Front cover image: angiogram taken during coil embolization of a posterior communicating artery aneurysm at DHMC by interventional neuroradiologist Clifford Eskey. Advanced capabilities of current-generation imaging technology, such as the Siemens biplane angiography system on which this image was captured, have fueled rapid growth in precise minimally-invasive neurointerventional procedures. (The patient in this instance arrived at DHMC in a coma as a result of an acute subarachnoid hemorrhage. Following the embolization procedure depicted here, he made a complete recovery.)
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With gratitude and fondness, we dedicate this report to our friend, facilities manager Paul Roy, retiring this spring after 26 years of commitment to the mission and the people of this department.
I take this occasion to offer an overview of the department, to reflect on the challenges and achievements of the four years since our last report, and to highlight ongoing initiatives and priorities for the future. These years have included difficult periods in which economic turmoil and rancorous debate on healthcare policy have tested our communities in many ways. So it is with great pleasure and gratitude I can report that the dedication and commitment to excellence which characterizes the entire Radiology staff remains intact. Across the spectrum of our endeavors—in the quality of our teaching and clinical care, our imaging capabilities, our leadership roles, and the impact of our research and scholarly work—we have achieved the results that reaffirm our standing among the nation’s finest radiology services.

We have made several outstanding additions to our physician staff. Dr. Elizabeth Dann, a former resident and DHMC fellow, has already made significant contributions and now leads our Breast MRI service. Dr. David Pastel, a superb addition to our growing neuroradiology staff, was also with us as a resident and fellow. The neuroradiology staff is further enhanced with the 2009 arrival of Dr. Clifford Belden, from Albany Medical College, who brings more than ten years’ experience in clinical neuroradiology, fMRI, and a strong track record in research. (Drs. Belden and Pastel almost immediately made us proud, sweeping top honors at the 2009 American Society of Neuroradiology Annual Meeting with a pair of scientific exhibits on hypopharynx imaging.) Dr. Julianna Czum joined us in 2006 as a specialist in non-invasive cardiac and vascular imaging and now directs cardiothoracic imaging. We have had the pleasure of welcoming longtime VA Hospital colleague Dr. Nancy McNulty to the full-time staff. Along with providing imaging expertise in several modalities and clinical divisions, Dr. McNulty plays an active and innovative role in the Medical Student Education program. Finally, we await the arrival this August of Dr. Albert Song, who will join the musculoskeletal division, bringing a much appreciated expertise in tumor imaging. We look forward to the contributions our new colleagues will bring in patient care, scholarship and teaching.

The faculty continues to play leadership roles within and beyond the institution—which I note here but a few examples. Dr. Jocelyn Chertoff, department Vice Chair and former director of the residency program, serves as Assistant Dean for Clinical Affairs, chairs the Hitchcock Foundation, is active in various other institutional capacities, and fills key leadership positions at several of the country’s most influential radiology and medical education organizations. Dr. Clifford Eskey serves on the institution’s Inpatient Coverage and Care Committee, is President of the Eastern Neuroradiological Society, and serves on the Editorial Board of the American Journal of Neuroradiology. Dr. John Gemery represents the department on the Ongoing Professional Performance Evaluation (OPPE) Committee. Dr. Alan Siegel is an active proponent for the uses of new communications technologies in medicine; he serves on the Information Systems Steering Committee and the Clinical Informatics Group. Dr. Marc Seltzer, a nationally-recognized expert on PET-CT, teaches a popular course for the ACR and hosts our annual PET-CT conference. Dr. Clifford Belden sits on the Committee for the Protection of Human Subjects, and has taken over for Dr. Robert Harris as director of the Radiology Research Committee. Dr. Harris, who recently completed the MPH program at TDI, has developed a program for introducing portable ultrasound equipment and training to obstetric clinics in remote settings in under-developed regions around the world. Dr. Petra Lewis plays a major role in national medical student education; she and Dr. Nancy McNulty have authored various online education resources widely used both within and outside this institution.

Among recent D-H management changes, I note in particular the departure of Clinical Services VP Ron Sliwinski, whose wisdom and ingenuity have helped build and guide the
department for the past twenty years. We welcome Mary Oseid, who brings a record of institutional accomplishment and extensive systems knowledge to her new appointment as VP of Ambulatory Care; and with equal enthusiasm welcome Dr. James Weinstein—skilled orthopedic surgeon, TDI director, and medical outcomes advocate—to his new role as Dartmouth-Hitchcock Clinic president.

Department veteran Jim Roberts—more than once tapped to take on key roles when needed—accepted the position of Administrative Director in mid-2008. His organizational and communication skills are already much in evidence, and with over 30 years as an imaging technologist and manager at DHMC, he brings insights and experience that will benefit the department in years to come. The position of Clinical Operations Manager, previously filled by Jim, is now held by the team of Chriss Kvinlaug (for CT, VIR, nuclear imaging, and MRI) and Karen Burgess (for DX, mammo, and ultrasound). Chriss, taking on this role just as we go to press, has been a highly effective director of the radiologic nursing staff for many years, and we have strong expectations that she will provide excellent leadership in this new role as well. Karen, very ably serving in her present capacity since 2008, began her radiology career with us as an RT over 20 years ago, returning now after a successful interlude in regional mammography research and clinical practice. A final note on administration changes includes a farewell to Facilities Manager, Paul Roy. In his 26 years of service, Paul played a key role in building the department and sustaining our technological edge—his skill and dedication will be missed and long remembered.

### Clinical Programs

In FY 2009 the department completed nearly 246,000 exams and procedures, representing a 31% increase in the four years since FY 2005—a 7% annualized growth rate. This volume growth has occurred in all major imaging modalities. Our teams in the DX core performed 30,000 more exams and procedures in 2009 than in 2005. MRI and ultrasound saw strong growth on a percentage basis, of 35% and 42%, respectively. The more regular use of obstetric screening explains part of the growth in ultrasound, but volume growth in all diagnostic modalities generally has been strong. The increase in the number (and variety) of image-guided interventional procedures has been even more dramatic. While the VIR team, with its comprehensive array of interventional procedures, accounts for much of angiography’s 45% volume growth, there has also been an expansion in the number and complexity of image-guided procedures done outside the angiography suite—fluoroscopic PICC guidance, MR-guided procedures, and, especially, interventional CT.

Current generation CT systems permit highly accurate instrument placement for an expanding range of percutaneous interventions when highly detailed structural imaging is essential. In FY 2009, we performed over seven hundred CT-guided procedures, an increase of 88% in the past four years. The growth of CT-IR is expected to continue, driven by strong demand, increased versatility, and a superb new wide-bore scanner ideal for interventional cases. The neuroradiology interventional service begun in 2005 now offers the full range of endovascular treatments for cerebrovascular diseases; the biplane angiography suite opened in 2009 is expected to spur expansion in both the number and variety of procedures. In early 2010, following installation of a powerful new 3T magnet, Dr. Belden opened northern New England’s first clinical fMRI service, providing clinicians with precise pre-surgical localization of brain structures. We anticipate continued growth in neuroradiology, with initiatives that include a new stroke service, additional neuro-IR procedures, and the possible establishment of a neuroradiology center of excellence.

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<th>Modality</th>
<th>FY 2005</th>
<th>FY 2009</th>
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<tr>
<td>ANGIO</td>
<td>4,025</td>
<td>5,856</td>
<td>45.5</td>
</tr>
<tr>
<td>CT</td>
<td>30,998</td>
<td>39,835</td>
<td>28.5</td>
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<tr>
<td>DX</td>
<td>98,163</td>
<td>128,518</td>
<td>30.9</td>
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<tr>
<td>MAMMO</td>
<td>16,108</td>
<td>20,365</td>
<td>26.4</td>
</tr>
<tr>
<td>MRI</td>
<td>15,858</td>
<td>21,456</td>
<td>35.3</td>
</tr>
<tr>
<td>NUC MED</td>
<td>8,040</td>
<td>10,061</td>
<td>25.1</td>
</tr>
<tr>
<td>ULTRASOUND</td>
<td>13,930</td>
<td>19,853</td>
<td>42.5</td>
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<tr>
<td><strong>Total</strong></td>
<td><strong>187,122</strong></td>
<td><strong>245,935</strong></td>
<td><strong>31.4</strong></td>
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Our Musculoskeletal division continues to experience growing demand. Equipment upgrades and purchases (such as the innovative 1.5T small-bore MR “extremity” magnet installed last year) and hiring new staff, such as Dr. Song, are part of an ongoing expansion which includes the possible creation of a multi-discipline MSK Center.

Several other services introduced in recent years have become well-established. Breast MRI has grown in response to increasing awareness of the modality’s utility for high-risk and pre-operative patients. Dr. Czum, one of only several New England physicians certified in cardiovascular CT, heads up our cardiac CT program. While volume growth has lagged expectations, the service has become a key element in the institution’s multi-disciplinary cardiovascular program. Drs. Michael Tsapakos and Nancy McNulty now offer CT (“virtual”) colonoscopy for failed colonoscopies, providing an important service even as wider use of CT colonography for screening purposes remains on hold pending regulatory agency review.

The contributions of our nurses and radiologic technologists remain central to the success of our clinical programs and the department’s overall mission. In all modalities, the RT staff excels not only in meeting the technical and patient-care demands of their clinical role, but in the many ancillary ways which illustrate their dedication and resilience—as teachers and mentors, as innovators, as originators of quality and safety improvements. I note with gratitude the legacy of dedication and innovation left by former DX Core team leader Gerald Bergen, retired recently after 30 years of service.

**Imaging and Information Systems** Radiology relies upon the availability of increasingly complex and powerful imaging systems—and the rapid pace of technical innovation in this field presents both opportunities and challenges. Highlights of recent imaging acquisitions include: two new 1.5T MR scanners; the extremity MRI scanner noted earlier; a state-of-the-art interventionalangiography suite featuring a new flat panel biplane system; upgraded mammography units including a stereotactic prone biopsy system; a cutting-edge Hologic breast tomosynthesis unit; a SPECT-CT system to bolster already strong capabilities in nuclear imaging; a wide-bore “adaptive” CT scanner with fluoroscopy that delivers instant multi-planar reformatting; and finally, a new 3T MRI system that enhances our MR capabilities generally, but especially in facilitating services in neuroradiology such as a clinical fMRI.

Maintaining the quality and competitiveness of our capacities in traditional diagnostic X-Ray systems—where roughly half of our volumes are still generated—remains a priority. We have upgraded equipment in our rapidly-growing bone densitometry (DXA) suite; installed upgraded X-ray units and touch-screen workstations in the DX core and the ED; expanded capabilities in mammography with a specialized suite for supine MR breast interventions; and we were among the first institutions to test and use portable X-ray wireless units.

Current generation radiographic, MR, and nuclear imaging systems can quickly generate studies containing thousands of images that form the basis for complex, customized reconstructions of almost endless variety. John Sundnas, RIS/PACS Administrator, continues to guide us in new information-systems acquisitions and to ensure the reliability of the data systems needed to support the work of our staff. Recent initiatives include: extending our RIS and PACS to the Hitchcock Clinic facilities in southern New Hampshire and the implementation of an effective interim solution for managing patient studies from outside institutions conveyed on disc, even as we continue development of a more ideal system of direct hospital to hospital digital transfer.

**Outcomes and Quality Assurance** The department has a twenty-year record of support for outcomes-based medicine, and in recent years has been proactive in implementing the new standards of quality management. The Radiology Outcomes Group is responsible for promoting outcomes-based QI initiatives, and draws on the ideas and resources of The Dartmouth Institute (TDI), one of the nation’s leading centers for comparative effectiveness research. The group includes TDI pioneer Dr. William Black and five other faculty graduates of the institute’s MS or MPH programs.
A noteworthy safety initiative undertaken last year concerned the problem of “unexpected findings”—indications of serious pathology unrelated to an exam’s primary condition of interest. The standard practice had been to note the finding in the radiologist’s report communicated to the attending physician via CIS—leaving open the possibility of the note being overlooked. With support from the institution’s Risk Management Department, we designed and implemented an improved process that ensures follow-up, and established the position of Results Reporting Coordinator to ensure compliance.

Radiology Education The success of our residency program owes much to the expertise and dedication of Dr. Jocelyn Chertoff, who steps down this summer after 17 years as Residency Director. During the years of Dr. Chertoff’s leadership, the program doubled in size, kept pace with frequent changes in ACGME requirements, and saw steady improvements in all aspects of resident education. Most recently, Dr. Chertoff spearheaded the expansion of the resident complement to 20, and guided us to a third consecutive unconditional five-year ACGME accreditation. Dr. Anne Silas, our new Residency Director, is a multi-talented physician with expertise in cardiac CT, VIR, and uroradiology, and four years’ experience as Associate Director. Willo Sullivan, recruited two years ago as Program Coordinator has significantly enhanced the efficiency and value of candidate visits, for students and faculty alike. For my part, meeting candidates—with their remarkably diverse academic, regional and cultural backgrounds—remains a great pleasure, and provides me a chance to speak on some of my favorite themes—our rich institutional history, the strengths of our program, and the attractions of life in the Upper Valley.

Our fellowship programs—cross-sectional, MRI, neuroradiology, and VIR—continue to attract highly qualified candidates. Many of our residents end up staying on as fellows—testimony to both the quality of the residency and the appeal of our fellowships.

The Medical Student Education program, directed by Dr. Lewis, actively involves much of our faculty and remains one of our key priorities. Roughly 10% of DMS students have been choosing radiology residencies—a measure of the program’s success. Spanning all four years, the program features a solid grounding in the basics of radiology and a final-year elective which is among the most heavily subscribed electives at DMS. Drs. Lewis and McNulty have been energetic proponents for innovative approaches to the curriculum, and have designed a variety of online resources widely used within the institution and at radiology education programs across the country.

Medical Imaging Research Imaging research, a central element in our mission, includes clinical trials and studies led by staff radiologists, basic-science investigations in advanced imaging techniques, and a number of major collaborative programs. Members of the clinical staff conduct clinical studies on aspects of imaging techniques and outcomes. The interventional radiology division is particularly active—Drs. Hoffer, Silas, Forauer, Gemery and McNulty have in recent years published on a variety of IR topics, including subcutaneous access, CT summation in RFA, endovascular stent-grafts, liver biopsy, and arterial closure. Dr. Lewis received considerable attention for her AJR-published study on MRI in breast-cancer screening. Dr. Cheung has published a series of recent pieces on MRJ for detecting ligament injury in ankle fractures; she is recognized as an authority of tendon-injury imaging and has been repeatedly invited to present courses and lectures at RSNA Annual Meetings and elsewhere. Drs. Eskey, Merlis, and Belden, with other colleagues from the
neuroradiology division, have published on aspects of MR imaging of the brain, optic nerve, and the spine. Dr. Chertoff has recently published on abdominal imaging, in addition to various articles on issues in medical education. Members of the Radiology staff are centrally involved in several of the institution’s most significant clinical trials and research programs: Dr. Poplack directs the clinical component of the alternative breast imaging program; Dr. Black is among the architects of the National Lung Cancer Screening Trial (NLST) and the Thayer School of Engineering. The ten-year, NIH-funded Alternative Breast Imaging (ABCI) program is our largest and longest-running research project. Led by Dr. Keith Paulson, Professor of Engineering and of Radiology, with the continuous support of Dr. Steven Poplack and faculty colleagues in the Breast Imaging Division, ABCI is one of the most extensive studies of its kind anywhere, and a prime example of Dartmouth’s success in generating solid results through collaborative research. Despite the difficult economy, the past year has brought over $10 million of NIH awards for multi-disciplinary medical imaging programs that include renewal funding for the ABCI and related projects; a new RO1 grant for digital breast tomosynthesis studies; and a $4 million “GO” grant for a cancer-imaging outcomes study led by Dr. Black and Dr. Anna Tosteson that may include the establishment of a DHMC-based comparative effectiveness research center.

