Signals

Number 54

2005 Issue 3

NEWSLETTER OF THE SECTION FOR MAGNETIC RESONANCE TECHNOLOGISTS

IN THIS ISSUE

Message from the President

Karen Bove Bettis, R.T. (R)(MR)

While the summer vacation period is over for those in the Northern Hemisphere, vacation planning is just beginning in the Southern Hemisphere. When planning for fun, have you remembered to plan for your future? Paraphrasing Benjamin Franklin, there is no better investment than in one's own self. The SMRT provides Continuing Education (CE) credits through its Annual Meeting, the Home Study Program and Regional Educational Seminars. The value of networking with other MR professionals is often overlooked when participating in these programs.

It's easy to recognize what separates "professionals" from "average workers." Two factors in distinguishing these workers are the commitment to and the support of professional organizations and the concept of continuing education as a fluid dynamic.

How do you see yourself? Do you visualize yourself as an average worker or as a committed professional?

Two SMRT Regional Educational Seminars were held this summer, which is unusual in the U.S. Mark Spooner served as able host for the July seminar that took place in Syracuse, New York. Denise Davis, who co-hosted the August meeting with Jennifer Petruski in Pittsburgh, Pennsylvania, did not experience the customary turnout associated with a meeting held later in the year. Undaunted, Denise is already planning to hold another Regional Seminar in Pittsburgh. Why? Certainly, it shows her commitment to the SMRT but more importantly, it shows her commitment to bettering herself and to bettering the technologists she works with and those from the surrounding areas.

Other technologists invested in themselves and their fellow technologists are Bobbie Burrow, Carolyn Brown and Donna O'Brien who hosted a Regional in Atlanta, Georgia (17 September 2005). Caron Murray, Joanne Muldoon and Garry Detzler hosted a Regional in Toronto, Canada (24 September 2005). A Regional in New York City, hosted by Cindy Comeau and Carol Finn, took place 15 October 2005. Boston also held a Regional Seminar with Carolyn Bonaceto, Patricia Devine, John Shirosky and Paul Wilson as hosts (22 October 2005). Stanford, California was the site of a two-day regional, again hosted by Anne Marie Sawyer-Glover, on 12-13 November 2005. Program content details can be found on the SMRT Homepage http://www.ismrm.org/smrt/regional.htm.

How many regional programs will you be able to attend this year? How many Regional Education Programs will you host in this year or in the coming year?

Executive and Policy Board Members have been busy since May's annual meeting. Two standouts are Julie Strandt-Peay, who has done a superb job of editing and formatting Signals and Anne Marie Sawyer-Glover, who is continuing her excellent job as editor of the Home Studies. The Ad Hoc Committee for Recognized Continuing Education Evaluation Mechanism (RCEEM), chaired by Heidi Berns, has prepared the final documents for accepting and approving CE accreditation under the RCEEM agreement with the ARRT. The RCEEM Committee will review applications from organizations seeking accreditation. Congratulations to the committee members for undertaking this large, multi-year project and for completing its first full year of the accrediting process.

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A reception held at the NIH, Bethesda, MD (USA), honoring 2003 Nobel Laureate (Medicine), Dr. Paul C. Lauterbur. Also pictured: his wife, M. Joan Dawson and SMRT President, Karen Bove Bettis.

***President's Letter** continued*

Dedicated to her commitment as Chair of the External Relations Committee, Julia Lowe traveled to New York for a meeting with the American Registry of Magnetic Resonance Imaging Technologists (ARMRIT). She and future SMRT President, Cindy Comeau, were invited to meet with ARMRIT officers to discuss the plans of the American Registry for Radiologic Technologists (ARRT) and the creation of an MR certification pathway for non-radiology technologists. Julia will also travel to the Hospital Professions Network (HPN) meeting scheduled for late September. While Julia is at the HPN meeting, members of the Ad Hoc Committee for Education Standards will travel to Minnesota for a roundtable discussion with the ARRT. Luann Culbreth, Chair of the Committee, along with SMRT Past President Cindy Hipps and Carolyn Bonaceto, Education Chair, will represent the SMRT at the ARRT Headquarters in Minneapolis, presenting the SMRT Mission of Education. Dr. John Crues, another committee member, will also be attending as a joint representative of the ARRT and the SMRT. While the SMRT does not govern credential pathways, members will have with them the messages transmitted through the MR Tech List Serve. Radiographers worldwide are discussing MR education requirements and certification pathways for non-radiology technologists because countries are planning to expand the usual certification pathways with the hope to ease the global, severe shortage of qualified MR personnel. Although certification and credentialing methods vary from country to country, most MR technologists expect a fair resolution to the crisis without compromising MR education, MR safety and especially, patient care.

The Program Committee is busy planning for the 2006 Annual Meeting. Committee Chair Todd Frederick has subscribed committee members to suggest and decide upon speakers for the meeting in Seattle, Washington. The committee will also decide, with the help of the Education Committee, how to best structure the program. Attendees from the Annual Meeting in Miami suggested keeping most of the 30-minute time slots for speakers, though some felt a combination of 30- and 50-minute talks allowed for more continuity and relativity of topics.

