potential use of BNN with ARD priors for joint feature selection and classification in computer-aided diagnosis (CAD) in medical imaging. They designed four simulation studies corresponding to four feature spaces: (1) uncorrelated linear feature space of multivariate normal distributions; (2) uncorrelated nonlinear feature space of multivariate normal distributions; (3) correlated nonlinear feature space of multivariate normal distributions; (4) nonlinear feature space of the exclusive-OR pattern. Each feature space consisted of a number of useful features and a number of useless features. For each of the four feature spaces, three combinations of feature selection and classifier training are investigated: (A) linear discriminant analysis (LDA) trained with stepwise LDA selected features; (B) Bayesian neural network trained with stepwise LDA selected features; (C) Bayesian neural network trained with ARD selected features. The ARD-BNN approach is shown to have the ability to select a near optimal subset of features on the designed linear feature space and the ability to select the optimal subset of features on the designed nonlinear feature spaces where the stepwise LDA approach fails. We believe that ARD-BNN is a promising method for pattern recognition in CAD in medical imaging.

An Image Database Management System for Conducting CAD Research

The development of image databases for CAD research is not a trivial task. The collection and management of images and their related metadata from multiple sources is a time-consuming but necessary process. By standardizing and centralizing the methods in which these data are maintained, one can generate subsets of a larger database that match the specific criteria needed for a particular research project in a quick and efficient manner. A research-oriented management system of this type is highly desirable in a multi-modality CAD research environment. Graduate student Nicholas Gruszauskas, along with Karen Drukker, PhD and Maryellen Giger, PhD are designing an online, web-based database system for the storage and management of research-specific medical image metadata for use with four modalities of breast imaging: screen-film mammography, full-field digital mammography, breast ultrasound and breast MRI. The system was designed to consolidate data from multiple clinical sources and provide the user with the ability to anonymize the data. Input concerning the type of data to be stored as well as desired searchable parameters was solicited from researchers in each modality. The backbone of the database was created using MySQL. A robust and easy-to-use interface for entering, removing, modifying and searching information in the database was created using HTML and PHP. This standardized system can be accessed using any modern web-browsing software and is fundamental for various research projects on computer-aided detection, diagnosis, cancer risk assessment, multi-modality lesion assessment, and prognosis. The CAD database system stores large amounts of research-related metadata and successfully generates subsets of cases that match the user’s desired search criteria.
New Fields for Computer-Aided Diagnosis

Computer Detection of Prostate Carcinoma in Histology Images

Graduate student Yahui Peng and Yulei Jiang, PhD, collaborating with a Cornell University pathologist and former University of Chicago faculty, Dr. Ximing Yang, and University of Chicago Pathology Professor Emeritus, Dr. Francis Straus, have been developing computer analysis methods for prostate cancer histology images. Their goal is to use computer image analysis to help pathologists diagnose prostate cancer more accurately. Yahui Peng presented at the American Urological Association (AUA)’s 2007 Annual Meeting their initial results on a technique analyzing images of prostate tissue stained with a triple antibody cocktail (AMACR/p63/34_E12). On a validation set of 272 images the computer achieved 88% sensitivity and 90% specificity in identifying digital snapshot of histology images that contain prostate carcinoma. The computer was able to identify prostate cancer by recognizing the specific colors associated with stained benign basal cells and malignant cytoplasm. They are also developing computer techniques to analyze the workhorse H&E images. These techniques are used to segment cell nuclei and other structural elements important for the diagnosis of prostate carcinoma, and further automatically recognize the prostate glandular structure. These techniques together will form a basis for automated identification of prostate carcinoma in the standard H&E images of prostate tissue.

Temporal Radiographic Texture Analysis in the Assessment of Osteolysis

Periprosthetic osteolysis is one of the most serious long-term problems in total hip arthroplasty. It is caused by the body’s inflammatory response to submicron polyethylene particles worn from the hip implant, and it leads to bone loss and structural deterioration in the surrounding bone. Recent PhD-graduate Joel Wilkie, PhD, Maryellen Giger, PhD, Lorenzo Pesce, PhD, and John Martell, MD also assessed any potential age-dependence on osteolysis development in the database, and investigated whether RTA and tRTA performance varies across age groups. This was accomplished by dividing the 202-case database into three age groups, measuring osteolysis-free survival curves for these groups, and separately testing the performance of RTA and tRTA features within these groups. Results indicated that younger patients in the database tend to develop osteolysis more quickly than older patients, and this is consistent with previous results. Patient age at surgery tended to have opposite effects on RTA and tRTA performance; however the differences were not shown to be statistically significant. The performance of RTA appeared to improve with increasing age group while the performance of tRTA tended to be better for the younger age groups. These results suggest that a patient’s age at surgery may have an effect on texture performance and should be further investigated for its potential clinical significance.

Imputation Methods for Temporal Radiographic Texture Analysis in the Detection of Periprosthetic Osteolysis

Recent PhD graduate Joel Wilkie, PhD, Maryellen Giger, PhD, Lorenzo Pesce, PhD, and John Martell, MD also investigated imputation methods for use with temporal radiographic texture analysis (tRTA) to help detect periprosthetic osteolysis. One method involves merging feature measurements at multiple time points using a linear discriminant analysis (LDA) or Bayesian artificial neural (BANN).
The major drawback of this method is that several cases do not meet the inclusion criteria because of missing data, i.e., missing image data at the necessary time intervals. In this research, we investigated imputation methods to fill in missing data points using feature averaging, linear interpolation, and first and second order polynomial fitting. The database consisted of 101 THR cases with full data available from four follow-up intervals. For 200 iterations, missing data were randomly created to simulate a typical THR database, and the missing points were then filled in using the imputation methods. ROC analysis was used to assess the performance of the CAD scheme in distinguishing between osteolysis and normal cases for the full database and each simulated database. The calculated values from the 200 iterations showed that the imputation methods produced negligible bias, and substantially decreased the variance of the AUC estimator, relative to excluding incomplete cases. The best performing imputation methods were those that heavily weighted the data points closest to the missing data. The results suggest that these imputation methods appear to be acceptable means to include cases with missing data for tRTA.

**Development of a Computer-Aided Diagnostic Scheme for Detection of Interval Changes in Successive Whole-Body Bone Scans**

Bone scintigraphy is the most frequent examination among various diagnostic nuclear medicine procedures. It is a well-established imaging modality for the diagnosis of osseous metastasis and for monitoring osseous tumor response to chemotherapy and radiation therapy. Although the sensitivity of bone scan examinations for detection of bone abnormalities has been considered to be relatively high, it is time consuming to identify multiple lesions such as bone metastases of prostate and breast cancers. In addition, it is very difficult to detect subtle interval changes between two successive abnormal bone scans, because of variations in patient conditions, the accumulation of radioisotopes during each examination, and the image quality of gamma cameras. Therefore, Junji Shiraishi, PhD, Qiang Li, PhD, Daniel Appelbaum, MD, Yonglin Pu, MD, and Kunio Doi, PhD developed a new computer-aided diagnostic (CAD) scheme for the detection of interval changes in successive whole-body bone scans by use of temporal subtraction image which was obtained with a nonlinear image-warping technique. They carried out 58 pairs of successive bone scans in which each scan included both posterior and anterior views. They determined 107 “gold-standard” interval changes among the 58 pairs based on the consensus of three radiologists. Their computerized scheme consisted of seven steps, i.e., initial image density normalization on each image, image matching for the paired images, temporal subtraction by use of the nonlinear image-warping technique, initial detection of interval changes, rule-based tests by use of 16 image features for removing some false positives, and display of the computer output for identified interval changes. One hundred seven gold standard interval changes included 71 hot lesions (uptake was increased compared with the previous scan, or there was new uptake in the current scan) and 36 cold lesions (uptake was decreased or disappeared) for anterior and posterior views. The overall sensitivity in the detection of interval changes, including both hot and cold lesions evaluated by use of the resubstitution and the leave-one-case-out methods, were 95.3%, with 5.97 false positives per view, and 83.2% with 6.02, respectively. The temporal subtraction image for successive whole-body bone scans has the potential to enhance the interval changes between two images, which also can be quantified. Furthermore, the CAD scheme for the detection of interval changes by use of temporal subtraction images would be useful in assisting radiologists’ interpretation on successive bone scan images.

**Integrating PET and CT Information to Improve Diagnostic Accuracy for Lung Nodules: A Semiautomatic Computer-Aided Method**

Yongkang Nie, MD, Qiang Li, PhD, Feng Li, MD, Yonglin Pu, MD, Daniel Appelbaum, MD, and Kunio Doi, PhD developed and evaluated 3 semiautomatic computer-aided diagnostic (CAD) schemes for distinguishing between benign and malignant pulmonary nodules by use of features extracted from CT, 18F-FDG PET, and both CT and 18F-FDG PET. Clinical cases in this study included 92 consecutive cases of pulmonary nodules (<3cm) in patients who underwent both thoracic CT and whole-bode PET/CT. Forty-two of the nodules were malignant and 50 benign, as confirmed by pathologic examination and clinical follow-up. The interval between CT and PET was less than 1 month. Four clinical parameters, including patient age, sex, smoking status, and history of previous malignancy, were used for the CAD schemes. Sixteen CT features based on size, shape, margin, and internal structure of nodules were independently rated subjectively by 2 chest radiologists. Four PET features were viewed on a PET/CT workstation. CAD schemes based on clinical parameters together with CT features, PET features, and both CT and PET features were then used to differentiate benign from malignant nodules. Finally, the output from the CAD schemes was evaluated by use of ROC analysis. When the research team used clinical parameters and CT features as input units (CAD scheme 1), the area under the ROC curve (Az value) of the CAD scheme was 0.83. When they used clinical parameters and PET features as input units (CAD scheme 2), the area under the ROC curve (Az value) of the CAD scheme was 0.85.
input units (CAD scheme 2) the Az value for the computer output was 0.91. However, when they used all data as input units (CAD scheme 3), the Az value for the computer output was 0.95. The performance of CAD scheme 3 was better than that of CAD scheme 1 or 2. A statistically significant difference existed between the Az values of CAD schemes 3 and 2 (P= 0.037) and between those of CAD schemes 3 and 1 (P=0.015). The researchers CAD scheme based on both PET and CT was better able to differentiate benign from malignant pulmonary nodules than were the CAD schemes based on PET alone and CT alone.