Cross-discipline collaboration is a central feature of the extended Dartmouth research community—and is decidedly the case in imaging research, which includes a number of joint investigations involving faculty and staff from our department, other DMS disciplines, the Norris Cotton Cancer Center, and the Thayer School of Engineering. The Nuclear Magnetic Resonance (NMR) Lab conducts studies on hemodynamics, brain oxygenation and functional MRI—research which will be enhanced with the installation of a new 9.4T small-bore magnet in late 2010. NMR Director Dr. Risto Kauppinen is joined this year by Dr. Barjor Gimi—a gifted scientist with a background in physics, electrical engineering, bioengineering, and radiology—who brings extensive experience in molecular magnetic resonance microimaging and is known for groundbreaking work in encapsulation nanotechnology.

Recent developments at the department’s Electron Paramagnetic Resonance (EPR) Center have dramatically underscored Dartmouth’s prominent role in this field. EPR Center founder and director Dr. Harold Swartz now leads a consortium of four institutions seeking to develop EPR–based portable dosimetry devices that can be used for medical triage in the event of catastrophic radiation exposure events. To be funded by an NIH “U19” grant expected to total nearly $16.6 million over the next five years, this Dartmouth-led group will comprise one of NIAID’s “Centers for Medical Countermeasures against Radiation” (CMCR). Significant additional funding for the development of an EPR tooth-dosimetry device is also expected later this year.

The Nuclear Magnetic Resonance (NMR) Lab fMRI brain images from the Philips 3T magnet in the Advanced Imaging Center, reconstructed on SPM software.

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It is now 114 years since Hanover physician Gilman Frost teamed up with two Dartmouth physicists—his brother, Edwin Frost, and Frank Austin—to perform the nation’s first clinical X-ray, producing an image of 14-year-old Eddie McCarthy’s fractured wrist. From that time to the present, Dartmouth-Hitchcock has maintained its place as one of America’s premier imaging centers, providing direct patient care and diagnostic support to all clinical areas of the hospital while training new generations of radiologists, and supporting a range of research activities designed to improve the utility of modern medical imaging. It has been a privilege to be custodian of this rich tradition, and to have served as facilitator for a faculty and staff which will most assuredly be among tomorrow’s leaders in radiologic services, patient care, and medical innovation.
The DHMC Radiology Residency program trains residents to the highest standards of competency across the spectrum of imaging modalities and procedures. Prepared for independent exercise of medical judgment and initiative, our residents continue to be selected for highly competitive subspecialty fellowships. In 2009, we added four positions, expanding the program to 20 residents. The larger complement creates flexibility in meeting the clinical training needs of our residents, greater opportunity for resident research, helps meet the demands of new ACGME call requirements, takes advantage of a strengthened faculty and state-of-the-art imaging equipment, and will contribute to improved clinical care. In April 2010 the program was awarded ACGME’s strongest possible endorsement—unconditional five-year accreditation. We strive to make the resident recruitment process, especially the visits of residency candidates, as informative and congenial as possible. We begin the interview season early, and emphasize a highly individualized experience: each applicant meets with radiology attendings one-on-one, for up to a half-hour, and all candidates meet with the Radiology Department chair.

Residency directors and the faculty subject the curriculum to an ongoing assessment that includes close attention to new ideas in radiology education, a readiness to implement innovative changes, and responsiveness to feedback from our resident staff. The core curriculum follows American Board of Radiology (ABR) guidelines: modality-based sections and two-year series of conferences, with standardized annual evaluations. The ABR’s proposed change on oral boards promises a more clinically-focused fourth year and an exciting opportunity for initiatives throughout the program; anticipated changes include a more intensive research elective and increased collaboration with Dartmouth College. Our Managed Care Curriculum—designed to address outcomes research, evaluative sciences, ethics, and management—has been adopted as a model for the radiology curriculum being developed by the Association of Program Directors in Radiology (APDR) and the American College of Radiology (ACR). One of the best of the web-based radiology learning portfolio systems is the ACGME Learning Portfolio (ALP)—for which we participated as one of a handful of alpha test sites.

The radiology residency stresses hands-on experience, view-box teaching, and joint teaching conferences with faculty from Urology, General Surgery, Gastroenterology, Pulmonary Medicine, Thoracic Surgery, ENT, Maternal/Fetal Medicine, Neurology, Neurosurgery, and Pediatrics. We are privileged to be among a select group of institutions that offer residents a comprehensive course in radiological physics. Off-campus rotations include the VA Hospital in White River Junction, VT, providing an excellent opportunity for integrated patient care and graduated responsibility; Boston Children’s Hospital—a core experience in pediatric radiology that supplements the month of pediatric rotation at DHMC and the Children’s Hospital at Dartmouth (CHaD); and a month at the Armed Forces Institute...
of Pathology in Washington, DC, for a grounding in radiologic-pathologic correlations—a key step in building the conceptual framework for transforming oceans of data into the integrated knowledge needed in medical practice. The program also includes an unusually prominent role for residents in medical student education. Recent changes affecting the quality of resident life include a reduction of holiday call responsibilities to a maximum of 12 hours, and a noon-time start for days residents are scheduled for call. An active program for guest lecturers brings diverse ideas and exposure to medical leaders from around the nation and the world. Residents present grand rounds in a program of formal lectures that also includes presentations by fellows and faculty. Monthly Journal Club meetings provide an informal setting for discussion and critical evaluation of timely issues and peer-reviewed journal articles. The University of Vermont has a tradition of highly effective Mock Board Examinations, to which our residents are regular invited participants.

Many of the radiology teaching staff are closely connected, as graduates and faculty, to the Dartmouth Institute for Health Policy and Clinical Practice (TDI), bringing to residency instruction the insights of one of the nation’s leading institutions for research methodologies and evidence-based medicine. Our residents are encouraged to pursue TDI training through the Leadership Preventive Medicine Residency, a two-year program leading to the MPH degree and board-eligibility in Preventive Medicine and Radiology.

The incorporation of innovative, computer- and web-based learning resources is a key component of our program. The Radiology Learning Laboratory includes the ACR’s teaching file, with thousands of referenced, annotated cases on film, CD-ROM and laser disc format, and audiovisual seminars in general radiology and emergency radiology. We have developed computer-based tutorials for residents and medical students. To validate and improve our teaching, we participate in the ACR In-Training Examination, which permits comparison with exam results from residents in programs throughout the country. To ensure that residents are ready for independent exam interpretations and taking call, we rely on a variety of rigorous assessments that include competency checklists and the Radiology Resident Pre-Call Evaluation exam. Developed by Dr. Lewis, the pre-call exam asks students to provide preliminary reads on up to 55 different cases in a PACS-like environment characteristic of what can be expected on call; the exam has been used here for the past three years, and is now available online to other institutions via MedEdPORTAL.

Residents contribute to the research activities of the department, independently or in collaborations which may include partnerships with the department’s regular faculty or dedicated research staff. Attendance at national meetings is encouraged, and meaningful scholarly activities—abstracts, conference presentations, journal articles—are expected of residents, as well as participation in the design and implementation of quality improvement initiatives. A partial list of resident-authored studies published in peer-reviewed journals is included in the appendix.

Residents are encouraged to attend the scientific sessions of the New England Roentgen Ray Society and the NH Radiological Society. Our chief residents attend the annual meeting of the Association of University Radiologists (AUR). Residents are nominated for the highly competitive Introduction to Academic Radiology program presented at the RSNA Scientific Assembly and the ARRS Scientific Meeting, and also for the Siemens-AUR Radiology Resident Academic Development (SARRAD) program. The department participates in the Roentgen Research Award program; recent resident alumni award winners include Scott Napinsky (2006), Rihan Khan (2007), Jeremy Hopkins (2008) and Kiley Perrich (2009).
Program Administration

From 1993 to July 2010, the residency program was directed by Dr. Chertoff, department Vice-Chair and Director of Gastrointestinal Radiology. She plays an active management and policy-making role at DHMC and DMS, and is current Chair of the Hitchcock Foundation. Dr. Chertoff is Co-Vice Chair of the Commission on Education at the American College of Radiology, and is directing development of the gastrointestinal portion of the core ABR exam; she holds key positions in medical education organizations including the Alliance of Clinician-Educators in Radiology, the AUR, the Association of Program Directors in Radiology (APDR), and the Accreditation Council for Graduate Medical Education (ACGME).

Dr. Silas, who assumes the role of Residency Program Director in July 2010, will be assisted by Dr. Chertoff, who continues active participation in the program as Associate Program Director, and by Assistant Directors, Drs. Merlis and Lewis, all of whom pursue medical education interests within the institution and in national organizations. Dr. Silas, an active member of the APDR and the AUR, had been responsible for the rotation and call schedule, and for program management in the Director’s absence.

Dr. Lewis, who also serves the department as Director of Medical Student Education, serves in a variety of leadership capacities at various professional organizations, including a recent term as President of the Alliance of Medical Student Educators in Radiology (AMSER.) Dr. Lewis has been an energetic advocate for incorporating informatics technologies into the curriculum, and has developed a number of innovative online tools for resident education, including the Radiology Resident Pre-Call Evaluation exam mentioned above.
Recent Alumni: Post-Residency

E. Patrick Farley 2010  Neuroradiology Fellowship, University of North Carolina, Chapel Hill
Jonathan Kullnat 2010  Neuroradiology Fellowship, Oregon Health and Science University
Alexei Viazmenski 2010  MRI Fellowship, DHMC
Stephen J. Guerin 2010  Neuroradiology Fellowship, DHMC

Jennifer Krawitt 2009  Body MRI Fellowship, DHMC
Steven Krohmer 2009  VIR Fellowship, Johns Hopkins School of Medicine
Kiley Perrich 2009  MSK Fellowship, University of Washington, Seattle
Dagmar Savellano 2009  Instructor in Radiology, DHMC
Scott Smith 2009  Neuroradiology Fellowship, DHMC

Michael Beckerman 2008  MRI Fellowship, DHMC
Dianne Brann 2008  Private practice, Lexington, KY
Tien Burns 2008  Body Imaging Fellowship, Fletcher Allen Health, Burlington VT
                        Assistant Professor of Radiology, DHMC/VA Hospital
Paul Farris 2008  Cross-Sectional Fellowship, DHMC
                        Seattle Radiologists, Seattle WA
Jeremy Hopkin 2008  Neuroradiology Fellowship, Barrow Neurological Institute, Phoenix
David Pastel 2008  Neuroradiology Fellowship, DHMC
                        Assistant Professor of Radiology, DHMC

Lesly Benodin 2007  Private practice, Meriden Health, NJ
Elizabeth Dann 2007  Women’s Imaging Fellowship, DHMC
                        Assistant Professor of Radiology, DHMC
Rihan Khan 2007  Neuroradiology Fellowship, Barrow Neurological Institute, Phoenix
Michael Meszaros 2007  Neuroradiology Fellowship, DHMC

Marc Mancuso 2006  Childrens Hospital, Boston MA
Scott Naspinsky 2006  Diagnostic Imaging Flight, Elmendorf AFB AK
Elena Wechsler 2006  Mass General Hospital, Boston MA

Shervin Dean 2005  MRI Fellowship, DHMC
Tatum S. Johnson 2005  Pediatric Radiology Fellowship, Mallinckrodt
Timothy Mahoney 2005  VIR Fellowship, DHMC
David Siepman 2005  University of Wisconsin, Madison WI
Our faculty plays a major role in the Dartmouth Medical School curriculum, with multi-year courses intended to advance several overlapping goals: the effective use of medical imaging resources as learning tools in the clinical curriculum; a thorough introduction to the purposes and methods of modern radiology; and, for interested students, a clinical electives program designed to provide an in-depth understanding of the appropriate uses of medical imaging and interventional procedures, exam methodologies, the basics of image interpretation, and cost-effective image management.

Some measure of the program’s ongoing success can be found in a number of quantifiable achievements. *Basic Clinical Radiology*, our fully-subscribed fourth-year elective, is one of the most popular DMS electives, chosen by roughly 60% of all students. The number of our students electing radiology residencies remains large—averaging over 9% in the past decade, significantly above the comparable 6% national rate—and shows little sign of abating, as witnessed by the 14% of the DMS class of 2009 who chose residencies in radiology. And finally, we cannot help but take pride in the fact that for each of the past eleven years, our students seeking radiology residencies have succeeded in a 100% match rate.

First and Second Year Courses
The first-year anatomy curriculum includes Dr. McNulty’s classes on anatomical-radiological correlation, and routinely utilizes the lessons and image-database of the radiology component (designed by Dr. McNulty) of the DMS Human Anatomy website. The second year’s *Scientific Basis of Medicine* program includes a nine-hour introduction to medical imaging and the pathophysiological basis of imaging abnormalities. Additional radiology opportunities for first and second-year students include the eight-week informal *Spring Elective in Radiology* and regular *Radiology Interest Group* meetings.
**Clinical Electives**  
The centerpiece of our program is *Basic Clinical Radiology*, a four-week elective offered in any of four blocks during the fourth year, and in a fifth block available to third-year students. Designed for both future radiology residents and for students aiming at other specialties, the elective includes exposure to all areas of diagnostic and interventional radiology. Radiology residents take an active role as instructors in the program—an involvement which we believe enriches the educational value of the elective for residents and students alike. Specifically, the elective covers the advantages and limitations of the key imaging modalities; the clinical basis for appropriate imaging requests; how images are obtained and procedures are performed with the goal of understanding patient selection and suitability; how to provide informed advice to patients; how imaging is incorporated into logical medical problem solving; and the basics of radiological interpretation as applied to routine and emergency medical practice. The elective includes individually-tailored clinical rotations through the subspecialty areas, as well as student presentations and workshops. Students are expected to spend an evening on call with one of the residents, and to take advantage of the department’s extensive electronic and web-based resources during the scheduled blocks reserved for self-teaching. Image management workshops, and lively interactive sessions including “image jeopardy” and an “imaging lingo” conference form an additional part of a curriculum designed to emphasize multiple teaching methods. For the duration of the elective, students are welcomed to participate in all academic and social activities of the department.

In addition to this basic clinical elective, fourth-year students may choose from several shadowing-type electives. These 2 to 4 week courses are limited to one or two students and include the highly personalized Flexi-Elective; subspecialty electives in neuroradiology, interventional radiology and women’s imaging; and a research elective which forms the basis for short or long-term research projects which students are encouraged to undertake.