The ISMRM/SMRT Forum will again be held jointly at the ISMRM Annual Meeting on Monday, 8 May. The theme will be “Mother, Fetus and Newborn.” The Forum will provide an overview of the technical and clinical aspects of performing MRI on an expectant mother, fetus and newborn child. Executive member, Bobbi Lewis, is communicating with her ISMRM counterpart, Dr. Jeffrey Duerk, arranging and scheduling for speakers and topic specifics. Additionally, the ISMRM recently announced its “Call for Papers” with an abstract deadline of 16 November 2005. MR technologists often collaborate with MR engineers, physicians and physicists, submitting a collaborative effort providing an opportunity for learning. The SMRT Education and Program Committee has completed the “Call for Papers” with an abstract deadline of 18 January 2006.

My sincere thanks to the members who have assisted and those who continue to assist the SMRT in becoming the professional society that early members and supporters envisioned. Even though we have access to the ISMRM/SMRT corporate staff in Berkeley, California, the SMRT simply could not exist without its volunteer base of MR professionals.

What have you done to help? What can you do to help? What will your professional legacy be?

Post Script: This year we have witnessed destruction and devastation in Asia, Europe and most recently, the Gulf Coast of America. Technologists communicating via the SMRT List Serve have offered their personal and professional stories of consolation and devastation. Some technologists have opened their homes to fellow technologists and to their families, offering to help them find jobs. Industry leaders communicating on the list are designing disaster scenarios for the protection of MR equipment, MR personnel and patient data. While some technologists could offer nothing more than words of encouragement, it is so gratifying to be associated with professionals who value even the smallest kindnesses.

Editor's Letter

Julie Strandt-Peay, B.S.M., R.T. (R)(MR)

Greetings,

First of all I need to inform you that there have been personnel changes in the ISMRM/SMRT office which resulted in this issue of *Signals* being delayed from our usual schedule. More importantly, it is my pleasure to introduce **Sara Vasquez,** the new ISMRM/SMRT Publications Coordinator for Design and Layout. It has been a privilege to work with her on this issue and we welcome her and her expertise! Sara comes to SMRT with a background in retail advertising writing and editing and is eager to learn the ropes of our fast-paced environment.

In this issue President **Karen Bove Bettis** asks some tough questions of the membership and shares her visit with Dr. Lauterbur. Editor **Anne Sawyer-Glover** presents the SMRT Educational Seminars Home Study Program which accompanies this *Signals* newsletter. Past-President **Cindy Hipps** reminds us that we have an obligation as members to vote for the new president-elect and policy board members. An update of the SMRT membership is detailed by Chair, **Nancy Hill Beluk.**

SMRT Regional Seminar news is brought to us this quarter from two countries in North America. Policy Board member **Denise Davis** began the day in Pittsburgh, Pennsylvania as described by Co-Chair **Jennifer Petruski** of the seminar. Publication Committee Chair, **Mark Spooner** reports on the well attended Regional Seminar held in Syracuse, New York. A successful SMRT Regional Seminar was held recently in Toronto, Canada as accounted by the team of **Caron Murray, Garry Detzler** and **Joanne Muldoon.**

Continuing with our international contributors we have two SMRT members who were willing to share their knowledge of MR artifacts. Starting off is Policy Board member **Greg Brown** who explains artefacts, and how to spell them, from his experience in Sydney, Australia. From across the globe in Brussels, Belgium SMRT member **Filip DeRidder** and his colleagues offer a comprehensive exposition of MR artifacts. Both of these authors will share part II of their work in a future issue of *Signals*.

Those who are looking for ways to assist our colleagues affected by the hurricanes in the U.S. can find information organized by **Vera Miller.**

Todd Frederick invites us to plan now for the 15th SMRT Annual Meeting in Seattle. While you are making plans you may want to join the SMRT and the Associated Sciences at the Radiological Society of North America (RSNA) Meeting beginning 28 November 2005. ●

SMRT Educational Seminars Home Study Program

Anne Marie Sawyer-Glover, B.S., R.T. (R)(MR), Editor

We are pleased to present the SMRT Educational Seminars, Volume 8, Number 3, "Update: Safety in MR Examinations." This is the 29th home study developed by the SMRT, exclusively for the SMRT members. This issue is accredited by the SMRT for the ARRT. The SMRT was given RCEEM status by the ARRT earlier this year.

Safety and screening policies and procedures continue to be a topic of great interest to MR technologists and radiographers around the globe.

It has been almost five years since our last MR safety home study and much has changed. Many new biomedical implants and devices have been developed. We must become familiar with the challenges associated with a change in the magnetic field strength we are operating. Biomedical implants and devices must be re-tested at 3.0T. In addition, we need to review the potential issues in the placement of cables and conductors in a magnet operating at higher frequencies, especially those within the confines of the transmitting RF coil.