**Computerized Analysis of Double-Contrast Barium Images for Characterization of the Area Gastrica**

Graduate student Robert Tomek, Maryellen Giger, PhD, and Arunas Gasparitis, MD are investigating computerized methods to characterize texture patterns of the area gastrica from double-contrast barium examinations. Although computerized texture analysis has been performed on medical images in a variety of fields, very little has been performed on the stomach. The database in this study contained 78 digital images from double-contrast barium examinations with a 1024 x 1024 matrix size, each image being from one of 54 normal and 24 abnormal (with disease) cases. For each image, a square region of interest (ROI) was collected. Four texture features were used: standard deviation, first moment of the power spectrum, root-mean square variation, and the Minkowski dimension. The classification using these features was done using linear discriminate analysis (LDA) with round robin techniques, and assessed by computing the area under the ROC curve (AUC). For 64 pixel square ROIs, the AUC values ranged from 0.58 to 0.86, and when using 128 pixel square ROIs, the AUC values ranged from 0.65 to 0.89. This study showed that computerized methods can be used to classify images taken during double-contrast barium examinations as either having a disease or not.

**System Evaluation Methodologies**

**Software for ROC Analysis**

Charles Metz, PhD and his colleagues are continuing to develop receiver operating characteristic (ROC) methodology, which provides an objective basis for evaluation of diagnostic techniques in general and medical imaging modalities in particular. ROC analysis plays a vital role in many research areas of the department, including CAD research. Effort during the past year focused on completing the development and testing of an entirely new computer algorithm for maximum-likelihood estimation of “proper” binormal ROC curves from confidence-rating data. This new algorithm has now been validated on more than one million simulated datasets and on a broad variety of real datasets from human observers and automated classifiers. The group’s software, which is provided free of charge, is now accepted as the standard for ROC data analysis and has been obtained by more than 10,000 laboratories in more than 40 countries. Most of this software is available in versions for Windows, Apple Macintosh and Unix/Linux computers. Please see http://xray.bsd.uchicago.edu/krl/roc_soft.htm for further details.

**Bayesian Methods in ROC Analysis**

Graduate student Richard Zur, Lorenzo Pesce, PhD, Yulei Jiang, PhD, and Charles Metz, PhD have been investigating possible applications of Bayesian methods to receiver operating characteristic (ROC) analysis. Bayesian methods allow one to combine prior information concerning a mathematical model with experimental data to come up with an estimate of the model that may be better than the estimate from the data alone. For example, Bayesian methods may be used to estimate a combined ROC curve from two experiments in which the data of cannot be combined easily otherwise. Bayesian methods incorporate prior information via a prior probability distribution that needs to be constructed carefully. Bayesian methods compute the posterior probability of the model conditional on the experimental data. This computation can be done with a method known as Markov Chain Monte Carlo. The group has been investigating the Bayesian method for estimating the ROC curve in comparison to the conventional maximum-likelihood estimation of the ROC curve. They have also been investigating the possibility of using the Bayesian method to estimate ROC curves that are difficult to measure with conventional experiment, e.g., the ROC curve of a screening procedure for a low-prevalence disease such as breast cancer. With carefully constructed Bayesian prior distribution, it may be possible to estimate such an ROC curve with an experiment that is logistically practical.

**Extension of ROC Analysis to Evaluate Classification Performance in Tasks that Involve More than Two Groups**

Receiver operating characteristic (ROC) analysis is now widely accepted as the most meaningful methodology for evaluation of human or machine observer performance in two-group classification tasks. Postdoctoral Scholar Darrin Edwards, PhD, and Charles Metz, PhD, are attempting to extend this methodology to classification tasks that involve three or more groups. An immediate practical application of such an extension would be the ability to combine two existing types of CAD scheme: one for detecting abnormalities (such as lesions in mammograms) and one for classifying known abnormalities as malignant or benign. Drs. Edwards and Metz have approached this problem by addressing it explicitly as a three-group classification task; that is, the outputs of the detection scheme should be classified as
malignant lesions, benign lesions, and non-lesions (false-positive computer detections) and the classifier to be estimated is the so-called ideal-observer decision rule for this task. Such an approach presents considerable difficulties, however. On the one hand, decision rules, in particular ideal-observer decision rules, increase rapidly in complexity with the number of groups involved. On the other hand, a fully general performance evaluation method, such as a three-group extension of ROC analysis, has yet to be developed.

Drs. Edwards and Metz have analyzed a number of three-group classification decision rules from within the theoretical framework of the ideal observer, explicitly pointing out the situations in which the various proposed rules could or could not be considered ideal observer decision rules. This work is important because the inherent complexity involved in the three-group classification model, even for the ideal observer, makes it difficult to compare decision strategies proposed by different researchers, particularly when the assumptions underlying the strategies differ in non-trivial ways. Moreover, the lack of a fully general extension of ROC analysis to three-group classification tasks leaves us without an empirical justification for preferring one model over another for a given dataset. More recently, Drs. Edwards and Metz provided theoretical justification for the use of particular restricted ROC surfaces, developed by those researchers for use with their proposed decision rules. (These restricted surfaces depend on only three conditional classification probabilities -- analogous to sensitivity and specificity in a two-group task -- rather than the six required by a general observer in a three-group task.) Finally, Drs. Edwards and Metz proved that the constrained ideal observer in each case achieves the optimal restricted ROC surface made up of only the three quantities present in the simplified expression for expected utility.

Previously, Drs. Edwards and Metz had proved that an obvious generalization of the area under the ROC curve (AUC), a well known performance metric, is not useful for performance evaluation in tasks with three or more classes. To address this deficiency, they have developed, and are currently researching the properties of, a utility-based performance metric. This performance metric is explicitly defined in terms of the “utilities” used by the ideal observer to make decisions. It can be shown to be directly related to readily interpretable properties of the ROC hypersurface (again, generalizations of AUC); however, it is expected to generalize more usefully to tasks with three or more groups than does AUC.


Computer-aided diagnostic (CAD) schemes have been developed for assisting radiologists in the detection of various lesions in medical images. Many evaluation approaches, such as the resubstitution, leave-one-out, cross-validation, and hole-out methods, have been employed for the assessment of the performance of various CAD schemes. For these evaluation methods, some investigators have studied their bias in the estimated performance levels of CAD schemes trained with finite samples. However, systematic study has not been conducted for the comparison of these common evaluation methods in terms of multiple important characteristics such as the bias of the estimated performance, the generalization performance, and the uniqueness of the trained CAD scheme. Therefore, Qiang Li, PhD and Kunio Doi, PhD examined and compared these important characteristics for various evaluation methods and attempted to provide a guideline for investigators to select appropriate evaluation methods for the assessment of CAD schemes in typical practical situations.

**Analysis of Imaging Trials: How Many Radiologists do we need?**

Yulei Jiang, PhD, Charles Metz, PhD, and Robert Schmidt, MD, collaborating with Diana Miglioretti, PhD, of the Group Health Cooperate of Seattle, Washington, have published an article in Radiology on the analysis of imaging trials in the context of demonstrating improved cancer detection from new imaging technologies. Based on over 2 million screening mammograms read by over 500 radiologists in seven US regional registries over seven years (data collected by the Breast Cancer Surveillance Consortium) they estimated the extent of inter-radiologist variabilty in the cancer detection rate, and found that the average radiologist detects 3.91 cancers per 1000 screening mammograms (standard deviation 1.93, range 0.25—13.75 cancers per 1000 screen mammograms). Because of this large variation in the individual radiologist’s cancer detection rate, an imaging trial requires a large cohort of patients and also a large group of radiologists to demonstrate even a large increase in the cancer detection rate from a new imaging technology. They estimated that a trial would require 25 radiologists each reading 8000 or more screening examinations (200,000 patients), or 91 radiologists each reading 1000–2000 examinations (91,000–182,000 patients), to attain 80% statistical power to detect an extremely large hypothetical increase in the cancer detection rate from a hypothetical new technology that allows each radiologist to detect one additional cancer per 1000 screening examinations compared to screening mammography. These sizes are larger than most contemporary imaging trials of full-field digital mammography, computer-aided detection, and other emerging imaging technologies. This analysis is relevant in a current debate over a controversial New England Journal of Medicine paper, which found that use of computer-aided detection is not clearly associated with improved detection of invasive breast cancer, in part because the study was not large enough. Both the authors of the NEJM paper and the critics cited this analysis in agreeing that very large trials are required to ascertain any real increase in the cancer detection rate.
Evaluation of image quality, imaging procedures, and imaging technologies, are now in great demand. These investigators have been developing evaluation tools for assessing image quality and for evaluation or comparison of various imaging approaches and techniques. Objective-specific parameters and criteria are defined for evaluation of both estimation and detection tasks, including realistic clinical situations when the truth is unknown. They have utilized these approaches for evaluating a number of clinical cases of SPECT, and will build a collection of evaluation tools for other imaging modalities as well.

**Paul C. Hodges Alumni Society**

The Hodges Society, the alumni arm of the department, continues to expand and improve. The newest members of the Society were heartily welcomed as past residents, fellows and staff joined the department at the annual June celebration. As in the past the event is one filled with great excitement and nervousness over the challenges ahead, but the larger network of the alumni society is being seen and felt as alums land in all corners of the country and globe. The organization continues to focus support on the department’s mission of excellence in patient care, education and research while supporting and nurturing alumni through educational opportunities and communication.

The Society’s main form of contact continues to be the very successful quarterly newsletters that are sent via email. The newsletters continue to expand in size and feature a more dynamic layout, including images, courtesy of an in-house talent with past professional experience. Society contact lists continue to be improved and “lost” alums are popping up as more information becomes available. The vision of an interactive and alum controlled website where messaging can be shared through secure channels remains a prime goal. The basic programming has been finished but the project awaits the larger departmental internet website as a portal for access and link to Department alums.

The Society continues to support the incoming new housestaff with a gift of a basic radiology text, one that forms the backbone of a 6-month course that covers fundamental core knowledge on film interpretation and techniques on presentation. Access is also provided to the required physics texts to ease the transition into their new work flow.

The Society also provides research support in the form of internal grants which are decided in the fall prior to the annual RSNA meeting. These $5000 seed grants have been helpful in initiating research that has been not only been presented and published, but has also fostered an evolution to larger projects downstream.

The Hodges Society presented two Paul C. Hodges Research Awards in 2006. The winners were Martha-Gracia Knuttinen, MD, PhD, Vascular and Interventional Fellow; and Sean Foxley, B.S., Graduate student in the Committee on Medical Physics. Mr. Foxley has provided a summary of his work below.