**Education Leadership**  
Drs. Lewis and McNulty are advocates for the use of electronic and web-based technologies, with respect to both the application of radiologic resources to all areas of medical student education, and for medical imaging instruction specifically. Working together or individually, they have developed a number of online resources for medical student education:

- The *Basic Clinical Elective* utilizes a Blackboard™-based collection of web-based teaching files, scheduling applications, evaluation tools, and the final exam.
- The *Human Anatomy Learning Modules* is a popular (100,000 hits/month) web-based curriculum now incorporated into the DMS anatomy curriculum (and at U. Penn and U.S.C.) Dr. McNulty created and continues to develop the site’s radiologic component.  
  (www.dartmouth.edu/~anatomy)
- The *Radiology ExamWeb*, part of a national initiative for standardized testing in radiology, was designed by Drs. Lewis and McNulty; funded by the RSNA and the Hudson Foundation, the project now includes 22 institutions nationwide.  
  (http://radiology.examweb.com)
- The *AMSER Shared Resources* website, developed by Dr. Lewis and McNulty; funded by the RSNA and McNulty; the Hudson Foundation, the site’s radiologic component.
  (www.dartmouth.edu/~amserimages)
- *CORE* (Case-orientated Radiology Education) is a web-based radiology curriculum for 3rd and 4th year medical students; developed by Dr. Lewis, CORE is now used throughout the medical school curriculum for case-based simulations and problem-solving exercises within the surgery, pediatrics, medicine and neurology clinical clerkships.  
  (http://core.instruct.de)

In addition, a web-based teaching file application under development by Dr. Siegel, with support from a DMS Venture Fund grant, will become a significant additional resource upon implementation later this year. Both Drs. Lewis and McNulty are active with national organizations dedicated to medical student and residency education. Dr. Lewis served as president of the Alliance of Medical Student Educators in Radiology (AMSER) in 2006–2007, and now chairs its Electronic Communications Committee. Dr. Lewis holds committee assignments at the Association of Program Directors in Radiology, at the American Board of Radiology (various faculty and resident certification committees), and at USMLE/NBME (the Anatomy and Embryology Exam Committee). Dr. McNulty is similarly active in national medical education organizations, and serves currently as President of AMSER.
The Body Cross-Sectional Imaging Division provides CT and MRI studies mainly concerned with the chest, abdomen and pelvis. The division overlaps with and complements various subspecialties (e.g., cardiothoracic, MSK, abdominal) that also rely on cross-sectional imaging modalities. Most of the Radiology staff have general expertise in cross-sectional imaging, and most spend at least some of their clinical time on body cross-sectional rotation. The division works closely with a variety of clinical departments. We attend the weekly the Gastrointestinal Tumor Board conference, and a GI-Radiology conference to review MRI and CT studies in a case presentation format. The division also actively supports the numerous investigators at the Norris Cotton Cancer Center, including recent collaborations concerning pancreatic imaging and treatment.

**Body CT**

Computed tomography plays a critical role in diagnosis and management in emergent, inpatient and outpatient settings. Our facilities include four CT systems: two 16-slice GE Lightspeed scanners; a 64-slice Lightspeed multidetector CT system capable of extensive diagnostic evaluations including cardiac, vascular, and 3D studies; and a versatile wide-bore “adaptive scanner” installed last year—the Siemens Somatom Definition AS. Featuring fluoroscopic capabilities and instant multi-planar reformattting, the new Siemens system significantly facilitates CT-guided interventional procedures such as biopsies, drainages, and thermal ablation therapies. Interventional CT has been a rapidly growing component of our practice—698 CT-guided interventions were performed last year, a 150% increase over the 277 done in 2004.

CT has benefited from Radiology’s PACS system, which displays digital CT, Ultrasound and MR Images, and links them to the electronic patient record. The impact of PACS continues to be remarkable, allowing much quicker reading times and much quicker turnarounds of interpretations to referring clinicians.

Patient care and safety remains at the forefront of our mission. CT imaging is a powerful modality that has provided advances in diagnostic accuracy. Used appropriately, the medical benefits of CT far outweigh the risks associated with exposure to ionizing radiation. Monitoring patient dosages, minimizing exposure levels, and regular review of protocols are standard safeguards and constitute priorities in our practice. For younger patients, the need for caution is greater still, and the department participates in the nation-wide *Image Gently* campaign designed to find and share opportunities to reduce radiation exposure in children.

**CT Colonoscopy**

The division has established a CT colonoscopy ("virtual colonoscopy") service used on a limited basis in cases of failed colonoscopies. High-resolution thin-section CT series can be reformatted on 3D workstations for accurate, non-invasive “fly-through” examinations of the colon lumen for polyp detection. Drs. Tsapakos and McNulty have both received training in the procedure. As of spring 2010, CT colonoscopy for screening purposes remains on hold, pending regulatory agency approval and the availability of insurance reimbursements.

**Body MRI**

The safety, versatility, and range of unique imaging attributes of magnetic resonance imaging continues to drive increases in both the variety and volume of studies performed. In addition to its established role as an adjunct to CT, MRI is widely and increasingly used as a primary imaging modality for pediatric patients and for many soft-tissue imaging purposes, such as hepatic, kidney, pancreatic, prostate, and adrenal gland imaging. A number of the division’s MRI services that have become key areas of interest include:
• MR enterography, used for evaluation of patients with inflammatory diseases of the bowel (e.g., Crohn’s), produce detailed real-time imaging and permits radiation-free imaging for patients who will need ongoing monitoring over a period of many years;

• MR Cholangiopancreatography (MRCP) is a growing noninvasive corollary to Endoscopic Retrograde Cholangiopancreatography (ERCP).

• pelvic imaging, for detecting pelvic neoplasms, uterine congenital anomalies, and other ovarian and cervical pathologies;

• fetal imaging, as an adjunct to fetal ultrasound for certain types of multi-planar views;

• magnetic resonance angiography (MRA).

The department operates two permanent 1.5T magnets, a mobile 1.5T scanner, and as of March 2010, a new 3.0T magnet—the GE Discovery MR750 system. Fast and powerful, the MR750 provides exquisitely detailed studies that facilitate a range of chest, abdomen, pelvic and MSK exams, including MRI for localizing prostate neoplasms in pre-surgical planning. (The 3T magnet also offers important enhancements and new capabilities in neuroimaging—most notably, fMRI.)

3D Imaging  With ongoing advances in 3D post-processing, the plane of imaging has become irrelevant. Image series obtained from high speed multidetector CT scanners are now reconstructed as remarkably lifelike 3D volumes for angiographic imaging, cardiac imaging, excretory urographic imaging, and a range of endoluminal imaging purposes. Clinicians and, in particular, surgeons have increasingly come to rely on such studies to help with surgical planning.

Since 2008, 3D capabilities are available on workstations throughout the department, including various service-specialized applications such as Prism Clinical Imaging (for IMRI reconstructions) and Vitrea (for virtual colonoscopy). Visage CS, a web-based thin-client 3D application, is available at all workstations. In addition, the Body Cross-Sectional Division maintains a 3D lab for CT angiography reconstructions. Directed by Kayla Denny, RT, the lab uses GE Advantage workstations to generate highly sophisticated 3D volumes.

Education Programs  Education continues as a priority for the division. Didactic CT and MRI instruction is incorporated across all radiology sections to help residents handle the myriad CT cases they will encounter over the course of their residency, in both medical and surgical subspecialties. Our fellows and residents learn the intricacies of clinical imaging parameters and actively participate in reading MRI studies. We have incorporated cardiac imaging into our residency and fellowship training as an adjunct effort with Cardiology.

Cross-Sectional Imaging Fellowship  The highly competitive Cross-Sectional Imaging Fellowship, now in its 17th year, includes training in neuroradiology, abdominal imaging, musculoskeletal MRI, and ultrasound. The fellowship is unusually flexible, with opportunities for tailoring the program to meet the interests of individual fellows. Electives include cardiac imaging (with the Department of Cardiology), mammography, musculoskeletal radiology, and CT-guided interventional procedures.

MRI Fellowship  Initiated in 2005, the one-year MRI fellowship program emphasizes—to an unusual degree in comparison with other such programs—a comprehensive range of MRI training that includes cardiac, neurologic, musculoskeletal, abdominal, pelvic, MR angiography and MR-guided interventional procedures. The MRI fellowship, like the Cross-Sectional, encourages individualizing the program to meet special interests and needs.
GASTROINTESTINAL RADIOLOGY

GI Radiology’s success depends on our teamwork, and on close collaboration with the departments of Gastroenterology, General Surgery, and Internal Medicine. Weekly CME-accredited multidisciplinary GI conferences, at which students may participate, feature diagnostic and therapeutic issues in a case-based format, and selected clinical advances presented by subspecialty experts. The performance of imaging studies in a focused, expedient, and logical progression is one positive outcome of this multidisciplinary conference. Local physicians from outside the institution also participate at the conferences, as do visiting professors of gastroenterology, surgery and radiology.

Exams are performed in three fluoroscopy suites, on pulsed digital systems (Philips EasyDiagnost™ Eleva) providing rapid, efficient studies while minimizing radiation exposure. Digital fluoroscopy with image transfer to PACS improves efficiency, communication, and cost effectiveness. Our concurrent use of real-time fluoroscopy, captured on DVD, lets us further decrease radiation exposure, as well as expediting review, documentation, teaching, and communication with referring physicians. Our radiologic technicians are highly regarded—Philips Medical rates the Diagnostic Core and its staff as a “luminary site,” and several technologists hold “clinical super user” recognition for above-average knowledge and skill. The division is committed to safe, child-friendly care, and works closely with the Children’s Hospital at Dartmouth (CHaD). We actively participate in CHaD’s Pain-Free Program, and in the Image Gently campaign, an initiative by the Alliance for Radiation Safety in Pediatric Imaging that seeks to raise awareness of the opportunities to lower radiation dose in children’s imaging. Maintaining a reassuring environment is also a priority, and the section has enthusiastically taken on the responsibility of making the visits of our pediatric patients as comfortable and pleasant as possible.

We continue to implement the core curriculum in GI Radiology. Presentations by department faculty are supplemented by visiting professors, New England Roentgen Ray meetings, and Grand Rounds. One-on-one review of teaching file cases remain a very useful and popular part of the fluoroscopy rotation and Dr. Chertoff’s experience as a GI examiner for the American Board of Radiology examination enhances the review sessions held for the senior residents.

The delivery of high-quality care to patients with complex disorders requires close coordination of services provided by various departments; the New England Hepatobiliary Disease Center—a collaboration between DHMC gastroenterologists, surgeons, and radiologists—was developed to meet this need. The Center’s goals include state-of-the-art diagnostic and therapeutic services, the promotion of research on hepatobiliary diseases, and hepatobiliary disease education and data sharing.

Division director Dr. Chertoff plays an active leadership role at DHMC and DMS. She chairs the Board of Directors of the Hitchcock Foundation; is Co-Vice Chair of the Commission on Education at the American College of Radiology (and is directing development of the gastrointestinal portion of the core ABR exam); and holds key positions in medical education organizations including the Alliance of Clinician-Educators in Radiology, the AUR, the Association of Program Directors in Radiology (APDR), and the Accreditation Council for Graduate Medical Education (ACGME).
The goals of the Division of Ultrasound Imaging are to provide effective, high-quality imaging services to patients in the most compassionate and stress-free manner possible; to provide high quality educational opportunities to students across a spectrum of professional backgrounds—radiology fellows and residents, medical students, and sonography trainees; to advance knowledge in clinical care and the technologies of ultrasound imaging; and provide an effective and collegial referral service to clinicians from throughout the Dartmouth-Hitchcock community. We work closely with the Children’s Hospital at Dartmouth (CHaD), and with the Department of Obstetrics and Gynecology. Utilization of ultrasound imaging has been increasing steadily—our clinical volumes have increased at an annual rate of roughly 9% over the past five years.

Ultrasound is used for imaging all body areas except the heart and vascular system, and also plays a role in image-guided interventional procedures, including the Prostate Biopsy Clinic at NCCC. We work in close collaboration with the members of the Maternal-Fetal Medicine (MFM) staff and Reproductive Endocrinology/Infertility (REI) specialists, who conduct a complementary imaging service. Anal sphincter sonography is used to diagnose defects in the sphincter, which may lead to urinary or fecal incontinence following childbirth or trauma. Screening programs include nuchal scans for the early detection of Down’s syndrome, liver and portal vein screening for cirrhosis.

The division employs eight sonographers, and maintains an eight-room facility equipped with Philips Medical and Siemens ultrasound systems and, new this year, the GE Logic E8. 3D imaging is increasingly common, as well as the use of cine clips that can be captured and displayed on workstations. Dennis Seguin, ultrasound team leader, has been invaluable in maintaining the quality of our service and systems.

Teaching and research are key components of our mission. Education occurs at the patient bedside; in resident, fellow, and medical student training programs; in sonography apprenticeships; and in monthly conferences on ultrasound and maternal-fetal medicine. At our monthly perinatal working group, obstetricians, neonatologists, radiologists, and geneticists gather to discuss interesting and difficult cases. With respect to technologists’ education, we are collaborating with Lebanon College on a training program in sonography. Ongoing research interests and activities include:

• A pilot trial testing the validity of compact US for use in developing countries
• A multi-center retrospective analysis of the chorionic bump, a first trimester ultrasound finding first described at DHMC
• Participation in a multi-center study of US characteristics of thyroid nodules
• the use of ultrasound-guided core needle biopsy for diagnosis of bilateral testicular sarcoidosis

Several staff members, including Dr. Harris, are graduates of the MS or MPH programs at The Dartmouth Institute (TDI). Last spring, the division participated as a clinical improvement test site in a TDI course on continuous quality improvement. Other recent QI initiatives include the implementation of an OB/GYN automated reporting system aimed at decreasing the likelihood of recording errors.
The Neuroradiology Division is an integral part of the Clinical Neurosciences Program at DHMC and of the extended medical neuroscience community of New England, for which we provide consultation services. The division conducts imaging studies of the brain, spine, head and neck, and offers the full spectrum of neurointerventional procedures. Advancing knowledge to improve diagnosis and treatment of brain and spine disease is a crucial part of our mission, and we are actively involved in research and in the training of residents, fellows, and medical students.

Drs. Cromwell and Merlis bring many years of expertise in all areas of neuroradiology; in addition to clinical duties, both are active in many aspects of departmental administration, scheduling, and medical education. Dr. McIntyre is Director of Spine Radiology, and is a sought-after resident mentor and national speaker. Dr. Eskey, division head and director of the neuroradiology fellowship, is skilled in a range of interventional procedures; he serves currently as president of the Eastern Neuroradiological Society and as a member of the Editorial Board of the American Journal of Neuroradiology. With rapidly rising volumes in all areas of neuroradiology, the department has in the past two years recruited several highly talented new colleagues. Dr. Belden, joining us from Albany Medical Center, is a seasoned neuroradiologist with expertise in head and neck imaging and fMRI. We were delighted to welcome Dr. Pastel to the faculty following completion of his fellowship here in 2009. Dr. McNulty, previously practicing at both DHMC and the VA Hospital, is now with the department full-time, splitting her clinical responsibilities with neuroradiology and the VIR division.