Thanks to our authors for taking the time from their busy schedules to write articles specifically for this publication. The SMRT is very fortunate to have the support and contributions of Dr. Frank Shellock, Michael Kean, Drs. Joel Felmlee, Joe Schaefer and Donald Hadley.

For additional information regarding MR safety and screening, please refer to SMRT Educational Seminars home study, Volume 4, Number 1, "Safety Aspects in MRI." Home study back issues may be purchased through the Berkeley, California, USA, office of the SMRT/ISMRM.

Thanks to Maureen Ainslie and April Davis from the Duke Image Analysis Laboratory in Durham, North Carolina, USA, for writing the questions that compose the quiz. Thanks also to Cindy Hipps from Greenville Radiology, Greenville, South Carolina, USA for being our expert reviewer of the home study quiz. Thank you to Mark Spooner, SMRT Publications Chair, and in the Berkeley, California, USA office of the ISMRM/SMRT, Jennifer Olson, Associate Executive Director, and the staff for their insight and long hours supporting these educational symposiums.

Accreditation (USA) for all home study issues of the Educational Seminars is maintained annually by the SMRT. Previous issues may be obtained from the SMRT/ISMRM office located in Berkeley, California, USA for twenty dollars (USD) each. For a complete list of back issues, please go the SMRT website: http://www.ismrm.org/smrt. If you live outside of the U.S. and have interests or questions concerning accreditation within the country you reside, please contact me at amsg@stanford.edu or +1 (650) 725-9697.

If you are looking to become more involved in the SMRT, please consider writing questions or an article for one of our home studies. The instructions for writing questions will be posted on the SMRT website in the near future. For additional information, please contact me directly or Jennifer Olson, ISMRM Associate Executive Director, at the office in Berkeley, California, USA (smrt@ismrm.org, +1 (510) 841-1899).

Finally, I would like to thank Tom Schubert and all of the wonderful people at Invivo/MRI Devices Corporation for their continued support of our home studies program, SMRT Educational Seminars. ●

Membership Update

Nancy Hill Beluk, R.T. (R), Membership Committee Chair

The SMRT membership numbers truly "rode the wave" out of our Annual Meeting in Miami by adding 168 new members. This amounts to an 11 percent increase over last year!

While the incoming Membership Committee in no way takes credit for this increase, we are definitely encouraged. With a current membership of 1,686, we continue to look for new opportunities to encourage MRI technologists to join the SMRT. MR Technologists and Radiographers will realize the benefits of participating in the only global organization dedicated to continuing education in the field of MR.

We are currently writing a draft for "student" membership and will be talking to instructors of MRI schools for their input. If we can encourage those students who are new to our growing field and show them the excellent opportunities provided to them through an SMRT membership, we believe that we will meet and exceed their expectations.

I would like to thank the new committee members: Christine Harris of Children's Hospital in Philadelphia and Ashok Saraswat of The Ohio State University in Columbus who joined the membership committee in May. Should you have any input that you think may promote membership or increase the benefits of belonging to the SMRT, please let us know. ●

SMRT Members: Exercise Your Right to Vote

Cindy T. Hipps, B.H.S., R.T. (R)(MR), Past President and Nominating Committee Chair

As a voting member of the SMRT, you have the ability to decide the future leadership of the SMRT. It is your responsibility as a member to exercise this right as well as educate yourself concerning the nominees of each position. If you are not familiar with the nominees, read each biography and make a decision based on what that person has done and can do to further the SMRT and the benefits the SMRT offers to the members and the profession. You can make a difference!

You will have an opportunity to vote for the President Elect position. This is the future leader of our organization and is a three year commitment. Policy Board members are also elected for three years. You will be given a chance to choose five. You will also have the opportunity to decide who will receive the prestigious Crues-Kressel Award for outstanding contributions made to education of MR Technologists.

Ballots will be mailed in October and they are due back and must be postmarked by 1 December 2005. All of the nominees meet the qualifications of the office and promise to fulfill their commitments, but you must decide who can do the BEST job for the SMRT. Please make every effort to send in your ballot. You must be a member in good standing with your dues paid for your vote to be eligible. Your vote is important as is your participation in choosing the future of the SMRT. Let's make 2005 a record year for ballots returned and see what a difference it will make. ●

SMRT Northeast Regional Educational Seminar — Pittsburgh

Jennifer Petruski, B.A., R.T. (R)(MR), Co-Chair

The August 6 SMRT Northeast Regional Educational Seminar in Pittsburgh, Pennsylvania was a great success. MRI technologists came from near and far to participate in a day of education and a chance to network with fellow technologists. The seminar was held at the Biomedical Science Tower located in UPMC Presbyterian Hospital.

After a pleasant welcome from Denise Davis, Bill Faulkner was introduced to the audience. His oration, "MR Contrast Agents" was a great overview of MR contrast agents available on the market today and their similarities and differences. Bill also explained the importance of conducting crossover studies when comparing the differences between standard agents and MultiHance.

Bill stayed on course by going right into his next lecture, "Parallel Imaging." He explained the reasons for using parallel imaging, such as achieving higher resolution and greater coverage for same scan times, reducing ETL for SSFSE and EPI sequences, and reducing SAR on 3T scanners.