Society Members: Please remember to send any address or email changes to Thelma Wright, University of Chicago, Department of Radiology, 5841 S. Maryland Avenue, MC2026, Chicago, IL 60637. You may also send changes via fax to 773-702-2523 or email at pchodges@radiology.bsd.uchicago.edu. Society business questions may be directed to Dr. Christopher Straus at the address listed above, or via email at cstraus@uchicago.edu. Donations may be made using the enclosed envelope.
Prostate cancer is the most frequently diagnosed cancer and second leading cause of cancer related death in men in the US. While prostate specific antigen screening is the current preferred method for early detection, MRI has gained attention as a complimentary procedure, demonstrating greater sensitivity for the detection of prostate cancer than both digital rectal exams and transrectal ultrasound.

In this research the male mice from a transgenic line (SV40-TAg) were used to image developing prostate cancer using echo-planar spectroscopic imaging (EPSI). Imaging was performed with a 4.7T small bore magnet (Bruker, Billerica, MA). This MR imaging technique allows for the collection of high spectral and spatial resolution (HiSS) datasets in which a water spectrum is acquired for each tiny voxel imaged. Water peak height (PH) images were generated where image contrast was produced by the variation of the main water peak’s signal intensity on a voxel by voxel basis. PH images were compared with those acquired using conventional non-spectroscopic imaging techniques, including gradient echo (GE) and spin echo (SE) pulse sequences.

The prostate was manually segmented from each image and imaging metrics were calculated. The in vivo prostate was found to have approximately twice the signal-to-noise ratio and three times the contrast-to-noise ratio in PH images compared with GE and SE images. Further, a texture analysis technique was applied in which the ratio of the surface area of the segmented prostate to that of its in-plane area was determined. PH images had greater textural variation than GE and SE images, and it was indicated that texture decreased with increasing age. Examination of histological slides prepared with H&E staining showed relatively normal prostate in younger and extensive hyperplasia approaching PIN in older mice. It was also suggested that there was a direct correlation between increased age and increased prostate size.

While these findings are preliminary in that they represent a cohort of only 7 mice between 29 and 38 weeks of age, they indicate exciting potential for HiSS imaging of developing prostate cancer. The improved imaging metrics of HiSS allow for imaging with increased spatial resolution, and the details of the water spectra can be prospectively exploited as novel sources of image contrast. This affords HiSS imaging of the prostate the potential to improve MR’s sensitivity to anatomic and/or physiologic features associated with early onset of prostate cancer that conventional imaging techniques cannot detect. The future course of this work will include data acquisition with the Lynn S. Florsheim MRIS lab’s new 9.4T small bore scanner (Bruker, Billerica, MA). A larger cohort of mice will be followed from an earlier age, imaged with increased frequency, and for a longer period of time. This will provide for a more complete monitoring and characterization of the development of prostate cancer in this model with HiSS.

Much gratitude is extended to the Paul C. Hodges Alumni Society for its interest and investment in this project. It is our hope that this work will provide translation results, further aiding clinicians in their ability to detect and diagnose prostate cancer at an earlier stage. Without the gracious funding of start up work such as this, potential developments in improved health care become increasingly difficult to investigate.
Fellowship Programs

Abdominal Imaging Fellowship

The Abdominal Imaging Fellowship is a one-year comprehensive fellowship emphasizing state-of-art 3D clinical applications in all aspects of abdominal imaging. There are 1-2 fellows per year. The fellowship is ACGME approved but since there is no longer a national match program, we offer some flexibility in the curriculum to meet the needs of fellow candidates. The fellow is involved in all aspects of body imaging: CT, MRI, ultrasound, fluoroscopy and image-guided biopsy procedures with emphasis on becoming adept in interpreting complex cases, creating 3D images using cutting-edge software. The fellow will usually participate in research and publication activities. The fellow participates in resident education as well, giving conferences, didactic lectures and showing cases in our daily interesting case conference. Fellows also participate in one or more clinical management conferences such as the GI, GU, Oncology, Liver or Gyn weekly multi-specialty conferences. The fellow has the opportunity to attend the Departmental CME course on virtual colonoscopy and become an experience reader in this new emerging field.

This year’s departing fellow, Adnan Qalbani, MD, has accepted a position in South Dakota with The Breast Care Center. The Section’s incoming fellow, Kirti Kulkarni, MD, completed her residency at the College of Physicians and Surgeons, Sir JJ Group of Hospitals, India.

Breast Imaging Fellowship

The Breast Imaging Fellowship curriculum has been revised and expanded this year, with emphasis on core competencies. The fellows spend two weeks on the breast pathology service in addition to their clinical breast imaging duties. Each fellow is expected to conduct a research project and to participate in resident teaching. Fellows are assigned to selected noon conferences and participate in informal clinical teaching during the working day. Each fellow attends a basic teaching course given by Laszlo Tabar, during their fellowship year. Individual fellow reports are included below.

This year’s departing fellow, Kirti Kulkarni, MD, will remain with the Department to compete a fellowship in abdominal imaging. The incoming fellow, Susan Sung, MD completed her residency at Thomas Jefferson University Hospital.

Interventional Radiology Fellowship

Vascular and Interventional Radiology Fellowship is a one-year comprehensive program, the goal of which is to provide in-depth clinical, teaching and research experience in all aspects of both adult and pediatric angiography and interventional procedures. Fellows perform Interventional Radiology procedures and provide clinical care of patients under the daily supervision of full-time faculty members. In addition to reading CT and MR angiographic studies, fellows perform vascular and non-vascular procedures using sonographic, fluoroscopic and CT guidance. Education of fellows is performed through a combination of clinical experience in the Interventional Radiology suites, didactic teaching during film interpretation procedure review sessions, attendance at multidisciplinary conferences, attendance of monthly meetings with review of morbidity and mortality cases, and attendance of lectures provided by the faculty.

Essential to their educational development, the Vascular and Interventional Radiology fellows are central components in the day-to-day clinical management of the VIR section at the University of Chicago. The VIR section is unique in the Radiology department in that it is entirely a clinical service, performing patient consultations, history taking, physical examinations, inpatient rounds, patient consents, physician consultations, procedures, post-procedure care and patient follow-up. The fellows are not just trainees, but represent an integral part of this clinical management, communicating with referring physicians, coordinating patients through the section, over-seeing patient care, and performing clinical rounds and follow-up. The fellows are expected to participate actively in ongoing scholarly projects under the supervision of the faculty members. This work should result in publication in refereed or educational journals and presentation at institutional, regional or national scientific meetings in accordance with ACGME recommendations.

In addition to these clinical responsibilities, the fellows obtain in-depth teaching and research experience by preparing and providing resident conferences and directly participating in quality assurance, educational, and research projects ongoing within the section.

The program is accredited by the ACGME for three positions per year. The section has hired two fellows for 2007-2008 and expects to match two fellows for 2008-2009.

The Section had three fellows complete training this year. Martha-Gracia Knuttinen-Kalweit, MD, PhD has accepted a position at University of Illinois Chicago. Olga Vinokur, MD, has accepted a position with MacNeal Hospital in Berwyn, Illinois. Steve Zangan, MD, will remain with the Department, having accepted a position as an Assistant Professor.

The Section will welcome two new fellows who will begin their training July 1, 2007. They are: Rashid Al-Sukaiti, MD, who completed his residency at McGill University and Scott Santeler, MD, who completed his residency at the University of Chicago.
Musculoskeletal Fellowship

The Musculoskeletal Fellowship is a one year program that began July 1, 1999; thus far, six individuals have completed the program since inception. Prerequisites for the program include completion of a residency in Radiology as well as selective criteria, such as an interest in both clinical and academic MSK radiology. Good letters of reference from the residency program director and other faculty members are essential. Finally a personal interview day with the candidate is mandatory.

The goal of the program is to train a radiologist in all aspects of clinical MSK radiology as well as to promote academic radiology interest. Each fellow participates in case reading sessions four days a week with the fifth day for academic interest. Participation is expected in the weekly orthopedic oncology and weekly rheumatology conferences. Formal conferences in musculoskeletal are offered every week and there is a weekly case conference in the section. Fellows are expected to prepare conferences for residents, and to have projects leading to publications. The fellow is also expected to perform procedures including biopsies, arthrograms, and RFAs, as well as supervise and train radiology residents.

The Section will welcome Saad Naseer, MD to the program on July 1, 2007. Dr. Naseer completed his residency at Emory University Hospitals.

Neuroradiology Fellowship

The Neuroradiology fellowship is a one-year program which provides experience in all aspects of adult and pediatric diagnostic neurological CT and MR and in diagnostic cervical, spinal and cerebral angiographic and nonvascular procedures. Dr. Dianna M. E. Bardo is the Director of the fellowship program.

Dr. Jeffrey Ho completed the neuroradiology fellowship in June 2007 and has entered private practice in Detroit, Michigan. Drs. Feng Zhu and Hong Cheng have begun fellowships in neuroradiology which will include one year of research in the Brain Research Institute (BRIC), under the direction of Dr. Jia-Hong Gao.

Diagnostic Radiology Residency

The Department of Radiology’s mission is to provide outstanding training in diagnostic radiology which will prepare residents for future careers in academic radiology or full-time clinical practice. Our basic four-year residency training program, supported by clinical and research-oriented fellowships, is well balanced and offers excellent preparation for a broad variety of career pathways including academic careers, general radiology and subspecialty practice in both academic and private practice.

The residency program has increased in size for each of the past three years and will reach a full complement of 28 residents for the 2007-2008 academic year. The increase has allowed the Department to provide additional rotations in cardiac imaging, mammography and PET imaging among others. It will also allow the flexibility to offer new programs for incoming residents with research interests.

This past year has been very successful with numerous resident publications and honors:

Derek Fimmen, MD

Sheela Konda, MD, PhD & Monica Harish, MD

Sheela Konda, MD, PhD
Sheela Konda, MD, PhD
What Are The Top 25 Questions We Hope to Answer Through Research? "Might reliable methods of image-guided measurements of tumor perfusion and angiogenesis be applied to tumors to measure response to therapy and, moreover, these or other markers then used to assess treatment response in the short term allowing the early and effective introduction of optimal alternative treatment protocols in patients not responding?" Radiology, 2007 (in press).

Christopher Molvar, MD

Rajshri Shah, MD
Awards

Joseph Carabetta, MD
• President-elect of the resident division of the Chicago Radiological Society.
• Weiss Hospital Award (Outstanding Clinical Work at Weiss Hospital), 2007 Outstanding Medical Student Instruction, 2007.

Monica Harish, MD

Gregory Henkle, MD
• Outstanding Medical Student Instruction, 2007.

Sheela Konda, MD, PhD
• Neuroradiology Award (Outstanding Performance in Neuroradiology), 2007.
• Siemens Association of University Radiologists (AUR) Radiology Resident Academic Development (SAR RAD) Program 2007 Award Recipient.

Albert Li, MD
• Chien Tai Lu Award (Outstanding Clinical Work in Vascular Interventional Radiology), 2007.