Our technological capabilities have expanded with the acquisition of the flat-panel biplane angiography suite last year, and with new and upgraded MR scanners—including a powerful GE 3T system, permitting Dr. Belden to initiate...
fMRI clinical service this spring. While DHMC has been active in fMRI research for years, the new service represents the first availability in northern New England of clinical fMRI. Capable of mapping the motor, sensory and visual cortex, as well as certain language and memory functions, fMRI scans can be reconstructed for highly lifelike, versatile images which significantly enhance pre-surgical planning for a range of neurological procedures. Other areas of expanded capabilities in the division include diffusion tensor imaging and CT perfusion studies.

The interventional neuroradiology service, comprising both spine and endovascular procedures, was introduced five years ago and has been growing steadily. Working closely with the sections of Neurosurgery, Otolaryngology, and the Department of Neurology, we provide endovascular treatments that include the most effective advances in bioactive coils, cerebrovascular access devices, liquid embolic materials, stents, and clot retrieval devices. The digital biplane angiography suite is producing studies of excellent quality while reducing radiation exposures. The interventional service relies on the contributions of our associate providers, Sharene Evans, ARNP and Anne Michaels, PA, the nursing teams, and the highly skilled cadre of CT and MR technicians.

Education is a key part of our mission, and we are proud of our role and the recognition we have received—Dr. McIntyre, for example, was the 2008 recipient of the Residents’ Teaching Award. Weekly didactic or case conferences for residents provide both structured learning and practice with boards-style cases. In addition to the didactic conferences, we hold regular clinical conferences with Neurology, Neurosurgery, Otolaryngology, and Pediatrics. Weekly or monthly case conferences include general Neuroradiology, Cerebrovascular Imaging and Treatment, Neuro-oncology, Endocrinology, Pediatric Neuroimaging, and Head and Neck Oncology. The ACGME-accredited neuroradiology fellowship, now in its seventh year, provides thorough training in CT and MR, imaging and interventional procedures, including advanced endovascular brain techniques.

Neuroimaging research is performed by the core clinical faculty and by several dedicated basic scientists. We continue our collaborations with the Dartmouth Brain Imaging Laboratory and the Advanced Imaging Center. Projects underway cover innovation in advanced imaging at 3T in glioblastoma recurrence, MRI in pediatric head trauma, CTA in intracerebral hemorrhage and aneurysm evaluation, imaging of pharyngeal carcinoma, vertebroplasty, and synovial cyst rupture.
The Musculoskeletal (MSK) Radiology staff consists of full-time specialists, Drs. Cheung and Goodwin, and the support of a part-time staff consisting of neuroradiologist and spine-imaging specialist Dr. McIntyre, and Dr. Seltzer of the nuclear imaging division. The division provides image interpretation, consultation, and interventional services for patients with disease or injury of the axial and appendicular musculoskeletal system, especially of the bones and joints. Modalities include X-ray, MRI, fluoroscopy, ultrasound, CT, and DXA. Interventional procedures are a growing component of our practice, and include arthrography services, epidural steroid injections, and image-guided biopsies of bone and soft tissue. Bone densitometry (DXA) is performed by a staff of certified technologists, and interpreted by Drs. Cheung, Goodwin, and Seltzer. Volumes have increased strongly in all areas of our service, driven in part by the growth in orthopedics and rheumatology referrals, particularly for hand surgery and myositis imaging requests. We utilize almost all imaging modalities of the department, but would highlight several new MR acquisitions: the ONI Systems 1.5T “MSK Extreme”—a magnet which combines the simplicity of patient comfort of small extremity imaging with the power of a full-sized system; and the GE Discovery™ 3T system installed in March of this year.

The MSK staff is committed to the department’s educational mission. The Basic Clinical Radiology elective for DMS students includes an MSK rotation; some students additionally take the specialized MSK elective. Residents join for a month-long MSK rotation which, in addition to the MSK lecture series, includes reading experience in the full range of MSK imaging; arthrography and biopsy procedures; weekly orthopaedic and rheumatology conferences; and a monthly osteoporosis conference. We are proud of the recognition the MSK staff has received for teaching excellence, such as Dr. Goodwin’s 2008 “Outstanding Teacher Award” from the Society of Magnetic Resonance in Medicine.

The MSK staff is active in imaging research. Dr. Cheung, who anticipates completing the MS program at TDI this year, recently completed (with former chief resident, Dr. Kiley Perrich) a comprehensive series of ankle-ligament studies which was published in the AJR last year. Dr. Goodwin has collaborated with Dr. Kauppinen of our NMR Research Center on studies of the structure and imaging properties of articular cartilage; current work includes a project correlating cartilage T2 with immunohistochemistry of early degenerative changes in articular cartilage in the human knee.
The Breast Imaging Division is dedicated to women’s health and to providing up-to-date and compassionate breast-cancer screening and diagnostic care. We participate in NCCC’s Comprehensive Breast Care Program, an integrated approach to breast-cancer patient care which coordinates care from the departments of radiology, surgery, oncology, pathology, and radiation oncology. The division performs screening exams utilizing both traditional mammography and MRI. Diagnostic imaging is performed with mammography, ultrasound and MRI. Our mammography screening takes place in five exam rooms built around an all-digital complement of Hologic Selenia™ systems designed to maximize accuracy while subjecting patients to less radiation, fewer call-backs, and less discomfort and anxiety.

The breast-MRI program, now directed by Dr. Dann, has experienced significant growth in recent years, being increasingly used for breast-cancer screening of high-risk patients, as well as for diagnostic exams for cancer staging. Interventional procedures in the division include a range of image-guided needle- and vacuum-assisted biopsies utilizing all three modalities—mammography, ultrasound, and MRI. MRI exams and procedures are facilitated by a dedicated breast-MRI table/coil with built-in imaging offering greater patient comfort, increased imaging clarity, and access for interventional procedures. We work with colleagues in Radiation Oncology to perform image-guided catheter placement for accelerated partial breast irradiation. Additional imaging services include galactography, sentinel lymphadenectomy, and lymphoscintigraphy.

The curriculum for residents emphasizes direct clinical experience, with responsibilities and independence increasing in each of the three month-long rotations. At the end of these rotations, the resident is expected to be proficient in the entire spectrum of screening, diagnostic, and interventional breast imaging.

The division is active in funded and unfunded research and publishing. Dr. Poplack has for over ten years been clinical director for the multi-disciplinary Alternative Breast Cancer Imaging (ABCI) Program, in which Drs. Nagy and diFlorio have also participated. Other areas of research interest include assessing MRI in monitoring tumor cryoablation, and studies on the efficacy of the MammoSite® radiation therapy system. Dr. Lewis has recently published (AJR, 2009) an investigation about the effectiveness of preoperative MRI on patients with newly diagnosed breast cancer.

Digital breast tomosynthesis (DBT), an imaging technology which is likely to become an important adjunct to traditional mammography, continues to be a research priority for the division. Division members led by Dr. Poplack have pioneered DBT clinical studies. A new experimental DBT system installed last year will permit a number of new studies to go forward, including comparisons of DBT and breast-MRI, and—in collaboration with Thayer biomedical engineers—a new five-year NCI-funded program to assess the potential of combining DBT with near-infrared spectral tomography. The ABCI program, the DBT studies, and other breast-imaging research are described in detail later in this report. The division supports the research efforts of the New Hampshire Mammography Network, which gathers and collates mammographic and pathologic data on New Hampshire women.
The divisions of Chest and Cardiac Imaging have been recently reorganized as Cardiothoracic Imaging. The division director, Dr. Czum, is fellowship-trained in cardiovascular MR and subspecialty board-certified in Cardiovascular CT. Dr. Black, an outcomes scientist and authority on lung cancer screening, divides his time between clinical and research endeavors, and is on the faculty of The Dartmouth Institute for Health Policy and Clinical Research. Dr. Savellano is a recent graduate of our residency program, with a significant research background in MR imaging.

Chest radiography and chest CT comprise a significant portion of the imaging performed in the department. Chest CT includes dedicated non-contrast imaging for interstitial lung disease, breathing maneuvers to assess obstructive airways disease, low radiation dose technique for follow-up evaluation of nodular disease, and contrast-enhanced CT pulmonary angiography, as well as standard protocols for airspace disease and oncology staging.

Non-invasive cardiovascular modalities include cardiac CT, coronary CTA, cardiac MR, and MR angiography. Cardiac MR structural and functional evaluation is used to evaluate pericardial, valvular, ischemic and non-ischemic heart disease, as well as cardiac mass evaluation. Pharmacologic stress MR perfusion imaging is an alternative to stress echocardiography and myocardial perfusion scintigraphy. The delayed enhancement technique is used to localize and quantify infarcted and viable myocardium, as well as to evaluate cardiomyopathies. ECG-gated 64-detector row CT is a robust means to non-invasively image the heart and coronary arteries in appropriate clinical circumstances.

With the aim of selecting the most appropriate evidence-based modality-protocol combinations for each patient’s unique circumstances, division staff consults on a daily basis with primary care providers and a range of specialists including pulmonologists, thoracic surgeons, thoracic oncologists, cardiologists, electrophysiologists, and cardiac surgeons. Daily intensive-care unit team rounds, weekly multidisciplinary thoracic oncology conferences, and monthly pulmonary-radiology conferences are characteristic of the collaborative approach to cardiothoracic care at DHMC.

Single midventricular short axis slice through left and right ventricles obtained with double inversion recovery “black blood” cardiac MR technique demonstrating normal anatomy.
A variety of new technologies continue to enhance the effectiveness of cardiothoracic imaging. Thin-client software available at all workstations permits real-time assessment of pulmonary nodule volume doubling time—an increasingly important means for discriminating benign from malignant lesions. Post-processing of airways image data creates virtual bronchoscopic reconstructions that aid in planning of transluminal interventions and surgery. Co-registration of 3D cardiac–MR or CT data with electrical maps permits radiofrequency ablation of lesions with increased safety, improved accuracy, and reduced complications. With increased surgical success in treating pediatric victims of congenital heart disease, cross-sectional MR or CT surveillance has become both more effective and more essential in monitoring chronic post-operative sequelae and in the timing of further interventions.

Radiology residents spend 14 weeks in cardiothoracic imaging rotation, as 4- or 5-week blocks in the first, third and fourth years. Didactic lectures (one pulmonary lecture and one cardiac lecture each month) are based on the knowledge-based objectives of the Society of Thoracic Radiology curriculum. The third and fourth year rotations include a cardiology option offering exposure to transthoracic and transesophageal echocardiography, invasive coronary angiography, and electrophysiology procedures. Cardiology fellows rotate through the department for experience in cardiac MR and CT, in addition to nuclear cardiology training. Pulmonary fellows and internal medicine residents spend the majority of their radiology elective time in chest imaging.

Medical student education includes lectures in chest imaging during second-year courses in pulmonary medicine and cardiology by Drs. Czum and Black, both of whom have received teaching awards. The regular fourth-year radiology elective includes participation in chest imaging read-out sessions; and, through the individually-tailored electives also available to third and fourth year students, the possibility of additional cardiothoracic imaging experience.

Dr. Black is one of the principal designers of the National Lung Screening Trial (NLST), a major multi-center trial comparing non-contrast CT with chest radiography in cancer screening of smokers; he is PI for Dartmouth-Hitchcock and also directs the study’s cost-effectiveness component.

Quality improvement projects being undertaken include systematic radiation reduction for chest CT studies as well as an ongoing collaboration with radiologic technologists using a PACS-based reporting system for image quality assurance that has resulted in improved problem-solving, performance metrics, and in-service education initiatives.

Our newest MRI system, the GE MR750 3T, enhances capabilities across a broad range of indications and imaging needs, including functional MR brain imaging.

The MR750 arrives—January 2010.
The Division of Vascular and Interventional Radiology (VIR) performs image-guided, minimally invasive procedures ranging from basic interventions (e.g., biopsies, abscess drainage, central venous access) to more complex procedures such as pulmonary thrombectomy, Yttrium-90 radioembolization for hepatic cancers, radiofrequency ablation and cryoablation (for liver, renal, bone, and lung tumors), vertebroplasty, stent-graft repair of arterial or dialysis access aneurysms, and uterine artery embolization for the treatment of symptomatic fibroids. Imaging modalities include fluoroscopy, ultrasound, and computed tomography. The VIR staff provides consultation to physicians throughout the institution and northern New England, and manages inpatient service and the VIR outpatient clinic. We participate in multidisciplinary conferences in trauma, vascular surgery, oncology, urology, and gastroenterology—interdisciplinary collaborations that underline our commitment to provide care based on the most effective, evidence-supported therapies.

Each of our attendings holds ABMS subspecialty VIR experience. Dr. Hoffer, division chief since 2005, offers expertise in transcatheter embolization for traumatic injury, stent graft repair of aortic trauma, and TIPS treatment for portal hypertension. Drs. Forauer, Gemery and Hoffer are full-time interventional radiologists; Drs. Silas and McNulty are part-time, with clinical responsibilities in other areas of the department. The inpatient clinical side of the service is largely coordinated by our versatile associate providers, nurse practitioner Shari Evans and physician assistant Anne Michaels. They are involved in all phases of inpatient care—from ensuring thorough pre-treatment patient evaluations to post-discharge follow-up. The associate providers also independently perform routine procedures such as paracentesis, thoracentesis, chest tubes, and central venous access. Shari and Anne hold faculty positions at DMS as clinical instructors and are integral in the education of hospital nurses and residents, and play an active role in research and quality improvement initiatives. The department maintains a nurse-staffed PICC service—only the most difficult cases require referral to VIR.
Our facilities consist principally of 4 angiographic suites, two of which utilize state-of-the-art flat panel systems. The Siemens digital flat panel biplane system, our most recently installed unit, includes powerful software for reconstructing axial images from selective contrast injections—a feature which permits precise subselective catheterization for tumor embolization procedures. Each of these suites also contains a dedicated ultrasound unit. In addition, CT-guided interventions are performed on a new Siemens wide-bore fluoro-CT unit.

The division plays an active role in the training of fellows, residents, and medical students. Residents typically rank VIR among the most demanding, and rewarding, of their radiology rotations—and in recent years roughly one quarter have chosen VIR fellowships. We are grateful to our institution’s vascular surgeons for their role in fellow education; the endovascular rotation provides experience in the vascular ultrasound lab and in clinical and endovascular treatment of peripheral vascular disease, including abdominal and thoracic aortic stent grafting and carotid stenting.

Research interests of the VIR staff include: endograft repair and transcatheter embolization (Dr. Hoffer); dialysis access maintenance and percutaneous therapies for renal neoplasms (Dr. Forauer); CT summation techniques in radiofrequency ablation (Dr. Gemery); chest port placement and image-guided liver biopsy (Dr. Silas); dialysis access and radiology education (Dr. McNulty). Recent national conference activities include presentations on arterial closure devices, IVC filters, and antibiotic prophylaxis. Current or considered trials include studies of regional cancer therapies, such as Yttrium-90 radioembolization of primary or metastatic liver disease, cryoablation for renal tumors; dialysis access maintenance in the elderly; evaluation of a heparin-bonded hemodialysis catheters; and transcatheter arterial chemotherapy for bladder neoplasms.