When Bill finished, Dave Stanley from GE Healthcare got the crowd up and out of their seats for "MR Jeopardy!" Audience members John Posh, Karol Handrahan and Lori Kalp led three teams to answer questions about everything from MR Safety to MR Physics. Karol's team took first place.

John then delivered a very interesting lecture entitled, "Unusual MR Case Review." He presented several unique cases and explained the use of MR in solving crimes. He also displayed a few cases showing patients who ignored obvious symptoms which later turned into fatal conditions. He advised the audience to pay close attention when scanning because there are interesting cases everywhere!

Omar Almusa, M.D., a Radiologist from the UPMC Health System, then brought the audience back to everyday clinical scanning with his lecture, "Introduction to Body MRI." He discussed problems which often make MR abdominal imaging difficult and described the process of a typical MR abdomen exam. Dr. Almusa displayed case studies including renal artery stenosis, cholangiocarcinoma, oncocytoma and ascending cholangitis with abscess formation.

After a relaxing lunch and enjoyable time catching up on the lives of fellow MR technologists, we were treated to another lecture by Dave Stanley. Because time permitted, we were able to fit in "What You Need to Know About 3T." Dave stated the main reason the 3T is purchased is for increased SNR and he discussed the problems that come along with scanning at 3T as well as the safety concerns. Dave considers 3T only as good as the coils that are developed and available with the system.

Next was Brian Chapman, Ph.D. from the University of Pittsburgh. His lecture, "Principles of MRA," was a great overview about the pros and

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cons of MRA, general principles of acquisition, MRA techniques, and the factors to improve efficiency.

To round off the day, Robert Carlson from Siemens presented his lecture, "TIM Technology." He explained how TIM allows you to build your own supercoil by using a flexible coil combination to provide workflow and productivity advantages.

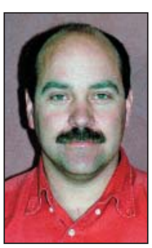
We would like to thank all of the speakers for donating their time on this special day. Also, we are very fortunate to receive sponsorship from various vendors and would like to give a special thanks to Bracco, GE Healthcare, Institute for Magnetic Resonance Safety, Education and Research, Magnetic Resonance Safety Testing Services, Medrad, Philips Medical Systems, Siemens and Toshiba America Medical Systems. With their continued participation, seminars are kept affordable for the attendees. We received positive comments about the seminar and hope to see everyone again next year!

Top: Attendees watch with interest during the discussion.

Bottom (l to r): SMRT member John Posh shares a moment with speaker and SMRT Past-President Bill Faulkner and Dave Stanley from GE Healthcare.

SMRT Northeast Educational Seminar — Syracuse

Mark Spooner, B.P.S., R.T. (R)(MR)(CT), Chair



The SMRT Regional Seminar took place Saturday 9 July at Weiskotten Hall on the campus of SUNY Upstate Medical University in Syracuse, New York. More than 50 people attended, from New York, Pennsylvania, Connecticut and Massachusetts.

The morning session began with two informative talks by Luann Culbreth from Baylor Medical Center in Plano, Texas. Luann described the various contrast agents that are under development, and gave a historical perspective of contrast use with MRI. Her next talk was titled "Breast MRI: Clinical Considerations." The history of breast imaging was described. Indications for breast MRI were listed, and the sensitivity and specificity was compared with other modalities.

Paul Dugrenier was the next presenter and his lecture titled "Breast MRI: Technical Considerations" complemented Luann's breast talk. Paul described the techniques he uses at St. Peter's Hospital in Albany, New York. He discussed the technical details of a dynamic contrast enhanced breast MR exam including MR guided biopsy and wire localization techniques. The importance of using a CAD system to interpret the more than 1500 images generated was emphasized. Everyone enjoyed Paul's video clip at the end of his presentation. Jim Stuppino from Valley Advanced MRI & Gamma Knife in Bethlehem, Pennsylvania was the last to speak before lunch. Jim described the use of MRI with Gamma knife surgery at his facility. He described the development of Radiosurgery, and the techniques used to prepare a patient for his or her treatment. Several case examples were described, with pre- and post-treatment MRI images for comparison.

Lunch was served on the 9th floor of Weiskotten Hall, with a beautiful view of downtown Syracuse.

After lunch, Cindy Comeau from Advanced Cardiovascular Imaging in New York City gave a lecture on "Cardiac MRI: Basic Principles and Applications." She described the basic cardiac structure and function, followed by cardiac pulse sequences and scan planes utilized. She gave several case examples from her facility.

Dr. Michael Rothman from Zoom Imaging in Bethlehem, Pennsylvania finished the day with two talks. His first talk was titled "Blood, Pus, and Tumor: Emergency Spinal MRI." He kept everyone entertained during the technical difficulties throughout his talk. He demonstrated the sensitivity of MRI for various spinal disorders, even with

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Left: Paul Dugrenier presents topical information.