Christopher Molvar, MD
• Chien Tai Lu Award (Outstanding Clinical Work in Vascular Interventional Radiology), 2007.

R. Evan Nichols, MD
• Golden Tip Award (Outstanding Performance in Gastrointestinal Radiology), 2007.

In January 2006, Rodney Corby and Rajshri Shah were chosen as co-chief residents and will serve until January 2008.

Departing Residents

The residency program has had yet another successful year. Six residents graduated, with five pursing fellowships and one continuing at the University of Chicago:

Jarvis Chen, MD will begin an Interventional Radiology Fellowship at the University of Washington.

Caroline Cranford, MD will begin a Women’s Imaging Fellowship in Arizona at the Mayo Clinic.

Derek Fimmen, MD has taken a job with a private practice in Quincy, Illinois.

Oneil Lee, MD, PhD will begin a Nuclear Medicine fellowship at Washington University, St. Louis.

Roi Lotan, MD will begin a Body Fellowship at Johns Hopkins in Baltimore.

Scott Santeler, MD will remain at University of Chicago and begin an Interventional Radiology Fellowship.

Incoming Residents

Radiology is pleased to welcome seven new residents for the 2007-2008 academic year in the hope that they will discover the unique program of study that our department has to offer. We are confident that they will make excellent residents.

These residents began their training on July 1, 2007:

Christopher Buckle, MD, completed his PGY1 at Cornell University.

Danny Cheng, MD, completed his PGY1 at Carraway Methodist Medical Center.

John (Jack) Collins, MD, completed his PGY1 at the University of Chicago.

Nicholas Krause, MD, completed his PGY1 at the University of Chicago.

Sarah Orrin, MD, completed her PGY1 at Weiss Hospital.

Jay Patel, MD, completed his PGY1 at Resurrection Medical Center.

William Whetsell, MD, completed his PGY1 at West Suburban Medical Center.
Medical Student Education

Medical student education has undergone some significant changes recently. Building on the momentum of the changes in the Human morphology course made last year their involvement in the first two years of medical school increases again. A large improvement has been noted, including in medical student boards part I scores. This also included a record 23 students volunteering to be teaching assistants for next years Gross Anatomy course - just short of 25% of the entire class. The program will now begin to include key imaging in the spring neuro anatomy course and make measured progress in incorporating imaging into the key MS II course Clinical Pathophysiology and Treatment. This will mean that nearly every course the student takes in their first two years will have radiology imaging as part of the content, much of it taught by radiologists; students will also have access and exposure to radiology staff throughout this time.

We continue to provide outreach in the form of small research grants which involve students through the Radiology Research and Opportunity Program (RROP). This makes smaller funds available for projects which involve students on a short turn around basis (usually two days) and with a short simple one page application. This was developed to ensure that money was available for equipment as the need arose and not allow the shorter windows of opportunity most students allow to close when an interest is expressed.

The educational resource and importance of quality housestaff also improved over the past year. More residents and fellows have shown an interest in being involved and this year we celebrated a tie for the most appreciated resident elected by our students. This year’s winners were Joseph Carabetta and Gregory Henkle.

As the year ended the next major change was discussed and adopted. This includes the restructuring of the senior elective to one which has equivalent flexibility but also provides more structure and role for our senior students while on this elective tract. The changes will include dedicated lectures for students, computer access and teaching files and a focus that will stress the importance of radiology imaging in overall patient care. These new changes will be in development over the following summer and implemented towards the start of the new year. These major changes continue to demonstrate the need and augment the core experiences which help motivate many who choose our specialty as a career but also supplement our mission of additionally steering many into academics and leaving others who choose other fields of study to understand and use our resources effectively.

Graduate Programs In Medical Physics

The Graduate Programs in Medical Physics are under the Committee on Medical Physics at the University of Chicago and offers research training at three levels that lead to the Master of Science degree and the Doctor of Philosophy degree, and provide postdoctoral training. Faculty on the Committee comes from the Departments of Radiology and Radiation & Cellular Oncology. Maryellen Giger, PhD is Chair of the Committee and represents it’s faculty within the BSD Basic Science Chairs. Primary areas of research interest by the program faculty include the Physics of Diagnostic Radiology, Physics of Nuclear Medicine, Physics of Magnetic Resonance Imaging, and Physics of Radiation Therapy. Unique features of this program are the faculty’s focused effort on research in medical imaging and on the training of high-level medical physicists. A continuing NIH training grant funds four pre-doctoral students and two post-doctoral fellows in the training of medical physics. Currently, we have 26 pre-doctoral students and 9 post-doctoral trainees.

Current post doctoral fellows are:

- Samuel LaRoque, PhD, from The University of Chicago, who is working under the supervision of Xiaochuan Pan, PhD, and conducting research on tomographic image reconstruction techniques.
- Antonio Marchado, MD, from The Heart Institute of the University of Sao Paulo, is working under the supervision of Chin-Tu Chen, PhD conducting research on the use of novel radiotracers for investigation of neurological and psychiatric disorders such as Parkinson’s disease. He is also involved in conducting imaging experiments for studying animal models of these brain disorders.
- Fangyuan Nan, PhD, from Michigan State University is working under the supervision of Kunio Doi, PhD and is conducting research on computerized detection and diagnosis of lung nodules on multi-detector CT images, which is a key technique for the automated measurement of cancer growth rate. He is now working on computerized schemes for detection and differential diagnosis of diffuse lung diseases on 3D multi-detector CT images.
• Michael Chinander, PhD, from The University of Chicago is working under the supervision of Maryellen Giger, PhD conducting research on the assessment of bone quality and osteoporosis using radiographic texture analysis of heel bone densitometry images. Dr. Chinander also works with Dr. Martell of surgery on non-invasive measurement of the temporal wear of total hip arthroplasty components from radiographic images.

• Darrin Edwards, PhD, from The University of Chicago, is working under the supervision of Charles Metz, PhD and is conducting the extension of ROC analysis to classification tasks with more than two classes. ROC Analysis evaluates observer performance in classification tasks with two classes. He is attempting to extend this methodology to classification tasks with three or more classes.

• Lara Leoni, PhD, from The University of Illinois at Chicago, works under the supervision of Brian Roman, PhD to conduct research on functional magnetic resonance imaging of pancreatic islets. Human pancreatic islet transplantation is currently being performed around the world to cure diabetes. Lara has demonstrated that MRI can be used to image pancreatic islets which have been activated by glucose stimulation and can be detected on a T1-weighted MR image. She has applied this approach to rodent and human islets and is currently correlating MRI signal intensity with insulin release.

• Qingguo Xie, PhD, from Huazhong University of Science and Technology, is working under the supervision of Chien-Min Kao, PhD, and is conducting research on the characterization and optimization of our SHAPET scanner. He also investigates the use of SiPM for PET imaging, new detector designs and time pick up methods for TOF-PET imaging, and the feasibility of all-digital data acquisition systems for PET.

• Guihua Zhai, PhD, from The University of North Carolina at Chapel Hill, is working under the supervision of Jia-Hong Gao, PhD conducting research on understanding the physiological mechanism of the brain function in the actions of glucose and alcohol. Cerebral blood flow based brain maps will be generated using functional MRI and the results will be compared with the neuronal activities in the hypothalamic region and other parts of the brain.

We expect four new pre-doctoral students to join us in the autumn of 2007. They are Elizabeth Hipp (Creighton University), Anita Dhyani (Marquette University), Zacariah Labby (University of Wisconsin-Madison), and Philip Vargas (Purdue University).

**2006-2007 Graduates**

Two students received their PhD’s during the academic year. They were:

Weijie Chen (Maryellen Giger, PhD, Advisor) “Computerized Analysis and Interpretation of Breast MR Images.”

Joel Wilkie (Maryellen Giger, PhD, Advisor) “Temporal Radiographic Texture Analysis for Assessment of Periprosthetic Osteolysis.”

One student received an MS degree during the academic year - Junsheng (Jason) Cao, (Mary Martel, PhD, Advisor) “The Effect of Respiratory Motion on Whole Breast Radiotherapy Dose Distributors.”

**Awards received within the past year by current pre-doctoral students:**

**Michael Altman:**
- First Place Award, Young Investigator’s Symposium, AAPM Midwest Chapter Spring Meeting (2007).

**Sunny Arkani:**

**Junguo Bian:**

**Weijie Chen:**
- Finalist for the Michael B. Merickel Best Student Paper Award, SPIE Medical Imaging (2007).

**Seungryong Cho:**
- Army Pre-Doctoral Prostate Cancer Research Award, Department of Defense (2006).
• Young Investigator Award (2nd place), AAPM Midwest Chapter Meeting (2007).
• Student Travel Grant Award, SPIE Medical Imaging Conference (2007).

**Martin King:**
• Lawrence H. Lanzl Medical Physics Graduate Award, Graduate Programs in Medical Physics and Committee on Medical Physics, the University of Chicago (2007).
• Student Trainee Award, IEEE -MIC Annual Meeting (2006).

**Beverly Lau:**
• Joint Annual Meeting of the International Society for Magnetic Resonance in Medicine (ISMRM-ESMRMB), Berlin, Germany (2007).

**Yahui Peng:**
• Travel Grant Recipient from the University of Chicago Women’s Board (2007).

**Peer-reviewed journal publications within the past year by our pre-doctoral students:**


**W. Sensakovic,** S. Armato, A. Starkey: Two-Dimensional Extrapolation Methods for Texture Analysis of CT Scans. Medical Physics (Accepted for Publication).


**Proceeding papers within the past year by our pre-doctoral students:**


J. Bian, H. Zhang, P. Zhang, X. Pan: A Cone-Beam Approach to ROI Imaging with a Detector Smaller than the Imaged Object. 9th International Meeting on Fully Three-Dimensional Image Reconstruction in Radiology and Nuclear Medicine, Lindau, Germany, 2007.


W. Sensakovic: Assessment of Mesothelioma Tumor Response: Correlation of Tumor Thickness and Tumor Area (4th Author), AAPM 2007.


Faculty Achievements

Honors & Awards

Hiroyuki Abe, MD, Robert Schmidt, MD, Charlene Sennett, MD, Gillian Newstead, MD, Akiko Shimauchi, MD, PhD

Abraham Dachman, MD
• Radiology Editor’s Recognition Award.

Alexandra Funaki, DO
• Senior Class Teaching Award, Honorable Mention, Department of Radiology, University of Chicago, 2006.