The Siemens Artis zee biplane angiography system, used in a range of interventional procedures (such as the embolization pictured on the cover of this report) by the VIR and neuroimaging teams.
Nuclear Imaging traditionally has been based on measuring variation in tissue concentrations of radioactive biomarkers, providing data which can be correlated to specific states of organ function and pathophysiology. The resulting functional images are then used to complement the structural imaging obtained by radiographic or MR studies. The past decade, however, has seen a fundamental shift in nuclear imaging technology with the advent of hybrid systems which combine functional and structural imaging. Our department has been on the cutting edge of these innovations, adding two SPECT-CT scanners—one of which, added in 2009, includes full ring diagnostic CT—and an on-site fixed PET-CT system which was the first in northern New England and remains the only fixed PET-CT scanner in the state.

The Division of Nuclear Imaging provides a full range of diagnostic imaging and therapeutic procedures. To the diverse selection of studies offered, the division has added, within the past several years, cardiac PET imaging for myocardial viability, Zevalin® studies (imaging and therapy for lymphoma, performed in conjunction with the Section of Radiation Oncology), Therashere® studies (for liver malignancy, performed in conjunction with the Division of Interventional Radiology and the Section of Radiation Oncology).

The Nuclear Cardiac Stress Lab, under the direction of Dr. Foote (board certified in Internal Medicine and Nuclear Cardiology) is a regional referral center for noninvasive assessment of all types of cardiac pathologies. Exercise and pharmacologic stress and rest imaging.
studies are performed to assess a variety of diagnostic and prognostic parameters and to measure ventricular size and function. Research focus in the lab has been on measures of exercise capacity, new myocardial imaging agents, and novel biomarkers of myocardial ischemia. The Dartmouth group was the first in the world to publish evidence clarifying the sensitivity of cardiac stress testing, as well as the first to demonstrate elevation of certain neurohormones in the blood of patients with transient myocardial ischemia.

The division continues to play a key role in PET and PET-CT education on a national level. Under the direction of Dr. Seltzer, who serves as director of our PET-CT program, we conduct regular sessions of the teaching seminar, Frontline of PET-CT. This course is given several times per year and has been attended by radiologists and nuclear medicine physicians from across the United States and from as far away as Asia and South America. The division hosts a highly regarded annual symposium The Role of PET-CT in Cancer Management. And in partnership with the American College of Radiology, division faculty led by Dr. Seltzer conducts “ACR-Dartmouth PET/CT,” a three-day course offered each June, September and December in Reston, Virginia.

The division pursues a variety of research interests, is active in quality improvement initiatives, and has participated in several recently concluded or ongoing clinical trials. These include: a multicenter study on the role of dopamine receptors in the diagnosis of Parkinson’s disease; the use of fatty acid tracers for the imaging of myocardial ischemia; FDG in the diagnosis of Alzheimer’s disease; and is currently participating in a multi-center trial testing the value of F-18 sodium fluoride for defining skeletal metastases. Drs. Foote and Herr, in the Cardiac Stress Lab, have conducted extensive work on the use of brain natriuretic peptide (BNP) in the diagnosis of heart disease.

Division Director Dr. Siegel also serves on the D-H Information Systems Steering Committee, is chair of its subcommittee on Medical Imaging, and is a member of the institution’s Clinical Informatics Committee and is Director of Radiology Informatics. He was recently awarded a DMS Learning Technology Venture Fund grant to develop a web-based teaching file application that facilitates image-uploads from any workstation, providing an easily accessible repository of cases and educational material.
The Division of Pediatric Radiology, as a component of the Children’s Hospital at Dartmouth (CHaD), participates across a broad spectrum of clinical cases, consultations, and teaching obligations. We expect that CHaD’s caseload growth, driven in part by integration with the pediatric community in the southern Hitchcock Clinic division, will result in continued growth in imaging volumes. CHaD has three pediatric general surgeons, two pediatric neurosurgeons, three pediatric oncologists, three pediatric urologists—and, for the first time, a pediatric otolaryngologist. The Child Protection and Advocacy Team handles referrals from around the region. This increase in staff is expected to provide increasing volumes of pediatric radiology cases.

Radiology’s PACS system makes it easy to correlate different pediatric imaging studies and enhances both the consultative and clinical aspects of pediatric radiology. Integration of the PACS systems between D-H north and south now allows viewing and consultation on cases imaged in Manchester. 64-slice CT scanning and more powerful MR imaging permits fast 3D reconstructions that are especially useful for vascular anomalies. Newly acquired Visage™ software brings this multiplanar and 3D capability to reading stations throughout the department. The faster scan times also reduce the need for sedation.

Minimizing radiation dose in children’s imaging is among our highest concerns. We support Image Gently, a campaign led by The Society for Pediatric Radiology aimed at decreasing children’s exposure to ionizing radiation. Pulsed fluoroscopy systems, available in all of our fluoro rooms, are important components in this effort, as they permit significantly
deductions in radiation dose. The “Pain Free CHaD” program has also helped make the pediatric sedation required by some of our procedures (e.g., a voiding cystourethrogram) safer and less stressful for children and their families.

Pediatric Radiology continues its vigorous teaching service, and participates in the two-year core curriculum for radiology residents. We conduct board review sessions for senior residents, and the pediatric elective is popular with the radiology house staff. For the DMS medical student elective, we participate with lectures, biweekly film sessions with the Neonatal Intensive Care Unit team, and weekly sessions with both the Pediatric Inpatient and Intensive Care Unit teams. Pediatric Radiology participates in the pediatric tumor board conference.
The Uroradiology Division in recent years has seen significant increases in both patient volumes and in the variety and complexity of cases. We conduct exams in CT, MRI and Ultrasound. Advanced imaging in the division includes multi- phasic CT imaging, CT angiography, and CT urography. 3D CT reconstructions are a key facet in the pre-operative and diagnostic workup of the urology patient.

Much of the growth in uroradiology cases is driven by the expansion of the institution’s Urology Section, which continues to add services and physicians. In 2005, a Pediatric Urology section was established, led by CHaD director, Dr. Paul A. Merguerian. With the addition of a third pediatric urologist in 2008, Dr. Leslie McQuiston, the new section has contributed to the steady increase in the number of pediatric patients seen in the Uroradiology Division.

The weekly uroradiology conference, used to review the diagnostic imaging and management strategies of urology patients, is a dynamic meeting between the two specialties. During this conference, various imaging studies are presented in an “unknown case” format to urology residents by radiology residents. Numerous facets of diagnosis and management are discussed, and treatment options are designed.

Over the past two years, a core series of uroradiology lectures has been developed. Repeated yearly, these lectures cover a wide range of topics, from intravenous urography techniques to the evaluation of adrenal masses and hysterosalpingography. Additional sessions for oral boards preparation are given in the spring. Though aimed at graduating seniors, “boards review” is often attended by junior residents who acquire a better sense for “taking the unknown case” by watching the seniors perform.
The Veterans Affairs (VA) Regional Medical and Office Center in White River Junction, VT, participates with DHMC and DMS in a range of medical student and residency education programs. The VA Hospital is a tertiary care hospital that serves veterans in northern New Hampshire and the state of Vermont. In addition to the main hospital, five satellite clinics offer services to veterans in the region.

The VA Hospital’s Department of Radiology is completely digitized with a PACS that includes voice-recognition transcriptions. Facilities include a mobile MRI unit operating four days/week, a 64-slice MDCT scanner, two GE Logic 9 ultrasound units, DXA bone densitometry scanning, and a newly renovated angio suite with a tilt table. Mobile PET/CT imaging, on a weekly basis, is expected to become available in the near future. Plans for a $7 million imaging center have been approved, with construction slated to begin later this year; among the enhancements provided by the new center will be the addition of a fixed MRI system. The Radiology Department is staffed by four full-time radiologists and one part-time radiologist. Dr. Morse, fellowship trained in cross-sectional imaging, leads the department as the Acting Chief of Radiology. Dr. Harper coordinates the resident rotation at the VA, is DMS Assistant Dean of Medical Education (responsible for the residency advising process for medical students) and serves as DMS representative for the National Residency Matching Program. Dr. Lenz heads the Interventional Radiology Section. Dr. Smith practices general radiology with a focus on CT and MR imaging. Dr. Burns, a former DHMC radiology resident, recently joined the VA staff after completion of a cross-sectional imaging fellowship at Fletcher-Allen.

Two vital aspects of the VA’s mission are education and research. Teaching of medical residents and students is offered through a daily radiology/medicine conference as well as the weekly Tumor Board. Radiology residents rotate through the department three days per week in two week blocks, with a focus on CT, plain films and fluoroscopy, as well as participation in the daily conferences. The VA faculty is currently involved in research collaborations with the sections of Oncology and Urology, and participates in the VA’s National Cancer Care Collaborative quality improvement projects.
The Division of Diagnostic Physics, in addition to research and teaching activities, is responsible for quality control (QC) for all imaging modalities. Specifically, this entails meeting the regulatory and radiation safety requirements of the Radiology Department and the medical center, as well as those of outside organizations, including ACR accreditation for the Breast Imaging Center, the State of New Hampshire, and the FDA.

The primary goal of QC is to insure optimal performance of all components of the imaging environment—achieving the highest possible image quality at the lowest possible radiation dose. Representative X-ray exposures for the most common procedures are measured annually for each X-ray producing device. Results are kept on record and are available for use in patient-physician consultations on request. Finally, the QC program seeks to help contain costs by identifying unnecessary or unproductive steps in the complex chain leading to finished and useful studies.

Dr. Weaver teaches essential diagnostic physics to radiology residents, with the curriculum regularly updated for changes in the ABR physics exam, such as the new emphasis on conceptual questions. Dr. Weaver continues to teach biomedical engineering and bioinformatics at the Thayer School of Engineering, and now teaches a biannual course for cardiology fellows on the physics of imaging.

Dr. Weaver plays a key role in imaging research conducted within the department and in collaboration with investigators throughout the Dartmouth community—particularly with the divisions of neuroradiology and breast imaging, and with the biomedical engineering faculty at Thayer. Many of these investigations have emphasized the development of new imaging modalities or clinical applications involving new combinations of existing techniques. Described in greater detail later in this report, highlights of recently concluded or ongoing studies include:

- **Magnetic resonance elastography** for the detection of breast cancer, in which a modified MR scanner creates images based on the differing elasticity of breast tissue;
- techniques for enhanced and more versatile monitoring of neoadjuvant chemotherapy progress;
- the development of techniques for imaging soft-tissue properties in the diabetic foot, with the clinical goal of earlier detection of foot infection in this vulnerable population;
- **Frequency Domain Optical Imaging of Breast Cancer**, which aims at establishing the diagnostic potential of a single platform combining the functional-imaging advantages of NIR with the spatial resolution of MR;
- **MR Microwave Absorption and Tomography Imaging**, seeking the development of hybrid imaging modalities (possibly in a single combined platform) based on magnetic resonance microwave absorption and magnetic resonance-compatible microwave tomography.
SPEARE MEMORIAL HOSPITAL

The department provides radiology services to Speare Memorial, a recently renovated and expanded critical-access hospital in Plymouth, NH. Dr. Trought directs the program, heading up a part-time DHMC-based staff which includes Drs. Crow, Nagy, Harris, Hoegemann-Savellano, and Sargent. The staff also interprets studies generated—and directly entered into the Speare PACS—at the new Boulder Point off-site outpatient facility.

Radiology facilities are fully digital and include standard diagnostic radiography systems, a Philips Eleva fluoroscopy unit, an upgraded (to 16-slice) Philips CT scanner, and a new Hologic digital mammography unit. All studies are displayed and stored on a Philips PACS, with dictations processed by MedQuist’s SpeechQ™ voice recognition system. MRI and nuclear medicine exams are performed on mobile units; the MR system was recently upgraded, and the nuclear imaging system is slated for new software and an upgrade to a dual-head camera.

Speare Radiology plays an active role in medical education. The radiology elective for DMS students includes visits to Speare for insight into the practice of radiology in a small community hospital. DHMC fellows and senior residents are encouraged to include rotations at Speare, a voluntary posting which provides the experience of a small-hospital setting and a degree of independent practice not as easily found at the Lebanon campus. All residents, as part of routine on-call responsibilities, participate in reading overnight exams transmitted from Speare.

SOUTHERN NEW HAMPSHIRE

Dartmouth Hitchcock Medical Center and Dartmouth Medical School are components in the Dartmouth-Hitchcock healthcare system, which also includes a network of independent multi-specialty community group practices, mainly in southern New Hampshire, of which the most significant are at Concord, Manchester, Nashua, and Keene. CHaD, the Children’s Hospital at Dartmouth, operates facilities in Manchester, Plymouth, and at Wentworth-Douglass Hospital in Dover. A network of smaller community practices are found in a half-dozen other NH locations.

The major D-H facilities in southern NH are now linked to the department’s PACS/RIS system, providing a seamless imaging and patient-records network in which cooperation is facilitated and encouraged—and the quality of patient care significantly enhanced. Our residents rotate through the radiology departments of these affiliated institutions, and physicians from these affiliates frequently participate in collaborative and educational events at our campus. The various radiology facilities of these affiliates are now members of an organizationally coherent single department under the leadership of Daniel Abbis, DO, Radiology Director for Southern New Hampshire.

MOBILE PET-CT

Dr. Seltzer directs our outreach program of providing interpretations of PET-CT scans performed at regional institutions by a mobile PET-CT scanner operated by New Hampshire Imaging Services. At present, we receive and read studies performed once weekly at Weeks Medical Center Hospital, Lancaster, NH.
PORTABLE ULTRASOUND INITIATIVE

Dr. Harris, Director of Ultrasound Education and Research, has been conducting research and taking direct personal involvement into the plight of women facing pregnancy and birth in less-developed areas around the globe. No single diagnostic technology holds more promise than ultrasound in preventing maternal, fetal and neonatal deaths—and serious complications such as obstetric fistula. Dr. Harris is among a group of informally affiliated radiologists who have been bringing low-cost portable ultrasound units to rural clinics. In the past several years, he has delivered ultrasound units and provided instruction to clinics in Vietnam, Nicaragua, Serbia, Sierra Leone, and, earlier this year, Haiti—a visit coinciding with the devastating earthquake. Dr. Harris’ review article describing this public health initiative was published in 2009 in the Journal of Ultrasound in Medicine.

Robert D. Harris, MD, MPH, with patient in a rural clinic in Sierra Leone, demonstrates scanning procedures with a portable ultrasound unit he has delivered.
Radiologic Technologists (RTs) are at the heart of our clinical mission—the imaging specialists whose work in X-ray, CT, MRI, ultrasound, mammography, nuclear medicine, and interventional radiology produce the images used for diagnosis and, increasingly, for image-guided treatments. Skilled technologists are truly multi-faceted, their work requiring not only technical expertise in their imaging specialties, but competence and compassion in communication—with physicians, equipment technicians, and most of all, with patients. RTs are to a large extent the “human face” of our practice, responsible for fostering a clinical environment which encourages trust and confidence. They greet patients, provide reassurance and guidance, and ensure that patients understand and are comfortable with post-procedure instructions when needed. And of course technologists conduct the exam itself, responsible for patient safety and comfort while providing high-quality imaging results for radiologists and referring physicians.