Below: Craig Pole (left) and Bruce Paquette (right) share experiences during the lunch break.

Far Below: SMRT Past-President, Luann Culbreth, lecturing at the seminar.

***SMRT Northeast Educational Seminar** continued*

older MR images from the 1980's. Dr. Rothman's second talk was titled "MRI of Brain Attack." He compared MRI and MRA images as well as CT images and gave several case examples.

We were honored to have in attendance SMRT Past President (Luann Culbreth), SMRT President Elect (Cindy Comeau) and the Program Chair of the 2004 Annual Meeting — Kyoto (Jim Stuppino). Cindy Comeau spoke about the benefits of SMRT membership.

I would like to thank the sponsors that made the meeting possible. SUNY Upstate Medical University provided the lecture hall, and Cooperative Magnetic Imaging in Utica, New York sponsored the luncheon. Siemens Medical, Bracco, and Berlex sponsored speakers, and Suros Surgical Systems had a tabletop display. I would also like to thank Dave Clemente from SUNY Upstate Medical MRI School for his help with the AV equipment. ●

Eastern Canada SMRT Regional Seminar — Toronto

Caron Murray, M.R.T.(R), A.C.(R) (MR) Local Chairperson
Garry Detzler, M.R.T.(R), A.C.(R) and Joanne Muldoon, M.R.T.(R), A.C.(R) Co-Chairs

The MR Research Technologists of Imaging Research, Sunnybrook and Women's College Health Sciences Centre were pleased to host their first SMRT Eastern Canada Regional Seminar on Saturday, 24 September 2005. The meeting was a huge success due to the generous support of General Electric Healthcare, Siemens Canada, Berlex Canada, Bracco Diagnostics Canada, Medrad Canada and Sunnybrook and Women's Health Sciences Centre. The local chairperson for the seminar was Caron Murray and co-chairs Garry Detzler and Joanne Muldoon assisted in the event.

The morning began with a continental breakfast and registration. After the opening remarks and welcome by Caron, the didactic session started with a talk on physics by Dr. Donald Plewes. Dr. Plewes is the Interim Director of Imaging Research at Sunnybrook and Women's College H.S.C. and a Professor of Medical Physics and Medical Biophysics at the University of Toronto. He presented a very entertaining and informative lecture on MR Spin Gymnastics. Dr. Plewes' enthusiasm for the subject was contagious and his physics animations were attention-grabbing. Who knew that MR physics could be fun?

Following Dr. Plewes was Dr. Alexander (Sandy) Dick, M.D., Interventional Cardiologist and Associate Scientist at Imaging Research at Sunnybrook and Women's College

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H.S.C. Dr. Dick presented a very instructive lecture on Cardiac MR and Interventions. Dr. Dick talked about his research on stem-cell therapies for Cardiac Infarctions and the future Cardiac Interventional Suite here at S&W, which will incorporate a 1.5T MR magnet into a Cardiac Catherization Lab.

After a brief morning break, Caron introduced Andrew Nelson, Charge MR Technologist at S&W. Andrew's topic was MR Colonography and he offered an excellent overview of the procedure. His lecture addressed the many applications for the study and included patient preparation and compliance, the use and types of contrast medias, anatomy and pathology of the bowel, as well as MRI's role in the workup following failed colonoscopy.

Dr. Alan Moody, Radiologist-in-Chief, Medical Imaging and Associate Scientist (Heart and Circulation), Imaging Research at Sunnybrook and Women's College H.S.C. discussed M.R. Direct Thrombus Imaging. This imaging procedure provides a closer, more in-depth look into occluded arteries, providing information never seen before and has the potential of changing the standard of imaging everywhere. This new MRI technique aims at early diagnosis and intervention to prevent strokes and heart attacks by detecting vulnerable plaques in arteries of patients who are asymptomatic. Dr. Moody has been instrumental in developing and incorporating this imaging technique into his clinical practice in a comprehensive effort to identify and stabilize vulnerable plaques in one integrated procedure.

Everyone enjoyed the opportunity to gather for lunch in the McLaughlin Auditorium. The time was well used to network and share MR experiences with each other. In addition, several vendors were on-hand to offer product information and support to all. Anyone that was interested was invited for a long walk down to the MR Research area and to introduce themselves to the research version of the Sentinelle MR Breast Intervention Bed. Many took the opportunity to stretch their legs and visit an active research site.

Immediately following lunch, Dr. Michael Bronskill, Academic Director of the 1.5T Research Facility and Professor of Medical Physics and Medical Biophysics at the University of Toronto spoke on one of his interests, Research in MR-guided Interventions. Dr. Bronskill walked the audience through the how and why of MRI-guided transurethral thermal therapy of the prostate gland. Aided by several cleverly animated slides, he demonstrated how the MR scanner can aid in the production of heat maps for the thermal therapy interventions.