Maryellen Giger, PhD

Heber MacMahon, MD

American Association of Physicists in Medicine
Maryellen Giger, PhD
Elected Treasurer
Chair, Finance Committee
Member, Board of Directors

American Board of Radiology
Brian Funaki, MD
Examiner, Certificate of Added Qualification, Vascular and Interventional Radiology
American College of Radiology
Abraham Dachman, MD
Media Spokesperson
Member, Subcommittee on Colon Cancer Screening
Member, Virtual Colonoscopy Screening Panel
Member, Colorectal Cancer Committee

Kate Feinstein, MD
Member, Committee on Drugs and Contrast Media
Member, Committee on Economics (Commission on Ultrasound)
Member, Commission on Pediatric Radiology
Member, Committee on Bylaws
Member, Continuing Professional Improvement, Expert Panel in Pediatric Radiology

Heber MacMahon, MD
Member, Appropriateness Committee for Thoracic Imaging

David Paushter, MD
Member, CT Accreditation Committee
Member, Economics Committee, Abdominal Imaging Site Reviewer, Ultrasound Accreditation

American College of Radiology Imaging Network (ACRIN)
Abraham Dachman, MD
Member, Subcommittee on Virtual Colonoscopy
Member, Publications Committee, ACRIN #6664

Maryellen Giger, PhD
Member, External Advisory Committee, ACRIN

Charles Metz, PhD
Member, Design and Analysis Committee

Michael Vannier, MD
Vice-Chair, Modalities

American Institute of Ultrasound in Medicine
David Paushter, MD
Chair, Subcommittee on Examination Documentation
Member, Clinical Standards Committee

American National Standards Institute (ANSI)
Paul Chang, MD
Representative (from RSNA), Medical Devices Standard Management Board

American Roentgen Ray Society
Abraham Dachman, MD
Member, CME Evaluation Subcommittee
Member, Education Evaluation Subcommittee
Moderator, Scientific Session SS20: GI Potpourri, 2006 Annual Meeting

Brian Funaki, MD
Associate Chair, 2007 Annual Meeting Program Committee Chair, Instructional Course Committee,

Vascular and Interventional Radiology, 2007 Annual Meeting Member, Self Assessment Module
Subcommittee, 2007 Annual Meeting Co-director,
Approach to Diagnosis: Case Based Imaging Review Course, 2007 Annual Meeting, Co-director,

Jonathan Lorenz, MD
Member, Interventional Radiology Subcommittee
Judge, Electronic Exhibits, 2007 Annual Meeting
Course Director, Abscess Drainage, 2007 Annual Meeting

Gillian Newstead, MD
Member, Program Review Committee

Association of University Radiologists
Paul Chang, MD
Member, Research Symposium Committee

Carnegie Science Center
Paul Chang, MD
Member, Biomedical Awards Committee

Chicago Radiological Society
Abraham Dachman, MD
President

Dartmouth Cancer Center
Michael Vannier, MD
External Advisor

Duke Virtual Colonoscopy Trial
Abraham Dachman, MD
Publications Committee

Fleischner Society
Heber MacMahon, MD
Member, New Glossary Committee. Secretary

Institute of Electrical and Electronics Engineers (IEEE)
Chien-Min Kao, PhD
Member, Technical Program Committee, Medical Imaging Conference

Kenji Suzuki, PhD
Panelist, Application Review Panel
Member, Program Committee, The 3rd International Symposium on Computational Intelligence and Industrial Applications

Illinois Radiological Society
Abraham Dachman, MD
Executive Committee
Alternate Councilor

Kate Feinstein, MD
President-elect/Treasurer
Councilor
International Mesothelioma Interest Group  
Samuel Armato, PhD  

International Commission on Radiation Units and Measurements  
Charles Metz, PhD  
Member, Committee on ROC Analysis in Medical Imaging

Paul Chang, MD  
Member, Electronic Imaging Work Group

Johns Hopkins Center for Integrated Surgical Systems Technology  
Michael Vannier, MD  
External Advisor

MedBiquitous Consortium  
Paul Chang, MD  
Representative (from RSNA), Standards Committee

National Cancer Institute (US National Institutes of Health)  
Samuel Armato, PhD  
Member, Lung Image Database Consortium Steering Committee  
Chair, Lung Image Database Consortium Inclusion Criteria Subcommittee  
Chair, Lung Image Database Consortium Evaluation Metrics Subcommittee  
Co-Chair, Reference Image Database for Evaluation of Response Steering Committee

Abraham Dachman, MD  
External Advisory Committee, Arizona GI SPORE  
Executive Steering Committee, Colon Imaging Study (NIH ROI CA 82344)  
Invited External Reviewer, Arizona GI SPORE Publications Committee, Colon Imaging Study (NIH ROI CA 82344)

Heber MacMahon, MD  
Member, CAD Database Committee, National Lung Screening trial

Michael Vannier, MD  
Parent Committee for Programs and Centers

National Center for Research Resources (US National Institutes of Health)  
Michael Vannier, MD  
Biomedical Informatics Expert Panel

National Library of Medicine (US National Institutes of Health)  
Paul Chang, MD  
Member, Subcommittee on Biomedical Imaging and Bioengineering

Radiological Society of North America  
Samuel Armato, PhD  
Chair, Update Course in Diagnostic Radiology Physics, 92nd Scientific Assembly and Annual Meeting, Chicago, IL, November 26 – December 31, 2006.  
Scientific Session Presiding Officer, 92nd Scientific Assembly and Annual Meeting, Chicago, IL, November 26 – December 31, 2006.

Richard Baron, MD  
Chair, Educational Exhibits Committee

Paul Chang, MD  
InfoRAD Docent  
Member, Electronic Communications Committee  
Member, Education Exhibits Committee  
Refresher Course Faculty

Abraham Dachman, MD  
Member, Gastrointestinal Subcommittee of the Education Exhibits Committee

Maryellen Giger, PhD  
Member, Annual Meeting Program Committee  
Chair, Physics Subcommittee of the RSNA Program Committee  
Chair, Research Grant Study Section

SPIE - International Society for Optical Engineering  
Maryellen Giger, PhD  
Chair, CAD Program Committee, Medical Imaging Meeting

Charles Metz, PhD  
Member, Committee on ROC Analysis in Medical Imaging

Society for Computer Applications in Radiology  
Paul Chang, MD  
Abstract Reviewer  
Member, Annual Program Committee

Society of Gastrointestinal Radiologists  
Richard Baron, MD  
Board of Directors  
President

Abraham Dachman, MD  
Member, Nominating Committee

Society of Interventional Radiology  
Brian Funaki, MD  
Co-Chair, Volunteers Committee

Jonathan Lorenz, MD  
Coordinator and Moderator of Abscess Workshops (commitment 2007 – 2010)  
Association of Program Directors in Interventional Radiology (APDIR)  
University of Chicago Medical Student Liaison to the SIR
Editorial Board Memberships

Automedica
Michael Vannier, MD
Editor-in-Chief

The American Journal of Orthopedics
Michael Vannier, MD
Editorial Board

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Paul Chang, MD
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Kenji Suzuki, PhD
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Open Biomedical Engineering Journal
Xiaochuan Pan, PhD
Editorial Board

Kenji Suzuki, PhD
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Dianna Bardo, MD
Editorial Board

Radiological Society of North America
Brian B. Roman, Ph.D
Editorial Board

RSNA Electronic Journal
Paul Chang, MD
Associate Editor, Computers in Radiology

Radiology & Imaging Letter
Paul Chang, MD
Editorial Board
American Association for Physics in Medicine, Orlando FL, July 30-Aug 3, 2006.


Bardo D, Newby B, Lang R, Mor-Avi V: Assessment of Left Ventricular Function by Computed Tomography: Effects of the Number of Reconstructed Phases on the Calculated Ejection Fraction.

American Society of Clinical Oncology Meeting, Chicago, IL, June 1-5, 2007.


Abe H, Newstead G, Sennett C, Shimauchi A, Schmidt R: Incidental MR Detected Lesions - How Should We Deal With Them?


International Symposium on Virtual Colonoscopy, Boston, MA. October 16-17, 2006.


MacMahon M: Chest (Computer-aided Diagnosis).


MacMahon M: The State of Computer-aided Diagnosis (CAD): Are You Ready to Move?


Suzuki K, Li F, Engelmann R, MacMahon H, Doi K: Advanced CAD System Based on 3D Massive-training Artificial Neural Network (MTANN) for Detection and Classification of Lung Nodules in CT.

Suzuki K, Li F, MacMahon H, Doi K: Development of a Sequential Combination of Massive-training Artificial Neural Networks (MTANNs) to Construct a New Type of Computer-aided Diagnostic (CAD) Scheme for Detection of Lung Cancer in CT.


Yoshida H, Nappi J, Rockey D, Cadi M, Dachman A: Computer-aided Detection of Polyps in CT Colonography of Low-Prevalence Patient Cohorts from Two Large-scale, Prospective, Multicenter Clinical Trials.


Suzuki K, He L, Khankari S, Ge L, Verceles J, Dachman A: Mixture of Expert Artificial Neural Networks with Ensemble Training for Reduction of Various Sources of False Positives in CAD.


Yousefzadeh D, Doerger K, Sullivan C: Decreased

Femoral Head Blood Flow in Abduction: Arterial Compression or Venous Congestion.


Invited Presentations

Hiroyuki Abe, MD


Daniel Appelbaum, MD


PET/CT in the Oncology Patient. Radiology Visiting Professor, University of Illinois-Chicago, Chicago, IL, September 2006.

PET/CT with FDG: Beyond the Basics. Society of Nuclear Medicine Central Chapter Annual Meeting, Chicago, IL, March 2007.


Samuel Armato, PhD

Computer-aided Diagnosis in Thoracic Radiology: Lung cancer and beyond. Sir Charles Gairdner Hospital, University of Western Australia, Perth, Australia, November 2006.
Imaging-Based Tumor Response Assessment in Malignant Mesothelioma. Third Perth Mesothelioma Centre Symposium, Perth, Australia, November 2006.

Research in Computer-Aided Diagnosis (CAD), Biomedical Informatics Workshop, DePaul University, Chicago, IL, October 2006.

The Evolution of Imaging-Based Tumor Response Evaluation in Mesothelioma. Eighth Meeting of the International Mesothelioma Interest Group, Chicago, IL, October 2006.

**Dianna Bardo, MD**


Thoracic Aorta. 1st Baltic Radiology Congress, Kaunas, Lithuania, October 2006.


**Richard Baron, MD**


Departmental Realities in CQI implementation. Practice Quality Improvement (PQI) Summit Conference, American Board of Radiology, Chicago, IL, August 2006.

Differentiating Benign from Malignant Lesions in Cirrhotic Liver. Visiting Professor, Seoul National University Hospital, Seoul, Korea, May 2007.