INNOVATION
RTs work hard to promote an environment of collaboration and innovation, and play a major role in the introduction and implementation of quality-of-care and patient safety improvement. The RT staff has embraced, with other areas of the institution, a number of StuderGroup Hardwiring Excellence recommendations. These include team leader “rounding,” a formalized two-way communications process for proactively identifying problems and opportunities, and other programs (e.g., “AIDET”) for improving provider-patient communication skills.

The RT staff took a leading role in the shift to an all-digital imaging workplace—a transformation that could not have happened without their dedication and innovativeness. The conversion required enormous modifications in workflow practices at a time when protocols for digital imaging had not yet been fully determined or standardized. Gerry Bergen, recently retired DX team leader, wrote Digital Image Standards for Routine Radiography, a reference manual designed to fill that vacuum; it remains a key resource not only here, where it has been updated and reprinted several times, but for RTs throughout the country and internationally.

When CT tech Kayla Denny was asked to take on 3D Lab responsibilities, she responded with the resourcefulness typical of the RT staff. With mentorship from Drs. Zhen and Tsapakos, she quickly mastered the necessary techniques, assembled an illustrated manual systematizing 3D protocols, trained additional RT’s, and paved the way for “24/7” service in 3D reconstruction. Innovation need not be purely technical: warming and humanizing the clinical environment remain an important aspect of the RT staff’s dedication to compassionate professionalism. Many of our pediatric patients are seen in rooms full of murals, toys, coloring books, dinosaurs and Disney characters—all products of the individual talents and initiative of our staff.
EDUCATION
Several of our technologists have been designated Philips Healthcare “super-users” for their comprehensive knowledge and skill in the use of specific imaging equipment, and since 2006 we have been designated a luminary site for Philips. DX-core technologists host demonstrations and training in for visitors, an important teaching role and also an opportunity for our staff to share insights with representatives of other institutions. The relationship also provides early access and preferential pricing to the newest of Philips’ X-ray systems—in 2009, wireless digital X-ray detectors for the first time became available and DHMC Radiology was the first U.S. institution to beta-test the Philips’ entry into this market.

For almost 20 years, the RT staff, led by DX co-team leader Brenda Sleasman, has conducted spring and fall radiology educational conferences. RT specialists, industry representatives and radiologists provide instruction, demonstrations and workshops on issues across the spectrum of imaging modalities. Widely attended by our technologist staff as well as RTs from other institutions, the conferences represent an efficient and valuable way for RTs to earn CME credit and stay current with changes and innovations in the field.

DHMC Radiology collaborates with Lebanon College and the New Hampshire Technical Institute, hosting the clinical rotations for their radiographer training programs. The programs provide valuable experience for our staff to share their experience with future generations of radiographers, and significantly improve the regional availability of well-trained RTs. A new ultrasound training program is in the early stages of development. To be modeled on the current program at Lebanon College, the project involves the participation of several other hospitals in our region. RTs also play a key role in medical student instruction and resident training.

LEADERSHIP
Technologists are encouraged to pursue career development, including new modalities training, the assumption of management responsibilities, and ultimate positions as team leaders. Filling management roles from within has long been a feature of the department, and is one of the key factors in the remarkable stability of our staff. Six of our ten team leaders have been with us for 25 years or more: Dan Pluta, Dennis Seguin, Bob Ferranti, Rick Mazurek, Brenda Sleasman, and Terri Lorandou. The remaining team leaders—Jessica Rider, Heidi Nystrom, Jerry Seamans—have somewhat less tenure in their positions but no less expertise.

Clinical Operations Manager for DX, Mammography Ultrasound since 2008, Karen Burgess, has spent over 18 years at DHMC, starting as an RT in Routine X-ray and Mammography. She left us for a time to pursue interests that included developing a public health program for the city of Manchester, leading a national mammography study at DMS, and serving as Director of the Radiologic Technology program at Lebanon College. Chriss Kvinlaug, our newly-appointed Clinical Operations Manager for CT, MRI, VIR, and Nuclear Imaging, moves into this role following many years as the highly effective director of the Radiologic Nursing staff.

Administrative Director Jim Roberts served the department for many years as Clinical Operations Manager before stepping into the role of Acting Administrative Director in June of 2008; he was offered the permanent position in September of that year. Versatile and experienced in all imaging modalities, Roberts is a New Hampshire native who joined DHMC in 1975 and later earned a BS degree at the New Hampshire Technical Institute.
In 1994, Radiology hired its first nurse to monitor patients during angiographies. Today, there are eighteen registered nurses—an increase driven mainly by fifteen years of steady growth in both the volume and varieties of interventional radiology. The nursing staff is involved in meeting patient needs throughout the department, but is essential for vascular and interventional radiology (VIR), where nurses are responsible for patient care from planning to discharge. Facilities for image-guided interventions include four dedicated angiography interventional suites and a 10-bed recovery room. In addition to their work in the angiography suites, nurses provide sedation, pain management, catheterization and other services for patients undergoing CT-guided interventional procedures such as biopsies and drain placements; and, to a lesser extent, assist in image-guided procedures performed by the cardiothoracic imaging division and by neurointerventional radiologists. Nurses also support patient care in MR imaging when sedation or pain management is needed. The registered nursing staff is supported by licensed practical nurses who provide a key role in managing paperwork, maintaining recovery room readiness, assisting in patient care, and plenty of “behind-the-scenes” work to keep the service running smoothly.

The nursing staff plays an active role in quality improvement initiatives. Last year, nurses developed a contrast-reaction simulation exercise as part of a push to improve the recognition and response to patients experiencing an adverse reaction to imaging contrast. In January of 2010, the nursing service achieved a 98% compliance rate in the institution’s handwashing audit—an important infection-fighting initiative. Other recent or ongoing QI projects in which the nursing staff has participated include audits for pain assessment, and “scrub-the-hub,” a DMHC campaign to reduce IV access infection rate by more effective cleaning techniques. Nursing Manager Chriss Kvinlaug is a member of the department’s QI Steering Committee and spearheaded, with Dr. Dann, last year’s audit of contrast extravasation events.
RIS/PACS

Our recently upgraded picture archiving and communications system (PACS) is at the heart of the radiology information system (RIS) which has been developed over the past several decades to support the department’s clinical mission. John Sundnas, RIS/PACS Administrator, heads a team responsible for maintaining all aspects of imaging information acquisition, processing, utilization and storage, and for anticipating future information systems needs in an environment of increasingly complex imaging systems.

Recent accomplishments include: extending our RIS and PACS to the Hitchcock Clinic facilities in southern New Hampshire; the implementation of a system to effectively upload, store and integrate patient studies from outside institutions conveyed to us on CD or DVD. Hospitals and Health Networks magazine ranks us among the nation’s “most wired” hospitals—a recognition of the ongoing institutional commitment to informatics, toward which the Radiology RIS/PACS team remains a key contributor. The department relies on software systems provided by various developers and systems manufacturers, which include:

• GE Centricity RIS-IC
• Philips iSite PACS
• 3D and post-processing systems including GE Advantage Workstation (AWW), Visage Imaging, Vital Images, and Prism Clinical Imaging (for fMRI)
• AS Software for structured reporting
• SpaceTrax interventional inventory management

RADIOLOGY INFORMATICS

Informatics, as an organizing principle and as adapted to radiology, seeks to maximize the effectiveness of technology with integrated information systems comprising all aspects of data acquisition, distribution, utilization, and storage. The most significant informatics initiative now underway is the implementation of DHMC’s electronic health record (EHR). Known as “eD-H,” the system will work in concert with the department’s existing RIS and PACS to provide computerized order entry (CPOE) and immediate availability of completed imaging studies to clinicians throughout the institution.

Enhancements slated to follow the initial eD-H roll-out include an automated radiologic decision support system. Incorporated into a study request as a component of CPOE, decision support will provide referring caregivers with information on the relative appropriateness of an imaging request, suggested alternative studies, and a range of background information including relevant medical/scientific literature references. Another anticipated feature is the availability, via electronic transmission, of patient studies from outside institutions. At present, such studies are conveyed on disk and manually entered into RIS. Electronic transmission has special significance for incoming trauma patients, whose outside studies will be available for advance review by radiologists and clinicians.

Department staff has been active in the advocacy, development and implementation of electronic and online resources to enhance teaching and research. Dr. Siegel serves on the D-H Information Systems Steering Committee, is chair of its subcommittee on medical imaging, and is a member of the institution's Clinical Informatics Group. Drs. Lewis, McNulty and Siegel have created web-based learning tools that include applications to facilitate the creation of teaching files by clinicians at PACS, online anatomy atlases, and a variety of shared radiology resources for students and instructors. In the future, these research and education tools will be increasingly integrated into the clinical imaging-data system.

John Sundnas
PACS/RIS Administrator

Alan Siegel, MD
Director of Radiology Informatics
The department occupies 80,000 SF at DHMC’s Lebanon campus. Most of our imaging facilities are located the northwest quadrant of the medical center’s third floor. Additional systems (extremity MRI and one of the mobile MR units) are found on the second floor; in the Doctor’s Office Building (DXA, Mammography screening and tomosynthesis clinical trials); and in the Emergency Department. Research facilities are found at the medical school, and in various locations in the medical center.

Upgrading and expanding imaging systems are an ongoing priority and are essential to all areas of our mission: state-of-the-art equipment improves diagnostic accuracy and procedural outcomes, improves efficiencies, improves patient safety and comfort, and enhances teaching and research.

**DX Core** The diagnostic X-ray and fluoroscopy core, a designated Philips Healthcare “luminary site,” consists of eleven exam rooms—among which are three fluoroscopy rooms, a PICC room, and two rooms with automatic image-stitching capabilities. Apart from the fluoroscopy rooms—which use Philips EasyDiagnost Eleva™ systems—the Core utilizes Philips DigitalDiagnost™ systems as standard fixed equipment; eleven older GE portable CR units are deployed as needed throughout the medical center.

The DX Core team also is responsible for imaging service in the Emergency Department, where it operates a DigitalDiagnost VM unit (which includes Philips’ new wireless portable detector), and the TraumaDiagnost™ CS-4. The CS-4 unit is mounted on an overhead-rail system designed by former Facilities Manager Paul Roy, an innovation permitting the scanner to be easily repositioned for use at any of three ED bays.

**DXA Scanning** The department operates a bone densitometry scanning service, utilizing the Hologic Delphi-W DXA system.

**MRI** The department utilizes six clinical MRI systems: the GE MR750 3T magnet (installed March 2010), a new GE HDX 1.5T system, an upgraded GE Signa Twin Speed 1.5T, two leased 1.5T systems on mobile platforms, and the ONI Medical Systems’ MSK ExtremeTM 1.5T scanner—installed here in early 2009 as the first clinical application anywhere of this innovative system for imaging hands, arms, legs and feet. In addition, the department maintains a Philips 3T system used primarily for research purposes and housed at DHMC’s Advanced Imaging Center, and several small-animal research magnets at the Vail and Rubin research laboratories.

**Ultrasound** The Ultrasound Imaging Division operates six exam rooms, and equipment consisting of five Philips HDI scanners, two Philips iU22 systems, and four Siemens Antares™ units.

**Angiography** The four-room angiography suite for VIR procedures includes two GE single-plane angiography systems, a GE Advantx™ LCN biplane unit, and a new (Jan. 2009) Siemens Axiom Artis zee™ biplane system that facilitates a range of interventional neuroradiology procedures.

**Nuclear Imaging** The Nuclear Imaging Division utilizes four scanning systems: the Siemens Symbia T6™ SPECT-CT unit (Feb. 2009); the GE Infinia Hawkeye SPECT/CT; the GE Discovery ST™ PET-CT; and a Marconi IRIX Gamma Camera.

**Computed Tomography** CT systems include: two GE Lightspeed 16-slice scanners, and a GE Lightspeed VCT 64-slice system. In early 2009 we expanded our capacities in CT-guided interventions with the Siemens Somatom Definition™ AS system; offering multiplanar fluoroscopic reconstruction and merged 3D/real-time imaging. This versatile 40-slice scanner is used for a range of image-guided percutaneous interventions.

**Breast Imaging** Mammography screening and diagnostic studies are conducted on five Hologic Selenia™ full-field digital mammography systems. Biopsies are performed using a Selenia MultiCare™ Platinum stereotactic biopsy system. Breast-MR exams and interventions utilize a Sentinelle™ Breast MR Auxiliary Table with 8-channel coil array. A new (2009) Hologic™ tomosynthesis system is used for clinical studies.
The TraumaDiagnost CS-4 System, an in-house design that permits three ED bays to share one scanner.
The Department of Radiology and its faculty actively support clinical and basic science research in medical imaging and image-guided therapies. Within the department, research is conducted by a full-time, grant-funded research staff, as well as by our DHMC-based clinical faculty. (While many recent studies by the clinical faculty are not described here—as the focus of this section are the larger, externally-funded, and cross-disciplinary research programs underway—their work is an essential component of D-H imaging research, and the reader is directed to the list of publications in the appendix to this report.)

The department’s research is best seen in the context of a robust commitment to medical imaging studies throughout a Dartmouth medical and scientific community that includes various departments at DHMC and Dartmouth Medical School, Norris Cotton Cancer Center (NCCC), Thayer School of Engineering, and The Dartmouth Institute for Health Policy and Clinical Practice (TDI). Cross-disciplinary collaboration is a common characteristic of this work, resulting in synergies which have established us as leaders in multiple areas of medical imaging research.

I. RESEARCH FACILITIES

The principle resource for clinical radiology research consists of the department’s complement of radiographic, MR, CT, and molecular imaging systems. Additional clinical studies, as well as the bulk of the Dartmouth community’s basic-science imaging research, are conducted at several facilities, as described below.

The EPR Center The Electron Paramagnetic Resonance (EPR) Center for the Study of Viable Systems is home to the world’s first clinical EPR system, has been for over fifteen years a world leader in the development of biological and clinical applications for EPR spectroscopy, and plays a key role in international EPR research education and resource sharing. The center operates several laboratories, including an instrument-development facility at the Hanover campus, a small-animal research area within the NCCC (Rubin 6), and a clinical EPR facility in the Department of Radiation Oncology (Rubin 2). Directed since inception in 1992 by Dr. Harold Swartz, the EPR Center staff includes Dr. Nadeem Khan, Dr. Huagang Hou, Dr. Benjamin Williams, several adjunct faculty researchers, and a growing number of research associates and assistants.

The NMR Center The Biomedical Nuclear Magnetic Resonance (NMR) Research Center conducts basic research aimed at the development of MRI and MR spectroscopy (MRS) imaging techniques. A key focus is the use of MRS to identify and depict concentrations of metabolites which can be associated with specific tumor varieties. The resulting database of metabolic “fingerprints” may ultimately provide significant clinical tools for cancer staging and treatment monitoring. The center also provides support for the neuroscience program at Dartmouth College, with ongoing investigations of fMRI techniques based on hemodynamics and oxygenation to probe brain activation, and of MRI and MRS ‘biomarkers’ for detection of acute brain injury—research which capitalizes on the neuroimaging background of Dr. Risto Kauppinen, director of the NMR Center since 2007.