Keeping with the interventional theme, the next speaker was Cameron Piron, President of Sentinelle Medical. Cameron discussed Breast MRI Hybrid Imaging and Intervention Strategies. The field of Breast MRI has matured in recent years and is now commonly performed at many clinical imaging sites. Dedicated coil systems and peripheral interventional devices are being brought to the market at a rapid pace. Breast MRI presents new challenges to an MRI facility, as MRI-based intervention is required for proper patient management. Cameron reviewed the requirements for Breast MR Imaging and demonstrated the interventional options including wire-localizations, core biopsies and vacuum-assisted biopsies.

Following the afternoon break, Dr. Simon Graham, Director of the 3T Imaging Research Facility and Senior Scientist at Imaging Research, shared his experience with Functional MR Neuroimaging Applications. Dr. Graham's laboratory uses fMRI to research clinical conditions such as stroke and dementia. He illustrated the basics of fMRI in addition to the developing of behavioral tasks for fMRI experiments. He touched on the use of virtual reality in fMRI and how it has lead to the creation of flexible MR-compatible devices to simulate the "real world" particularly for stroke recovery patient research and how these devices could then enable longitudinal fMRI studies of stroke recovery mechanisms.

The last speaker of the day was Rhonda Walcarius, M.R.T. (MR) who donned her CAMRT hat to talk about the new exam process. The CAMRT is in the process of changing the certification examinations in all modalities and is looking for technologists who may be interested in becoming item writers, item reviewers or a member of the Exam Validating Committee.

This Regional Seminar would not have been possible without the support of the local vendors. We would especially like to thank all of our sponsors for their help and contributions. We would like to thank Sunnybrook and Women's College Health Sciences Centre and Imaging Research for hosting the meeting and all our speakers and attendees who helped make our meeting a great success. Caron, Garry and Joanne enjoyed hosting the event and have decided to do so again next year. Mark your calendars for September 2006 in Toronto. We hope to see you all there. ●

MR Artefacts I – Learning from Imperfection

Greg Brown R.T.

This article represents the views of its authors only and does not reflect those of the International Society for Magnetic Resonance in Medicine and are not made with its authority or approval.

Introduction

MR Technologists control the operation of the scanner and evaluate all images created. We have the first opportunity to recognise artefacts as they occur, and the responsibility to fix them or minimise their negative impact on image quality. Whether the Technologist recognises or understands the artefacts is a product of education, diligence, and experience; using the information artefacts contain requires some insight and imagination.

In order to deal with artefacts effectively, the MR Technologist needs to combine issues of physics, radiology, anatomy, hardware design and construction, system maintenance, site design and scanner control into a connected whole. This amalgamation of perspectives is a defining strength of the competent MR Technologist.

What Is An Artefact?

"A feature not naturally present...introduced during preparation or investigation....a product of human endeavour or workmanship."

This dictionary definition of the word artefact is a good starting point, because it removes us from any MRI considerations and lets us work conceptually for a bit.

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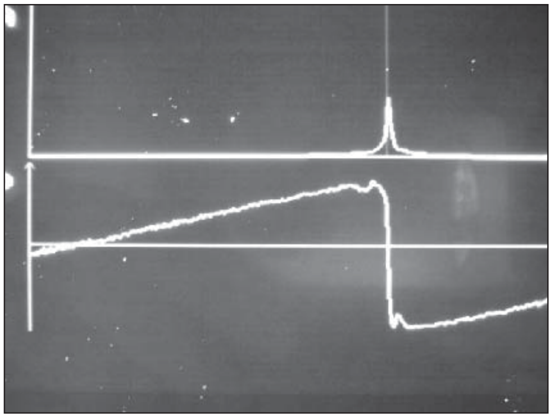
Digital photograph of an MRI film on a light box.



We can think of an image as something containing "natural" information showing the object, overlaid with artefactual information reflecting the machinery, methods and operator that made the image. The fine lines on a TV image, strobing and swimming patterns seen in checked fabrics worn by the presenters, or the chunky nature digital pictures from our mobile phones are artefacts we commonly see around us, as characteristic of the production technology as brush strokes on an oil painting.

So let's work backwards now as we do every day in MRI; starting with an image, and then trying to see and understand artefacts. The above image has a few obvious artefacts. White spots scattered on the black background, and a vaguely rectangular lighter ghost with an ovoid vertical pattern, ending in two faint diagonal stripes. Their source isn't immediately obvious, but if you are told that the image is a digital photograph of an MRI film on a light box, the artefacts make a bit more sense. The white spots are large specks of dust on the surface of the film. The brighter ghost is a reflection of viewing box light from the silver bodied digital camera back on the glossy surface of the film. Comparing the ghost to a picture of the digital camera used makes it even more obvious.

The more we know about the process and hardware used to create the image, the easier it is to recognise and explain the artefacts. If you also noticed a diagonal ghost reflecting the fingers holding the camera...extra marks for great observational skills.

Is Noise An Artefact?

Not really. Noise and artefacts can both degrade image quality and some artefacts will affect the whole image mimicking low SNR, but noise and artefacts are distinctly different. Noise is random signal, while artefacts contain "information" about the factors that cause them. If the "noise" has a pattern to it, then it's an artefact.