Imaging Benign Liver Lesions; Imaging Cirrhosis: Imaging-Patologic Correlation; Imaging Malignant Liver Lesions. Visiting Professor, Sungkyunkwan University School of Medicine, Samsung Medical Center, Seoul, Korea, May 2007.


Liver Imaging: Understanding Principles and Pathology to Optimize Diagnoses; Exploring the Spectrum of Biliary Tract Imaging. Visiting Professor, Michigan State University, East Lansing, MI, November 2006.


Understanding and Optimizing Multidetector CT and Contrast Techniques for Liver Imaging; Characterizing Benign Liver Lesions; Characterizing Malignant Liver Lesions; Important Issues in Imaging Cirrhosis; Imaging the Spectrum of Biliary Tract Disease. 35th Congresso Brasileiro de Radiologia, Curitiba, Brazil, October 2006.


**Paul Chang, MD**


Fundamentals of Computer Assisted Diagnosis (CAD) and Decision Support. Women’s Health and Imaging in a Digital Environment. University of Rochester School of Medicine, San Antonio, TX, January 2007.


Abraham Dachman, MD

CAD and Polyp Measurement. 7th International Symposium on Virtual Colonoscopy, Boston, MA, October 2006.


Kate A. Feinstein, MD

Twists and Turns: Part II. Annual Meeting of the John Caffey Society, Traverse City, MI, June 2007.


Alexandra Funaki, DO


Brian Funaki, MD


Evaluation and Treatment of Gastrointestinal Bleeding; How to Take a Case; Resident Case Conference. Visiting Professor, Indiana University, August 2006.

Maryellen Giger, PhD

Breast CAD. Forum on Emerging Biomedical Technologies. 2006 International Workshop on CAD, Taiwan National University, Taipei, Taiwan, November 2006.


Computer-Aided Diagnosis in Medical Imaging. International Workshop on Medical Imaging and Augmented Reality (MIAR06), Shanghai, China, August 2006.

Lessons Learned from Breast CAD. The 15th International Conference on Screening for Lung Cancer (I-ELCAP). Weill Medical College of Cornell University, New York, NY, October 2006. Multi-Modality Breast CAD. DePaul University, Chicago, IL, July 2006.
Multi-Modality Breast CAD. International Workshop on Medical Imaging and Augmented Reality (MIAR06), Shanghai, China, August 2006.

Multi-Modality Breast CAD. National Laboratory of Pattern Recognition, Institute of Automation, Chinese Academy of Sciences, Beijing, China, August 2006.

Multi-Modality Breast Computer-Aided Diagnosis and Prognosis. American Association of Physicists in Medicine Midwest Chapter, Lawrence Lanzl Award Lecture, Downers Grove, IL, October 2006.

CAD for Breast Ultrasound. Northwestern/University of Chicago Breast Imaging Course, Chicago, IL, October 2006.


Image-Based Breast Cancer Risk Assessment. American Society of Clinical Oncology, Chicago, IL, June, 2007. (Co-author: H. Li.)


Gregory Karczmar, PhD


HiSS MRI of Breast and Other Applications of Spectral/Spatial Imaging. NIH Symposium on Anatomic, Functional, and Molecular Imaging, Bethesda, MD, 2006.


Patrick La Rivière, PhD


Correction for Resolution Non-Uniformities Caused by Anode Angulation in Computed Tomography. Institute of Electrical and Electronics Engineers Medical Imaging Conference, 2006. (Co-author: P. Vargas.)


Monotonic Iterative Reconstruction Algorithms for Targeted Reconstruction in Emission and Transmission Computed Tomography. Institute of Electrical and Electronics Engineers Medical Imaging Conference, 2006. (Co-author: P. Vargas.)


Ultrasonic Attenuation Correction in Optoacoustic Tomography. Photonics West, 2006. (Co-authors: J. Zhang, M. Anastasio.)

Gregory Karczmar, PhD

Jonathan Lorenz, MD


Heber MacMahon, MD


Charles E. Metz, PhD


Gillian Newstead, MD


Problem-Solving MRI. Radiological Society of North America 92nd Scientific Assembly and Annual Meeting, Chicago, IL, November 2006.


Robert M. Nishikawa, PhD


Xiaochuan Pan, PhD


Advanced Biomedical Imaging Research. Capital Normal University, Beijing, China, October 2006.


Basics for Objective Assessment of Image Quality. Tsinghua University, Beijing, China, January 2007.

Computed Tomographic Imaging. Capital Normal University, Beijing, China, October 2006.

Data Acquisition and Image Reconstruction in Modern CT. Symposium on Medical Imaging and Augmented Reality, Shanghai, China, August 2006.
Exact ROI Image Reconstruction from Truncated High Dimensional Radon Transform and its Application to 4D EPRI. A Joint Conference of 12th In Vivo EPR Spectroscopy and Imaging 9th International EPR Spin Trapping/Spin Labeling, Chicago, IL, April 2007. (Co-author: H. Halpern)

How are Tomographic Images Obtained? Hong Kong Chinese University, Hong Kong, China, May 2007.

Image Reconstruction and Artifacts Correction in CT. World Congress on Medical Physics- Imaging the Future, Seoul, South Korea, August 2006.


Recent Development in Cone-Beam CT and Applications. Annual Meeting of Stereology Society of China, Nianbo, China, October 2006.

Some Numbers and Thoughts about Medical Imaging. Tsinghua University, Beijing, China, January 2007.

**Yonglin Pu, MD**

FDG PET Application in Oncology. Beijing PLA hospital, Beijing, China, October 2006. Also Zhoushan City hospital, China, October 2006. FDG PET Application in Oncology and Functional Brain Imaging with PET and fMRI. Zhejiang University Medical School, Hangzhou, China, October 2006.

Functional Brain Imaging with PET and fMRI. Lanzhou University Medical School, Gansu Province, China, October 2006. Also TianShui City hospital, Gansu Province, China, October 2006.

**Robert Schmidt, MD**


**Charlene Sennett, MD**


**Gregory Scott Stacy, MD**


**Thuong Van Ha**

Abscess Drainages Management and Endocavitary Abscess Drainages. Abscess Drainage and Management Workshop. 2007 Annual Scientific Meeting, Society of Interventional Radiology, Seattle, WA, March 2007. (Presented in conjunction with Dean Nakamoto, MD, Assistant Professor of Radiology, and Section Chief, Abdominal Imaging Section, Case Western Reserve University.)


**Mario F. Zaritzky, MD**


Knuttinen M, Van Ha T, Straus C, Funaki B. Radiofrequency Ablation of Liver Tumors using Balloons as a Diaphragmatic Device in an Animal Model.


Bardo D, Solanki A, Newby B, Greenberg B, Knight B, MacMahon H, Vannier M. Interpretation and Editing of the ECG in Coronary CTA: The Radiologist’s Skill in Interpreting and Editing the ECG Trace is a Major Determinant of Image Quality.

Bonta I, Armato S, Menon N, Griffin J, MacMahon H. Imaging Research in the Era of Informed Consent: Three Years Experience at the University of Chicago.

Doshi T, Rusinak D, Halvorsen R, Rockey D, Dachman A. Retrospective Analysis of Sources of Error in a Large CTC Retrospective Analysis of Sources of Error in a Large CTC Clinical Trial.


Muramatsu C, Schmidt R, Li Q, Shiraishi J, Newstead G, Doi K, et al. Determination of Subjective Similarity of a Mass Pair with that of a Calcification Pair?


Suzuki K, Li F, Engelmann R, MacMahon H. Advanced CAD System Based on 3D Massive-training Artificial Neural Network (MATNN) for Detection and Classification of Lung Nodules in CT.

Suzuki K, Yoshida H, Nappi J, Dachman A. Three-dimensional Massive Training Artificial Neural Network (MTANN) in CT Colonography: Applications to Computer-aided Detection (CAD) of Polyps.


SPIE Medical Imaging Conference, February 2007, San Diego, CA.


Reiser I, Nishikawa R, Sidky E, Chinander M, Seifi P. Development of a Model for Breast Tomosynthesis Image Acquisition.

Patents


Xie Q, Kao C, Hsiau Z, and Chen C: A device and method for digitizing gamma ray energy and characterizing peak time and decay time constant without the use of ADC. U.S. Provisional Patent No. 60/558,709, approved 2007.


Peer Reviewed Publications


Sakai S, Soeda H, Takahashi N, Okafuji T, Yoshitake T, Yabuuchi H, Yoshino I, Yamamoto K, Honda H, Doi K:


**Invited publications**


Regalado S: Closure devices. Seminars in Interventional Radiology (accepted for publication).


Schmidt R: Digital mammography, networking, PACS, and Dante’s Inferno. Applied Radiology (Supplement), September 2006.


Kao C, Sidky E, Pan X: Precise imaging of small animals by using a dual-head microPET scanner. SPIE Medical Imaging, San Diego, CA, February 2006.


Chapters, Books, and Review Articles


Suzuki K: Computational Intelligence in Medical Imaging: Techniques & Applications (Reviewer).


Primary Investigators

Samuel Armato, PhD
Title: Computerized Analysis of Mesothelioma on Computed Tomography (CT) Scans.
Agency: NIH
Project Period: 06/01/06-05/31/10
Total: $717,822

Chin-Tu Chen, PhD
Title: Biomedical Imaging Research.
Agency: National Health Research Institutes
Project Period: 03/01/07-02/28/09
Total: $165,780

Abraham Dachman, MD
Title: Comparison of Linear and Polyp Volumes in CTC.
Agency: Philips Medical Systems
Award Period: 01/01/07-11/30/07
Total/DC/IDC: $14,315/$10,225/$4,090

Title: Computerized Tomographic Colonography: Performance Evaluation in a Multicenter Setting.
Agency: NCI
Award Period: 06/01/07-05/31/07
Total/DC/IDC: $160,000/$104,918/$55,082

Title: Evaluation of Polyp Detection Software on False Negative Cases in a Large Multi-Center Clinical Trial.
Agency: ICAD, Inc.
Award Period: 06/15/06-12/31/06
Total/DC/IDC: $15,000/$10,714/$4,286

Title: CAD for CT Nodules in Lung Cancer Detection
Agency: NIH
Award Period: 09/19/03-08/31/08
Total: $1,331,000