1 For brevity, “Dartmouth” or “Dartmouth community” refers here to the academic and medical research community comprised of Dartmouth Medical School, Mary Hitchcock Memorial Hospital, Dartmouth-Hitchcock Clinic, Dartmouth College, the Thayer School of Engineering (“Thayer”), and affiliated institutions such as the Norris Cotton Cancer Center (NCCC) or The Dartmouth Institute for Health Policy and Clinical Practice (TDI).
The NMR Center operates a 7T Varian Unity-Inova high-field MRI scanner designed for rodent MRI and MRSpectroscopy. The capacities provided by the 7T unit are expected to be augmented later this year with the installation of a 9.4T large-bore animal MR scanner. This NIH-funded magnet will accommodate larger subjects than the existing 7T scanner, and offers improved sensitivity in both MRI and MRS modes, opening new possibilities for NMR, imaging research and for affiliated Dartmouth researchers in neuroscience, cardiology and oncology. Dr. Kauppinen and the Department of Radiology welcome the recent arrival of Dr. Barjor Gimi. Dr. Gimi, from the University of Texas, is a multi-disciplinary specialist in molecular microimaging with extensive background in encapsulation nanotechnology.

The Advanced Imaging Center (AIC) The Advanced Imaging Center at DHMC provides imaging support for NIH-funded studies, clinical trials and animal research studies, typically involving multi-disciplinary programs in cancer, vascular, and neurologic imaging. Specific projects include hybrid imaging (e.g., NIR-MR, and MR elastography), novel contrast agents for early cancer detection, fMRI brain-activation studies, and accurate image-based treatment guidance for heart disease and cancer. AIC facilities include a dedicated Philips whole-body 3T MRI scanner, hybrid MRI-Near Infrared imaging with micro-imaging capabilities, micro-PET, small-animal CT, and a microCT specimen scanner.

The AIC includes the Neuroimaging Research Center, and the Alternative Breast Cancer Imaging Center (ABCIC), which supports research programs for the development of alternative breast-cancer imaging modalities, and serves as an imaging clinic for associated patient trials. With support from the National Institutes of Health, the AIC was opened in 2006 as a joint venture by Mary Hitchcock Memorial Hospital, the Dartmouth Medical School, the Thayer School of Engineering, and a number of clinical departments at DHMC. John Peiffer is the AIC Managing Director; Dr. Keith Paulsen Professor of Engineering and of Radiology, is Scientific Director.

Cancer Imaging at NCCC The goal of the Cancer Imaging and Radiobiology (CIR) Research Program at the Norris Cotton Cancer Center is to foster a collaborative environment that promotes the incorporation of imaging, radiobiology, biophysics, and engineering approaches into the development and evaluation of new cancer diagnostic and treatment strategies. The CIR program is co-directed by Thayer’s Dr. Keith Paulsen and Dr. Harold Swartz, Radiology’s Scientific Research Director. The program utilizes the research labs at NCCC’s Rubin and Borwell facilities, which include a variety of spectrographic and other imaging equipment, as well as the Brain Imaging Laboratory, where the Radiology faculty has participated in fMRI neuroimaging research.

Thayer School of Engineering One of the key areas of research at Dartmouth’s Thayer School is medical imaging, especially in the development of new techniques for cancer detection and staging. The alternative breast-cancer imaging (ABCI) program has been a central element in this work for over a decade. Related projects aim at developing “hybrid” platforms in which established modalities (e.g., MRI, CT and ultrasound) are combined with functional-imaging techniques such as near-infrared or microwave spectroscopy, electrical impedance tomography, or modified MR systems designed to measure tissue elasticity. Additional hybrid imaging studies underway include the use of fluorescence imaging coupled to MR, and CT. Drs. Poplack, Weaver, Cheung and others from the Department of Radiology participate in Thayer imaging research as consultants, clinical directors, or co-principal investigators.

DISCOVERY The Dartmouth Initiative for SuperComputing Ventures in Education and Research (or “DISCOVERY”) is a supercomputing server cluster available to the Dartmouth research community. It consists (as of January 2010) of an 888-CPU Beowulf/Linux cluster with 3 Tb of memory, more than 35 TB of disk space, and high-speed Infiniband interconnects. Much of the radiology research at Dartmouth—including most of Thayer’s medical imaging work, and the alternative breast-imaging modalities program in particular—involves complex non-linear image reconstruction which would not be possible without DISCOVERY’s computational power.

II. RESEARCH PROGRAMS AND MAJOR PROJECTS

In the past five years, medical imaging research in the Dartmouth community has been supported by external grants totaling nearly $40 million. The synergies, flexibility, and culture of teamwork associated with these multi-disciplinary collaborations have energized imaging research and stand as one of this institution’s most distinguishing characteristics. The following summary includes medical imaging research from all faculties and disciplines of the Dartmouth community.

Alternative Breast-Cancer Imaging Program Now in its eleventh year, the $15 million, NCI-funded Alternative Breast Cancer Imaging Modalities (ABCI) program involves over 40 investigators throughout the Dartmouth community. The program seeks adjunct or alternative techniques to mammography and other existing modalities of breast cancer imaging. Keith D. Paulsen, PhD, Professor of Engineering and of Radiology, is PI for the program overall. Radiology’s Dr. Poplack is PI for the clinical core component, with additional clinical leadership provided by surgical oncologist Richard Barth, medical oncologist Peter Kaufman, and pathologist Wendy Wells.
The investigational modalities of the ABCI, unlike mammography, differentiate tissue on the basis of metabolic and electromagnetic properties such as oxygenation, hemoglobin concentration, elasticity, and electrical conductivity. In addition to anticipated improvements in diagnostic efficacy, the new techniques do not subject patients to ionizing radiation or compression of the breast. Described below are the four principal modalities under investigation.

**Magnetic resonance elastography (MRE)** is based on the association of tissue stiffness and cancer—which is why a clinical breast exam involves physical manipulation to feel for hardness or lumps. MRE uses a modified MRI scanner to create images based on variation in breast-tissue elasticity. Project leader: John Weaver, PhD, Radiology Department physicist.

**Electrical impedance spectroscopy (EIS)** uses a painless low-voltage electrode system to create a “tissue map” of the breast based on variations in how cells conduct and store electricity. These characteristics (conductivity and permittivity) are used to reconstruct images differentiating healthy from cancerous tissue. Project leader: Alexander Hartov, PhD, Thayer School of Engineering.

**Microwave imaging spectroscopy (MIS)** uses microwave deflection patterns to differentiate cell types on the basis of water content. Resultant high-contrast images can be used for diagnosing cancer and treatment monitoring. Project leader: Paul Meaney, PhD, Thayer.

**Near-Infrared Spectral Tomography (NIRST)** utilizes the blood sensitivity and tissue-penetrating properties of near-infrared light to locate and quantify regions of hemoglobin, a key indicator of the microvasculature characteristic of cancerous tissue. The program is using NIRST in two different configurations: as a stand-alone system designed to monitor tumors being shrunk with chemotherapy, and as a hybrid with MRI in which MR provides precise tumor location and NIR categorizes its vascular makeup. Project leader: Brian Pogue, PhD, Thayer.

**Digital Breast Tomosynthesis (DBT)** Recent controversy on the role of mammography screening in younger women highlights the need for further data and for improved screening technologies. *Digital breast tomosynthesis* ("DBT" or "BTS") is a tomographic application of mammography which may lead to improved cancer-screening sensitivity, and reductions in unnecessary recalls and breast biopsies, particularly in younger women with denser breast tissue. DBT involves multiple low-dose X-ray exposures across an arc of motion, creating 3D views which can reduce the incidence of false positives and false negatives found in conventional mammography.
Dr. Poplack and colleagues have been active in DBT research since its introduction, having conducted a groundbreaking early clinical trial comparing diagnostic tomosynthesis with that of conventional film-screen mammography. Study results strongly support a clinical role for diagnostic DBT and suggested the likelihood of reduced unnecessary recalls when used in conjunction with digital screening mammography (AJR, 2007). Subsequently, we participated in a larger study, as one of five institutions in the nation’s first multi-center DBT clinical trial.

With research capabilities enhanced by the 2009 installation of a next-generation DBT scanner, several DBT studies are now underway. The first, a clinical trial sponsored by Hologic, Inc., compares DBT and MRI for diagnostic accuracy in preoperative breast cancer staging. The second is the R01 program, Optical Imaging Fused with Tomosynthesis for Improved Breast Cancer Detection. This five-year program seeks to develop a clinical exam platform combining the functional imaging of near-infrared spectral tomography (NIRST) with the detailed spatial resolution of DBT—a hybrid device which may yield improved sensitivity, specificity, and a reduction in unnecessary patient call-backs. The program is led by Drs. Paulsen and Poplack, with the University of Massachusetts, and DBT industry leader, Hologic, Inc.

**Other Breast-Cancer Imaging Studies**

Breast-cancer imaging is the clinical focal point of several additional projects. Frequency Domain Optical Imaging of Breast Cancer looks at the diagnostic potential of a single platform combining the functional-imaging advantages of NIR with the spatial resolution of MR. **MR Microwave Absorption and Tomography Imaging**, another NCI-funded project, seeks the development of two hybrid modalities (possibly in a single combined platform): magnetic resonance microwave absorption (MRMA) imaging, and MR-compatible microwave tomography (MRMT). Both studies are collaborative efforts led by Thayer’s Dr. Paulsen and Radiology Department physicist Dr. Weaver.

The routine use of preoperative breast MRI is recognized as a potentially powerful, if still controversial, diagnostic adjunct to breast mammography. In 2009, AJR published the results of a significant recent study on the procedure, directed by Radiology’s Dr. Petra Lewis. **The role of breast MRI in the preoperative evaluation of patients with newly diagnosed breast cancer** considered 199 patients with newly diagnosed cancer who underwent breast MRI; for nearly 20 percent of these patients, additional malignant tumors were found by MRI which had not previously been discovered.

**In Vivo EPR Programs**

Electron Paramagnetic Resonance (EPR) spectroscopy is a technique for studying chemical species that have one or more unpaired electrons, such as organic and inorganic free radicals or inorganic complexes possessing a transition metal ion. The basic physical concepts of EPR are analogous to those of nuclear magnetic resonance (NMR) and MRI, but it is electron spins that are excited instead of spins of atomic nuclei. A number of unique capabilities for the measurement of physiologic parameters are available using EPR, including direct measurement of tissue pO2 through a repeatable non-invasive measurement procedure and the measurement of endogenous free-radical species. **In vivo EPR oximetry**, the central research activity of Dr. Swartz’s EPR lab since inception in 1992, has a number of potentially valuable clinical applications. By means of accurate pO2 detection, EPR can be used to monitor oxygen level in a variety of tissue types. In tumors, hypoxia is associated with angiogenesis as well as with resistance to radiotherapy and chemotherapy; accurate assessment of changes in tumor pO2 can be used in cancer detection and staging, and in monitoring of therapeutic efficacy. Other types of vascular pathology are also associated with decreased tissue-oxygen levels, such as the ischemia caused by peripheral vascular disease in diabetic patients and wound healing following radiation damage to normal tissues. EPR oximetry could provide information critical for effective clinical management of these and other oxygen-dependent pathologies and for the assessment of novel therapeutic measures.

Recently, the center has focused on the development of radiation biodosimetry techniques and devices. In a disaster scenario involving the accidental or hostile release of significant levels of ionizing radiation, public health officials remain without effective portable means of determining exposure levels in affected individuals, jeopardizing the ability to carry out appropriate triage strategies. During irradiation, free radicals are created in biologic tissues in proportion to the absorbed dose. In certain tissues, such as tooth enamel, bone, and nails,
these radicals remain in a stable state following irradiation and their concentration can be quantitatively measured using EPR to estimate the dose. The center has received major funding from a number of NIH and DoD sources, including the NIH Centers for Medical Countermeasures Against Radiation (CMCR) program and the Defense Advanced Research Projects Agency (DARPA). As this report goes to press, the EPR Center awaits confirmation of an expected new $16.6 million five-year NIH grant for dosimetry research.

**In Vivo Optical Spectroscopy**  Associated with the EPR Center, Dr. Roger Springett’s Redox Laboratory conducts independent research on the uses of visible light spectroscopy for imaging neural processes in the mammalian neocortex through the measurement of changes to mitochondrial oxygenation. Specifically, the current five-year NIH-funded program, *Imaging the Mitochondrial Response to Neural Activity*, seeks to develop and validate spectral domain imaging technology to collect and reconstruct images of the oxidation state of mitochondrial cytochrome, and of hemoglobin and extrinsic chromophore concentrations. Spectral domain imaging of mitochondrial oxygenation, presently unique to Dr. Springett’s lab, has the potential to add significant understanding of the manner in which the cortex process information, and also offers the possibility of precise, non-invasive location of tumors and other metabolically significant structures during certain types of neurosurgery.

**Neuroimaging Research**  Dr. Weaver, Dr. Eskey, and the neuroradiology faculty continue collaborations—with the Dartmouth Brain Imaging Laboratory, the Advanced Imaging Center in projects including innovation in advanced 3T imaging in glioblastoma recurrence, fMRI imaging, MRI in pediatric head trauma, CTA in intracerebral hemorrhage and aneurysm evaluation, imaging of pharyngeal carcinoma, vertebroplasty, and synovial cyst rupture. In addition, the Thayer School, independently and in collaboration with DHMC departments such as Radiology and Psychiatry, has been active in a range of neuroimaging research, including: the development of dynamic multimodal imaging; fluorescence signatures for image-guided neurosurgery; and molecular imaging for the detection of glioma brain tumors.

**Department-funded Research**  The Radiology Research Committee, chaired by Dr. Belden (following several years of capable leadership by Dr. Harris), assists faculty, residents and fellows with clinical research guidance and seed grants made possible by the Radiology Chair. In the past 3 years, the committee (also including Drs. Eskey, Weaver, Swartz, and Black) has funded studies on: hemodialysis access outcomes and complications in the elderly; interventional radiology procedure in patients with abnormal coagulation parameters; thyroid nodule ultrasound characterization and differentiation of benign vs. malignant nodules (part of a multi-center trial); and interobserver variability of CTA aneurysm perception.

**III. OUTCOMES RESEARCH**

The Dartmouth Institute for Health Policy and Clinical Practice (TDI)—formerly known as the CECS—originated the pivotal *Dartmouth Atlas* and has taken a leading role in advancing outcomes-based medicine. Nearly 20 years ago the Radiology Department signaled its embrace of the principles of outcomes research by recruiting radiologist William C. Black, MD, to a joint appointment with TDI. Dr. Black has developed and teaches a core curriculum on technology assessment, and is nationally recognized as an authority on the evaluation of screening and diagnostic testing. The department’s association with the institute has strengthened in recent years as five additional faculty members have earned MS or MPH degrees at TDI. In late 2008, we established the Radiology Outcomes Group (DHROG) in order to identify opportunities to apply outcomes-based medical practice to clinical imaging, cost-effectiveness, physician education, and shared decision-making with patients.