Are Artefacts All Bad?

Many Technologists have heard the joke that if it happens once it's an artefact; if it keeps showing up, it's a characteristic appearance. While this sounds like a cop out, it's probably true. Time of Flight MRA relies on flow related enhancement. Phase contrast angiography and flow quantification provides useful information from the same conditions that create motion induced ghosts in the phase direction. Artefactual signal loss in gradient echo sequences due to intra voxel magnetic field strength variations have been used to map brain activity in the BOLD fMRI method, detect blood products, and in MR Suspectography to create venous maps. Many of our methods are developed directly from conditions that were initially seen as artefacts, by teams who worked to understand, control and exploit the conditions that created them.

What Can I Do When I See An Artefact on My Image?

Once we have recognized an artefact, we must decide what to do; identify it, explain it, fix it or ignore it.

It's OK to ignore it if we have already dealt with the artefact and decided there is nothing that can be done and no real problem, but starting with a head in the sand approach won't get us far. Someone will notice it and come ask for an explanation. We make the images, so we need to be able to explain their appearance.

Start with some basic questions.

- Where have I seen this before?
- Where is that textbook?
- Can I fix it?
- Can I use it to some advantage?

Naming Artefacts

Considering that English language users can't even agree how to spell artefact (artifact) it's no surprise that MR users don't always agree how to name common artefacts.

As with sequences, different authors have labeled essentially similar artefacts with many different names. When we look at the basis of artefacts this is quite understandable. Artefacts caused by a single principle can exhibit a range of different appearances. Artefacts reflect the details of the particular image creation process, the particular imaging hardware, the particular object being scanned and unique external factors, so it's no surprise that unique patterns may occur, or that different equipment and locations can produce different manifestations and different names for the same problem. With education and experience we collect these variations into recognisable groups, but it's not unusual to get things wrong from time to time.

Learning Strategies

Textbooks, artefact galleries, and other conventional training aids are obvious starting points, but artefact explanations should come after a solid grounding in imaging and hardware principles. The next step is critical observation of images and naming of common artefacts (the eyes see what the mind knows). Solving intermittent artefacts is made easier by keeping good notes of occurrences, including scanning details, hardware details and the time of day the artefact appeared. Looking at artefacts from different scanners helps recognize the similarities rather than the differences. When artefacts occur, use them as learning opportunities. Record examples, along with the causes and solutions you find successful. Share this experience with colleagues and draw from their experiences.

Not all artefacts are obvious, so a range of window settings can be needed to see them clearly. Correct identification depends on the location of the artefact in relation to the full acquired F.O.V. so they are best appreciated in unmagnified views. Cropped or magnified images may mask the source on a subtle artefact. Looking at the K-space data will confirm spike artefacts that cause so-called corduroy, herringbone or zipper appearances in the image data. When tracking down artefacts in reconstructed images, you must look at the base images. ●

Artifacts in Clinical Magnetic Resonance Imaging Part I: Identification and Correction, A Review

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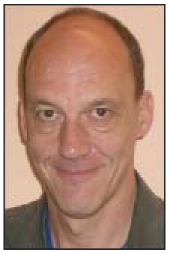

A large number of artifacts occur in magnetic resonance (MR) imaging. These artifacts can potentially affect the quality of MR images and may simulate pathologic conditions or produce pitfalls in interpretation. Recognition and if possible correction of artifacts is an important aspect of clinical MR imaging. This article aims to review the various types of artifacts in magnetic resonance imaging and how to identify them and if possible suggest ways for their correction. We consider artifacts under several distinct categories: static magnetic field perturbations, gradient related artifacts, RF related, signal processing and patient induced artifacts. For each case, a brief explanation of its cause, along with suggestions for avoiding or reducing it is given.

Introduction

Since the introduction of magnetic resonance imaging as an imaging modality, it was soon realized that an unfortunate side effect of the complex nature of MR imaging was a whole set of artifacts. The word artifact derives from the latin terms artis ("art") and facere ("to make"). This article reviews the various "works of art" encountered in MR today, including those related to the use of fast imaging techniques. The radiologist relies on visual impression to make a diagnosis. In MR imaging what we see can sometimes be a far cry from reality, images stretch, wrinkle or variations in signal intensities or mispositioning of signals. Some of these artifacts are due to equipment malfunctions whereas others are due to improper technique. However, in most cases they are intrinsic to the MR imaging technique and cannot be completely eliminated. Artifacts are signal intensities in the images, which do not correspond to the spatial distribution of tissue in the slices (1). Since most artifacts can be reduced, it is important to recognize them so that they do not negatively influence the diagnostic interpretation of the images. Artifacts can mimic pathology to such an extent that examinations have to be redone or other diagnostic modalities have to be used to exclude pathology. This article is intended to serve as a relatively complete atlas of the major types of artifacts in MRI, in each case giving a brief explanation of its cause, along with suggestions for avoiding or reducing it. First, principles of MR image reconstruction are reviewed. Artifacts caused by defective components or malfunctions of the imaging system will not be covered. We have tried to include artifacts from different vendors. Realizing that any classification of MRI artifacts is arbitrary and incomplete, we propose the following general outline based on the predominant causative agent or affected system component: static magnetic field perturbations, gradient related artifacts, RF related and signal processing and patient induced artifacts. We consider artifacts under several distinct categories, although in reality artifacts arise from interplay of these factors. The classification of artifacts is complicated by the multifactorial basis of production: the interrelationship among hardware, software and the system dependent nature of artifact related to static magnetic field strength, gradient strength, radio frequency and body part examined.