Jia-Hong Gao, PhD
Title: 3T MRI Scanner for High Resolution MRI/MRS Research
Agency: NIH
Award Period: 06/01/07-05/31/08
Total/DC/IDC: $2,000,000/$2,000,000/$0
<table>
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<tr>
<th>Title</th>
<th>Agency</th>
<th>Award Period</th>
<th>Total/DC/IDC</th>
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</thead>
<tbody>
<tr>
<td>MRI of Current Density and Current Pathways Study.</td>
<td>Department of Defense</td>
<td>01/01/07-03/31/08</td>
<td>$300,000</td>
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<tr>
<td>Development and Optimization of msMRI.</td>
<td>NIH</td>
<td>09/01/04-08/30/08</td>
<td>$729,058/$499,355/$229,703</td>
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<tr>
<td>Current Density MRI of Live Swine.</td>
<td>Department of Defense/The Henry M. Jackson Foundation</td>
<td>09/21/05-12/31/10</td>
<td>$1,274,000/$832,680/$441,320</td>
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<tr>
<td>Development and Optimization of msMRI.</td>
<td>NIH</td>
<td>04/24/01-03/31/07</td>
<td>$1,550,279/$1,037,140/$513,139</td>
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<tr>
<td>Computerized Radiographic Analysis of Bone Structure.</td>
<td>NIH</td>
<td>04/1/06-3/31/10</td>
<td>$1,345,751/$880,000/$465,751</td>
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<tr>
<td>Correlative Feature Analysis for Multi-Modality Breast CAD.</td>
<td>Department of Defense (Army Research Office)</td>
<td>12/01/06 - 11/30/09</td>
<td>$97,200</td>
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<tr>
<td>Optimization of Computer-Aided Diagnosis (CAD) Output in Breast Imaging (R21 Phase).</td>
<td>NCI</td>
<td>06/15/06-06/05/31/08</td>
<td>$320,578</td>
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<td>Research Training in Medical Physics.</td>
<td>NIH</td>
<td>05/01/05-05-04/30/10</td>
<td>$1,659,345/$1,581,250/$78,095</td>
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<td>SPORE in Breast Cancer.</td>
<td>NIH/NCI</td>
<td>09/27/06-07/31/11</td>
<td>$1,734,824</td>
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<tr>
<td>Computer-Aided Analysis of Histopathology Images of Prostate Cancer.</td>
<td>NIH/NCI</td>
<td>04/01/07-03/31/09</td>
<td>$423,728</td>
</tr>
<tr>
<td>Computer-Aided Diagnosis of Breast Lesions in Mammograms</td>
<td>NIH</td>
<td>4/2/02-2/31/08</td>
<td>$1,513,506</td>
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<tr>
<td>Development and Evaluation of an IGRT Technology for Prostate Cancer.</td>
<td>American Cancer Society</td>
<td>11/01/06-10/31/07</td>
<td>$20,000/$20,000/$0</td>
</tr>
<tr>
<td>In Vivo PET Study of Sensorimotor Recovery in Rat’s Brain after Stroke.</td>
<td>Baromedical Research Foundation</td>
<td>05/17/07-04/16/08</td>
<td>$25,000/$25,000/$0</td>
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<td>SPORE in Breast Cancer.</td>
<td>NIH/NCI</td>
<td>09/27/06-07/31/11</td>
<td>$1,522,490</td>
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<td>Magnetic Resonance Imaging Core Facility.</td>
<td>Cancer Research Center (University of Chicago)</td>
<td>4/1/03-3/31/08</td>
<td>$558,661/$367,981/$191,181</td>
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<td>Spectral/Spatial Resolution Imaging Breast Cancer.</td>
<td>PHSN/NIBIB</td>
<td>9/15/03–7/31/08</td>
<td>$1,227,994/$805,241/$422,753</td>
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<td>Spectroscopic MR Imaging of Breast Cancer.</td>
<td>NCI</td>
<td>9/1/99-2/29/08</td>
<td>$1,002,208/$657,186/$345,022</td>
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<td>Molecular Probes and System Development for Optoacoustic Imaging of Proteases in Breast Cancer.</td>
<td>NCI/CRC</td>
<td>05/01/07-04/30/08</td>
<td>$88,375/$75,000/$13,375</td>
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<td>CAD for Lung Cancer Detection and Classification in CT.</td>
<td>NIH/NCI</td>
<td>08/01/06-07/31/09</td>
<td>$612,465</td>
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<td>Improved DBM ROC Methods for Diagnostic Radiology.</td>
<td>NIH (via subcontract w/ University of Iowa)</td>
<td>4/1/07-3/31/11</td>
<td>$671,859/$440,563/$231,296</td>
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<tr>
<td>Molecular Probes and System Development for Optoacoustic Imaging of Proteases in Breast Cancer.</td>
<td>NCI/CRC</td>
<td>05/01/07-04/30/08</td>
<td>$88,375/$75,000/$13,375</td>
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<td>Title</td>
<td>Investigating Three-Group Classifiers to Fully Automate Detection and Classification of Breast Lesions in an Intelligent CAD Mammography Workstation.</td>
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<td>Total/DC/IDC</td>
<td>$450,971/$295,719/$155,252</td>
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</table>

**Gillian Newstead, MD**

Title: Development of a Computer-Aided Diagnosis (CADx) System of Breast MR Lesions.
Agency: Philips Medical Systems
Award Period: 06/01/06-05/31/09
Total: $130,200

Title: MRI of specimen images with pathologic correlation.
Agency: Cancer Research Center (University of Chicago)
Award Period: B6/01/06-03/31/07
Total: $30,000

Title: New Approaches to Sampling and Analyzing Contrast Media Uptake and Washout.
Agency: NIH
Award Period: 07/01/05-06/30/07
Total: $419,375

Title: Dynamic spatial and spectral, contrast enhanced MRI of breast.
Agency: NIH
Award Period: 07/01/05-06/30/07
Total/DC/IDC: $390,087/$254,969/$135,118

Title: Improved spectral, temporal, and spatial sampling for breast cancer diagnosis.
Agency: Philips Medical Systems
Award Period: 06/01/06-05/30/07
Total/DC/IDC: $202,807/$144,862/$57,945

**Robert Nishikawa, PhD**

Title: High-Performance Computer Cluster for Image Analysis.
Agency: NIH
Award Period: 03/01/07-02/28/08.
Total: $237,000

Title: Retrospective Collection of Mammograms for Research in CAD.
Agency: Eastman Kodak Company
Award Period: 08/01/06-07/31/07
Total: $50,000

Title: A Novel Method for Determining Image Similarity.
Agency: PHSN/NIBIB
Award Period: 09/01/05-08/31/07
Total/DC/IDC: $151,279/$98,825/$52,454

**Brian Roman, PhD**

Title: Computerized Lesion Detection in Breast Tomosynthesis.
Agency: NIH/NCI
Award Period: 09/22/06-08/31/08
Total/DC/IDC: $578,384/$275,986/$193,744

Title: Using CAD as a Surrogate Reader in Observer Studies.
Agency: NIH/NIBIB
Award Period: 09/30/05-08/31/07
Total/DC/IDC: $416,367/$272,063/$144,304

Title: Mammography Computer Aided Detection Study for the University of Chicago.
Agency: Eastman Kodak Company
Award Period: 01/01/07-09/30/07.
Total: $50,000

Title: Comparison of Computer-aided Detection on Digital and Film Mammography.
Agency: Illinois Department of Public Health
Award Period: 07/01/07-06/30/08
Total: $75,000.

Title: Algorith Evaluation and Optimization Using L-3 Data.
Agency: L-3 Communications Security and Detection Systems
Award Period: 07/01/06-09/30/06
Total: $39,387

Title: Phase-Enhancement Micro-Computed Tomography.
Agency: Department of Energy
Award Period: 10/01/06-09/30/07
Total/DC/IDC: $41,000/$41,000/$0

Title: Optimized Cone-Beam CT for Image-Guided Radiation Therapy.
Agency: NIH
Award Period: 03/01/07-02/28/08.
Total: $250,000

Title: Non-Iterative Methods for 3D SPECT Image Reconstruction.
Agency: NCI
Award Period: 04/01/00-03/30/07
Total/DC/IDC: $334,523/$224,230/$110,293

Title: Targeted Imaging in Helical Cone-Beam CT.
Agency: NIH
Award Period: 09/01/05-08/31/08
Total: $963,843

Title: Imaging Pancreatic B-cell Function by Magnetic Resonance.
Agency: NIH
Award Period: 09/30/03-07/31/08
Total/DC/IDC: $1,451,345/$1,000,000/$451,345
Title: NMR Detection of Gene Expressions.
Agency: NIH
Award Period: 08/01/03-07/31/08
Total/DC/IDC: $1,511,498 / $1,073,669 / $437,829

Robert Schmidt, MD
Title: Comparison of Konica Minolta REGIUS PureView Phase Contrast Mammography (PCM) System with Conventional Screen-Film (Analog) and Digital Systems for Diagnostic Mammography.
Agency: Konica Medical USA
Award Period: 06/01/06-06/01/07
Total: $60,000

Kenji Suzuki, PhD
Title: Advanced Computer-Aided Detection of Colon Cancer in CT Colonography.
Agency: American Cancer Society
Award Period: 04/01/07-03/31/08
Total/DC/IDC: $100,000 / $100,000 / $0

Title: Analysis of Computer-Aided Detection (CAD) of Lung Nodules in Chest Radiography.
Agency: Riverain Medical LLC
Award Period: 10/01/06-09/30/08
Total/DC/IDC: $85,000 / $60,714 / $24,286

Title: Development and Evaluation of Computer-Aided Detection of Polyps in CT Colonography on false Negative Cases in Large Multicenter Clinical Trial.
Agency: Radiological Society of North America Research & Education Fund
Award Period: 07/01/06-06/30/08
Total: $30,000
Principal Investigator: Kenji Suzuki, PhD

Title: Development of an Advanced Computer-Aided Diagnostic System for Early Detection of Colorectal Cancer in CT Colonography.
Agency: Cancer Research Foundation, Young Investigator Awards
Award Period: 01/01/06-12/31/07
Total: $50,000
Principal Investigator: Kenji Suzuki, PhD

Title: 3D Massive Training ANN for CAD for Colon Cancer in CT Colonography.
Agency: NIH/NCI
Award Period: 09/26/07-07/31/11
Total/DC/IDC: $760,000 / $760,000 / $0

Abraham Dachman, MD
Title: Computerized Detection of Polyps in CT Colonography.
Agency: NIH
Award Period: 07/01/03-06/30/08
Total: $1,890,500
Principal Investigator: H. Yoshida
Effort: 8.9%

Title: Development and Evaluation of Computer-Aided Detection of Polyps in CT Colonography on false Negative Cases in Large Multicenter Clinical Trial.
Agency: Radiological Society of North America Research & Education Fund
Award Period: 07/01/06-06/30/07
Total: $30,000
Principal Investigator: Kenji Suzuki, PhD