**The National Lung Screening Trial**  The National Lung Screening Trial (NLST) is a randomized, multi-center study designed to compare the efficacy of two different techniques to screen for lung cancer: low-dose helical computerized tomography (LDCT) versus chest radiography (“plain film” X-ray). With a budget of over $200 million and enrollment of over 53,000 current or former smokers with three annual screenings for each, NLST is the largest randomized study of lung cancer screening in a high-risk population ever conducted, and represents a major milestone in the application of outcomes-research principles to a major public health concern. The NLST has generated widespread interest and considerable controversy, and will almost certainly impact future policy-making for lung cancer screening. Publication of study results and analysis is expected in 2011.
Radiology’s Dr. Black was instrumental in the design of the study, directs its cost-effectiveness component, is PI for the DHMC site, serves on numerous national committees for the NLST, and is slated to present study results at the 2010 RSNA Annual Meeting. Dr. Black, in addition to clinical duties as a chest imaging specialist, serves on the TDI faculty, and as Chair of the Outcomes and Economics Core Laboratory at the American College of Radiology Imaging Network (ACRIN).

CER Center for Cancer Imaging In late 2009 a multi-institutional Dartmouth-initiated consortium was awarded a 2-year, $4 million NIH Recovery Act “Grand Opportunities” grant for *Comparative Effectiveness of Advanced Imaging in Cancer*. Funding is provided for establishing a research center as a component in a national infrastructure for comparative effectiveness of cancer imaging research. The project, led by NCCC’s Dr. Anna Tosteson and Radiology’s Dr. Black, includes several Dartmouth community disciplines and faculties, as well as the American College of Radiology Imaging Network (ACRIN), Brown University, and Tufts University’s Evidence-Based Practice Center.
CLINICAL FACULTY

Judith Austin-Strohbehn, MD
Assistant Professor of Radiology
breast imaging, gastrointestinal

Clifford J. Belden, MD
Associate Professor of Radiology
neuroradiology

William C. Black, MD
Professor of Radiology and Community & Family Medicine
Director, Radiology Outcomes Research
cardiothoracic radiology

Jocelyn D. Chertoff, MD, MS
Professor of Radiology and OB/GYN
Vice Chair, Department of Radiology
Director, Gastrointestinal Radiology

Yvonne Y. Cheung, MD
Associate Professor of Radiology
musculoskeletal, abdominal

Laurence D. Cromwell, MD
Professor of Radiology & Surgery
neuroradiology

Harte C. Crow, MD
Professor of Radiology and OB/GYN, Emeritus
ultrasound, cross-sectional

Julianna Czum, MD
Assistant Professor of Radiology and Medicine
Director, Cardiothoracic Radiology

Roberta diFlorio, MD, MS
Associate Professor of Radiology
breast imaging, ultrasound

Elizabeth W. Dann, MD
Assistant Professor of Radiology
Director, Breast MRI

David A. Desrochers, MD
Instructor of Radiology

Clifford J. Eskey, MD, PhD
Associate Professor of Radiology and of Surgery
Director, Neuroradiology
Director, Neuroradiology Fellowship

Andrew R. Forauer, MD
Associate Professor of Radiology
vascular and interventional

John M. Gemery, MD
Assistant Professor of Radiology
vascular and interventional

Douglas W. Goodwin, MD
Associate Professor of Radiology and Surgery
Director, Musculoskeletal Radiology

Robert D. Harris, MD, MPH
Professor of Radiology and OB/GYN
Director, Ultrasound Education and Research

Eric K. Hoffer, MD
Associate Professor of Radiology
Director, Vascular and Interventional Radiology
Director, VIR Fellowship Program

Petra J. Lewis, MD
Associate Professor of Radiology and OB/GYN
Director, Radiology Medical Student Education
breast imaging, ultrasound, nuclear imaging

David B. Haseman, MD
Adjunct Associate Professor of Radiology

John J. McIntyre, MD
Assistant Professor of Radiology
Director, Spine Radiology Service
neuroradiology, musculoskeletal radiology

Nancy J. McNulty, MD
Assistant Professor of Radiology
Co-Director, Body Cross-Sectional Imaging
neuroradiology, VIR

Anthony L. Merlis, MD
Assistant Professor of Radiology
Assistant Director, Radiology Residency Program
neuroradiology

Helene M. Nagy, MD
Assistant Professor of Radiology
Co-Director, Breast Imaging
breast imaging, nuclear imaging

David A. Pastel, MD
Assistant Professor of Radiology
neuroradiology

Steven P. Poplack, MD
Associate Professor of Radiology and OB/GYN
Co-Director, Breast Imaging
breast imaging, ultrasound

Steven K. Sargent, MD
Associate Professor of Radiology, of Pediatrics, and of OB/GYN
Director, Pediatric Radiology
Director, Ultrasound Clinical Operations
gastrointestinal, pediatric, ultrasound

Dagmar Hoegemann Savellano, MD
Instructor in Radiology
gastrointestinal, cardiothoracic

Marc A. Seltzer, MD
Associate Professor of Radiology
Director, PET-CT Service
nuclear imaging

Alan H. Siegel, MD
Associate Professor of Radiology
Director, Nuclear Imaging

Anne M. Silas, MD
Associate Professor of Radiology
Director, Radiology Residency Program
ultrasound, vascular and interventional, urology

Albert J. Song, MD
Assistant Professor of Radiology
musculoskeletal

Peter K. Spiegel, MD, FACP
Professor of Radiology
Chair, Department of Radiology

William S. Trought, MD
Assistant Professor of Radiology
Director, Speare Memorial Radiology

Michael J. Tsapakos, MD, PhD
Assistant Professor of Radiology
Co-Director, Body Cross-Sectional Imaging
Fellowship Director, Body Cross-Sectional

Therese J. Vaccaro, MD
Assistant Professor of Radiology and Pediatrics
breast imaging, pediatric, ultrasound

Stephanie P. Yen, MD
Assistant Professor of Radiology
nuclear imaging, ultrasound

John B. Weaver, PhD
Professor of Radiology
diagnostic physics
DARTMOUTH-HITCHCOCK MEDICAL CENTER DEPARTMENT OF RADIOLOGY 2006-2010

### CLINICAL FACULTY (VA Hospital)

Tien Burns, MD  
Assistant Professor of Radiology

Susan N. Harper, MD  
Assistant Professor of Radiology  
Director, VA Radiology Residency Program

James E. Lenz, MD  
Assistant Professor of Radiology

Richard A. Morse, MD  
Assistant Professor of Radiology  
Acting Director, VA Hospital Radiology

Edward Smith, MD  
Instructor in Radiology

### CLINICAL FACULTY (Secondary Appointments in Radiology)

Emily R. Baker, MD  
Professor of OB/GYN and of Radiology

Robert S. Foote, MD  
Assistant Professor of Medicine and of Radiology  
Director, Nuclear Cardiology Stress Lab

Charles Herr, MD  
Associate Professor of Medicine and of Radiology

Michele R. Lauria, MD  
Professor of OB/GYN and of Radiology

Judith H. McBean, MD  
Assistant Professor of OB/GYN and of Radiology

Misty Blanchette Porter, MD  
Associate Professor of OB/GYN and of Radiology  
Director, Assisted Reproductive Technologies

E. Rebecca Pschirrer, MD, MPH  
Assistant Professor of OB/GYN and of Radiology  
Director, OB/GYN Ultrasound

### RADIOLOGY FELLOWS

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<tr>
<th>Name</th>
<th>Position</th>
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<tr>
<td>Alexei Viazmensk, MD</td>
<td>MRI Research Fellow</td>
<td>2010-2011</td>
<td>MRI</td>
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<tr>
<td>Travis Mastroianni, DO</td>
<td>Cross Sectional Imaging Fellow</td>
<td>2010-2011</td>
<td>Cross Sectional Imaging</td>
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<tr>
<td>Stephen J. Guerin, MD</td>
<td>Neuroradiology Fellow</td>
<td>2010-2011</td>
<td>Neuroradiology</td>
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<tr>
<td>Lawrence J. Briggs, MD</td>
<td>VIR Research Fellow</td>
<td>2010-2011</td>
<td>VIR</td>
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<tr>
<td>Jennifer Krawitt, MD</td>
<td>MRI Research Fellow</td>
<td>2009-2010</td>
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<tr>
<td>Todd Noce, DO</td>
<td>Cross Sectional Imaging Fellow</td>
<td>2009-2010</td>
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<tr>
<td>Scott D. Smith, MD</td>
<td>Neuroradiology Fellow</td>
<td>2009-2010</td>
<td>Neuroradiology</td>
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### 2010-2011 RESIDENTS

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<tr>
<th>GL 5</th>
<th>GL 4</th>
<th>GL 3</th>
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<tr>
<td>Morgan Althoen, MD</td>
<td>Daniel Gibson, MD</td>
<td>Christyna Faulkner, MD</td>
<td>Hima Bindu Avutu, MD</td>
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<td>Benjamin Gilloon, MD</td>
<td>Hazem Hawasli, MD</td>
<td>Nicole N. Lee, MD</td>
<td>Sword Cambron, MD</td>
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<td>J. Allen Graham, MD</td>
<td>Marc R. Jordaan, MBChB</td>
<td>Justin R. Lewis, MD</td>
<td>Kimberly Jensen, MD</td>
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<td>Bryan Navarette, MD</td>
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<td>Rebecca J. Mueller, MD</td>
<td>Robert Percario, MD</td>
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<td>Vinay Ravi, MD</td>
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<td>Benjamin Salter, MD</td>
<td>Arash Saemi, MD</td>
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### RESEARCH FACULTY

Barjor Gimi, PhD  
Assistant Professor of Radiology and of Bioengineering

Huagang Hou, MD  
Research Assistant Professor of Radiology

Risto Kauppinen, MD, PhD  
Professor of Radiology  
Director, Biomedical NMR Research Center

Nadeem Khan, PhD  
Research Associate Professor of Radiology

Keith D. Paulsen, PhD  
Professor of Engineering and of Radiology

Roger J. Springett, PhD  
Research Assistant Professor of Radiology

Harold M. Swartz, MD, PhD, MSPH  
Director, EPR Center  
Professor of Radiology, Physiology, and of Community and Family Medicine; Adjunct Professor of Engineering and of Chemistry

Benjamin B. Williams, PhD  
Research Assistant Professor of Radiology

### ADJUNCT RESEARCH FACULTY

Oleg Y. Grinberg, PhD  
Adjunct Associate Professor of Radiology

Hiroshi Hirata, PhD  
Adjunct Associate Professor of Radiology

Ke Jian Liu, PhD  
Adjunct Assistant Professor of Radiology

Bernard Galiez, PhD  
Adjunct Assistant Professor of Radiology

Minoru Miyake, PhD  
Adjunct Assistant Professor of Radiology

### RESEARCH ASSOCIATES

Ruhong Dong, MD
Maciej M. Kmiec, M.Sc.
Venkata Krishnamurthy Nemani, PhD
Piotr Lesniewski, M.Sc.
Sriram Mupparaju, MS
Namjoon Kim, PhD
Maureen O. Ripple, PhD
Yasuko S. Sakata, MD, Ph
FACULTY PUBLICATIONS

Includes journal articles and book chapters by the clinical radiology faculty published since January 2006. Research faculty publications are since January 2007. Not included are publications by clinical faculty with secondary appointments in radiology, nor by the radiology staff of the VA Hospital. Residents are indicated by asterisks.


Davis SC, Pogue BW, Dehghani H, Paulsen KD. Tissue drug concentration determines whether fluorescence or absorption measurements are more sensitive in diffuse optical tomography of xenograft contrast agents. Appl Opt. 2009 Apr 1;48(10):D262-72.


Kepshire DS, Davis SC, Dehghani H, Paulsen KD. Pogue BW. Subsurface diffuse optical tomography can localize absorber and fluorescent objects but recovered image sensitivity is nonlinear with depth. Appl Opt. 2007 Apr 1;46(10):1669-78.


### A Century of Medical Imaging Leadership

**1797**
Dartmouth Medical School, the fourth oldest medical school in the U.S., is founded by Dr. Nathan Smith.

**1890**
First Clinical X-Ray in America is performed at Dartmouth College by Edwin and Gilman Frost. Patient is young Eddie McCarthy of Hanover, who fractured his wrist after a fall while skating. (X-ray takes a 20-minute exposure.)

**1900**
MHMH buys more powerful X-ray equipment for $1500. Pictures which formerly took 15 minutes can now be done in a few seconds.

**1903**
First Production X-ray apparatus is placed at MHMH.

**1920**
Kodak’s new mechanical film processor develops and dries film in 7 minutes, “practically a miracle” at the time.

**1922**
Harry T. French (DMS 1915) is appointed “Assistant Roentgenologist.” French had no specialist training in radiology.

**1927**
John Bowler (DMS 1917) founds the Hitchcock Clinic, one of the country’s early multispecialty group practices.

**1930**
Leslie Sycamore, first specialty-trained radiologist in northern New England, becomes chief of radiology after studying under George Holmes at Massachusetts General Hospital.

**1934**
3500 X-ray exams are done per year.

**1940**
Dr. Sycamore starts the MHMH Radiology Residency program, with one resident per year. Paul C. Briede is the department’s first resident.

**1946**
Hanover native Edward Wells (DMS 1940) becomes the first to complete the new radiology residency program. (Dr. Wells, our first radiology resident, was born attended by Dr. Gilman Frost, who presided over the first clinical X-ray in 1895!)

**1950**
William C. McCarty, trained at Mayo Clinic, joins Dr. Sycamore as the 2nd Radiologist in the department. 9,933 X-ray studies done.

First myelography, arteriography and ventriculography done, jointly with surgeons.

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**Mary Hitchcock Memorial Hospital (MHMH)** is built by Hiram Hitchcock in memory of his wife, Mary Maynard Hitchcock.

**Arthur B. Meservey (DC 1906)** joins physics department at Dartmouth, takes over X-ray operation and teaches radiologic physics to medical residents through the 1950’s.

**1997**
Dartmouth Medical School, the fourth oldest medical school in the U.S., is founded by Dr. Nathan Smith.

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**First GI studies with bismuth contrast agent, first fluoroscopy.**

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**First Production X-ray apparatus is placed at MHMH.**

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**Kodak’s new mechanical film processor develops and dries film in 7 minutes, “practically a miracle” at the time.**

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**First GI studies with bismuth contrast agent, first fluoroscopy.**
The principal facilities of the DHMC Department of Radiology are located on the third (main) floor of the DHMC Lebanon campus, as shown above. In addition, the department conducts clinical imaging in the Emergency Department, a DXA suite in the outpatient wing, and mobile MRI units and an extremity MRI scanner on the second floor. Imaging research labs are located at Dartmouth Medical School and The Thayer School of Engineering in Hanover, and at several DHMC locations including the Advanced Imaging Center, the Rubin building and the Bonwell Research wing.
Dartmouth College, February 3, 1896. Less than a year after German scientist Wilhelm Roentgen describes the penetrating properties of his “mysterious light,” Dartmouth physics assistant Frank Austin builds an X-ray apparatus based on Roentgen’s model. His senior colleague, physics professor Edwin Frost, proposes a medical use for the device, and speaks of it to his brother, Dr. Gilman Frost, Mary Hitchcock Hospital Physician-in-Chief. Frost’s patient, Eddie McCarthy, is a local fourteen-year-old who has broken his wrist ice-skating. The 20-minute exposure of Eddie’s left wrist made at Dartmouth College this day was the first clinical use of X-ray imaging in the U.S.—and possibly the first in the world.