Title: Development of an Advanced Computer-Aided Diagnostic System for Early Detection of Colorectal Cancer in CT Colonography.
Agency: American Cancer Society
Award Period: 04/01/07-03/31/08
Total: $100,000
Principal Investigator: Kenji Suzuki, PhD

Title: Pathways Linking Reduced Sleep Duration and Quality to Obesity Risk.
Agency: NIH
Award Period: 09/01/06-08/31/09
Total/DC/IDC: $1,300,000 / $849,673 / $450,327

Title: Functional Neuroimaging of Opioid Effects on Affective Experience.
Agency: NIH
Award Period: 08/01/07-07/30/08
Total/DC/IDC: $226,500 / $150,000 / $76,500

Gregory Karczmar, PhD
Title: Development of a Computer-Aided Diagnosis (CADx) System of Breast MR Lesions.
Agency: Philips Medical Systems
Award Period: 06/01/06-05/31/09
Total: $130,200
Principal Investigator: Gillian Newstead, MD
Title: Dynamic Spatial and Spectral, Contrast Enhanced MRI of Breast.
Agency: NIH
Award Period: 07/01/05-06/30/07
Total/DC/IDC: $390,087/$254,969/$135,118
Principal Investigator: Gillian Newstead, MD

Title: MRI of Specimen Images with Pathologic Correlation.
Agency: Cancer Research Center (University of Chicago)
Award Period: 06/01/06-05/30/07
Total: $30,000
Principal Investigator: Gillian Newstead, MD

Title: Improved Spectral, Temporal, and Spatial Sampling for Breast Cancer Diagnosis.
Agency: Philips Medical Systems
Award Period: 06/01/06-05/30/07
Total/DC/IDC: $202,807/$144,862/$57,945
Principal Investigator: Gillian Newstead, MD

Heber MacMahon, MD
Title: Evaluation and Analysis of CAD Scheme for Detection of Nodules.
Agency: Riverain, LLC
Award Period: 03/31/07
Total: $166,700
Principal Investigator: Kunio Doi, PhD
Effort: 5%

Title: Program Leaders.
Agency: NCI
Award Period: 03/31/07
Principal Investigator: M. Lebeau
Effort: 10.69%

Title: CAD for CT Nodules in Lung Cancer.
Agency: NCI
Award Period: 08/31/07
Total: $141,300
Principal Investigator: Kunio Doi
Effort: 2.65%

Title: Computerized Analysis of Mesothelioma on CT Scans.
Agency: NIH/NCI
Award Period: 06/01/06-05/31/10
Total: $1,078,763
Principal Investigator: Samuel Armato, PhD
Effort: 5%

Title: Advanced Image Processing for Mesothelioma.
Agency: NIH/NCI
Award Period: 06/01/06-05/31/10
Principal Investigator: Samuel Armato, PhD
Effort: 5%

Title: Standard Database for CT Lung Images.
Agency: NCI
Award Period: 07/31/06
Total: $30,000
Principal Investigator: Gillian Newstead, MD

Heber MacMahon, MD
Title: Evaluation and Analysis of CAD Scheme for Detection of Nodules.
Agency: Riverain, LLC
Award Period: 03/31/07
Total: $166,700
Principal Investigator: Kunio Doi, PhD
Effort: 5%

Title: Program Leaders.
Agency: NCI
Award Period: 03/31/07
Principal Investigator: M. Lebeau
Effort: 10.69%

Title: CAD for CT Nodules in Lung Cancer.
Agency: NCI
Award Period: 08/31/07
Total: $141,300
Principal Investigator: Kunio Doi
Effort: 2.65%

Title: Computerized Analysis of Mesothelioma on CT Scans.
Agency: NIH/NCI
Award Period: 06/01/06-05/31/10
Total: $1,078,763
Principal Investigator: Samuel Armato, PhD
Effort: 5%

Title: Advanced Image Processing for Mesothelioma.
Agency: NIH/NCI
Award Period: 06/01/06-05/31/10
Principal Investigator: Samuel Armato, PhD
Effort: 5%

Title: Standard Database for CT Lung Images.
Agency: NCI
Award Period: 07/31/06
THE ANNUAL FACULTY HOLIDAY PARTY

December 16, 2006 at the Cité.

GRADUATION PARTY FOR THE RESIDENTS

June 9, 2007 at Gibson’s Steakhouse
Richard L. Baron, MD
   Chairman

David M. Paushter, MD
   Executive Vice Chair, Clinical Operations

Maryellen L. Giger, PhD
   Vice Chair for Basic Science Research

Michael Vannier, MD
   Vice Chair for Clinical Research

Edward Smith, MHSA, FACHE
   Executive Director

Section Chiefs
Daniel Appelbaum, MD - Nuclear Medicine
Larry Dixon, MD - Musculoskeletal Imaging
Kate Feinstein, MD - Pediatric Imaging
Brian Funaki, MD - Vascular and Interventional Radiology
Maryellen Giger, PhD - Radiological Sciences
Jeffrey Leef, MD – Weiss Hospital Imaging
Heber MacMahon, MD – Thoracic Imaging
Gillian Newstead, MD – Breast Imaging
David Paushter, MD – Abdominal Imaging
Jordan Rosenblum, MD – Neuroradiology

Education Directors
Maryellen Giger, PhD – Director, Graduate Programs in Medical Physics
Jordan Rosenblum, MD – Director, Residency Program
Christopher Straus, MD – Director, Medical Student Education
Larry Dixon, MD – Associate Director, Residency Program

Fellowship Program’s
Dianna Bardo, MD – Director, Neuroradiology Fellowship Program
Abraham Dachman, MD – Director, Abdominal Fellowship Program
Larry Dixon, MD – Director, Musculoskeletal Fellowship Program
Jonathan Lorenz, MD – Director, Interventional Radiology Fellowship Program
Gillian Newstead, MD – Director, Breast Imaging Fellowship Program
## Faculty, Clinical Fellows, Residents & Researchers

### Clinical Faculty
- Hiroyuki Abe, MD
- Daniel Appelbaum, MD
- Dianna Bardo, MD
- Richard Baron, MD
- Paul Chang, MD
- Abraham Dachman, M.D.
- Larry Dixon, MD
- Kate Feinstein, MD
- Brian Funaki, MD
- Arunas Gasparaitis, MD
- Jeffrey Leef MD
- David Levin, MD, PhD
- Jonathan Lorenz, MD
- Heber MacMahon, MD
- Myrosia Mitchell, MD
- Saeid Mojtahedi, MD
- Steven Montner, MD
- Gillian Newstead, MD
- Aytek Oto, MD
- David Paushter, MD
- Yonglin Pu, MD
- Sidney Regalado, MD
- Jordan Rosenblum, MD
- Robert Schmidt, MD,
- Charlene Sennett, MD
- Gregory Scott Stacy, MD
- Christopher Straus, MD,
- Thuong Van Ha, MD
- Michael Vannier, MD,
- David Yousefzadeh, MD
- Mario Zaritzky, M.D.
- Alexandra Funaki, D.O.
- Brent Greenberg, MD
- Ann Kieran, MD
- Stephanie Rosania, MD
- Peter Doris, MD
- Jeffrey Ho, MD
- Grace Knuttinen, MD
- Kirti Kulkarni, MD
- Shital Makim, MD
- Adnan Qalbani, MD
- Olga Vinokur, MD
- Steve Zangan, MD

### Residents

#### (First Year)
- Anna Abramovitch
- Michael Hutchinson
- Vicky Lin
- Hao Lo
- Evan Nichols
- Michael Noud
- David Schacht

#### (Second Year)
- Samantha Fienberg
- Monica Harish
- Gregory Henkle
- Sheela Konda
- Albert Li
- Michael Lester
- Christopher Molvar

#### (Third Year)
- Joseph Carabetta
- Rodney Corby
- Phil Kurzman
- Rajshri Shah
- Steven Thiel
- Carl Valentin
- Ivica Vucic

#### (Fourth Year)
- Jarvis Chen
- Caroline Cranford
- Roi Lotan
- Scott Santeler
- Oneil Lee
- Derek Fimmen

### Research Associates with Rank
- Karen Drukker, PhD
- Xiaobing Fan, PhD
- Chad Haney PhD
- Feng Li, PhD
- Hui Li, PhD
- Qiang Li, PhD
- Milica Medved, PhD
- Ingrid Reiser, PhD
- Junji Shiraishi, PhD
- Emil Sidkey, PhD
- Jeffrey Souris, PhD

### Research Professional
- Karla Horsch, PhD

### Post Doctoral Scholars
- Michael Chinander, PhD
- Darrin Edwards, PhD
- Satoshi Kasai, PhD
- Lara Leoni, PhD
- Akiko Shimauchi, PhD
- Jiahui Wang, PhD
- Qingguo Xie, PhD
- Guihua Zhai, PhD

### Post Doctoral Fellows
- Samuel LaRoque, PhD
- Antonio Marchado, PhD
- Fangyuan Nan, PhD

### Visiting Appointments
- Chih-Feng Chen, PhD
- Lifeng He, PhD
- Yu-Erh Huang, PhD
- Seiji Kumazawa, PhD
- Lina Meinel, PhD
- Roberto Pereira, PhD
- Tetsuo Shimada, PhD
- Rie Tanaka, PhD
- Xing Zhao, PhD

### Emeritus
- Robert Beck
- John Fennessy, MD
- Chien-Tai Lu, MD

### Secondary Appointments in Radiology
- Jeanne Decara, MD
- Roberto Lang, MD
- Jonathan Silverstein, MD
- Kirk Spencer, MD
- R. Parker Ward, MD
- Kim Williams, MD

### Basic Science Faculty
- Samuel Armato III, PhD
- Chin Tu Chen, PhD
- Kunio Doi, PhD
- Jia Hong Gao, PhD
- Maryellen Giger, PhD
- Yulei Jiang, PhD
- Chien-Min Kao, PhD
- Greg Karczmar, PhD
- Patrick LaRiviere, PhD
- Charles Metz, PhD
- Robert Nishikawa, PhD
- Bill O’Brien-Penney, PhD
- Xiaochuan Pan, PhD
- Brian Roman, PhD
- Kenji Suzuki, PhD

### Clinical Associates
- Gabriel Angres MD
- Philip Caliguiri, MD

### Clinical Professors
- Hiroyuki Abe, MD
- Daniel Appelbaum, MD
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- Jeffrey Ho, MD
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- Ingrid Reiser, PhD
- Junji Shiraishi, PhD
- Emil Sidkey, PhD
- Jeffrey Souris, PhD

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- Jiahui Wang, PhD
- Qingguo Xie, PhD
- Guihua Zhai, PhD

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- Antonio Marchado, PhD
- Fangyuan Nan, PhD

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