Basic Principles of An MR Image Reconstruction

Many artifacts arise when signal received from the mobile protons in the tissue is converted into a spatial map (i.e. an image). This conversion requires parceling information into blocks that form a square or a rectangular grid. The size of each block (commonly called a voxel and called a pixel in the final two-dimensional image) is important. If the blocks are too large, they will contain many types of tissue and will not have the desired spatial resolution. If the blocks are to small, there will not be enough signals in each to form an image. The computer of the imager is used to place signals in each block by means of a two-step process that makes each block slightly different from all other blocks. First, the computer alters the magnetic field strength in each succeeding row of blocks by applying a magnetic field gradient (readout gradient) across the tissue. This difference in magnetic field strength changes the frequency of the signal from each row in the image, hence the name frequency-encoding direction. The number of frequency bands the computer divides the signal into determines the number of rows that will form the image (most commonly 256 or 512). Thus, each row represents a different frequency, with the resonant frequency at the center and the frequency varying to plus or minus a maximum value at the edges of the image. The total frequency range from one edge of the image to the other is called the bandwidth and is set by the imager. Some manufacturers allow the user to select the bandwidth for some pulse sequences. The frequency per row is simply the bandwidth divided by the number of rows. The bandwidth, together with the readout gradient field strength, determines the length of the field of view in the frequency-encoding direction. The second step separates the signals in the other direction to superimpose columns over the rows. A phase gradient is applied across the columns to speed up or slow down the radio waves that form the signal, hence the name phase-encoding direction. Although the signals in this direction are all the same frequency, the gradient causes the sine waves to start at a different point depending on the column in the image. This difference is called the phase shift and can be measured as an angle. The individual measurement, called a view, has to be repeated multiple times with the phase gradient increased each time until a maximum is reached. This process takes up most of the imaging time. The phase shift of the signal for each gradient step varies from 0° at the center column of the image to 180° at the edges of the image and is used by the computer to assign the signal to the correct column. The number of phase-encoding steps determines the number of columns in the image. This number is selectable and is usually 192 or 256. The computer uses the combination of the exact frequency and phase of each component radio wave from the signal to assign the signal to the correct block within the grid, thus forming the image. It is possible to switch the directions of the frequency and phase-gradients as long as they remain perpendicular to each other. Switching the directions of these gradients can be used to identify artifacts and reduce the effects of the artifacts because certain artifacts propagate along either the frequency or

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phase-encoding direction. The actual direction of increasing frequency on an image is arbitrary and depends on the manufacturer of the MR unit, the plane of slices and the position of the patient.

1) Magnetic Field Perturbations

Magnetic Field Instability

A fundamental prerequisite for MRI is a homogeneous static magnetic field. Imperfections in magnetic construction or more commonly, in shimming may disrupt the magnetic field homogeneity. Areas of image distortion or focal signal loss along the readout direction are the result. Magnetic field inhomogeneity may present as propagation of signal loss or noise in the phase-encoding direction across the entire image (2). Other causes of magnetic field inhomogeneity are temporal fluctuations in the power supply and thermal instability. Resistive magnets are susceptible to accidental power interruption and images may demonstrate severe artifacts resulting from magnetic field inhomogeneity many hours after restoration of power. State of the art super conducting magnets operate with temporal stabilities of 0.1 to 1 ppm over days to weeks (3). However, without routine active shimming, the thermal fluctuation of the system results in accumulated magnetic field inhomogeneity that can degrade image quality rapidly. Proper magnet design, production and regular shimming by service personnel maintain magnetic field inhomogeneity at a minimum. Objects both external and internal to the imaging volume of the MR system may interfere with static magnet field linearity. Sizable ferromagnetic structures in motion near the magnet, such as a truck or elevator, generate magnetic forces of their own. If static field shielding fails to compensate for these forces, these external fields may create magnetic field inhomogeneity artifacts.

Local Inhomogeneity

Any local internal distortion of the magnetic field cannot be corrected by shimming. The most common causes of local inhomogeneity are the presence of ferromagnetic foreign bodies. Most materials may be classified as ferromagnetic (strongly attracting lines of force), paramagnetic (weakly attracting lines of force) or diamagnetic (weakly repelling lines of force). These three classes of magnetic properties are all related by the relative magnetic susceptibilities. Magnetic susceptibility represents the ratio of induced magnetization to applied magnetization and is therefore a dimensionless quantity. Diamagnetic substances (water) have an induced magnetization that is a million fold less than the applied field, with opposite polarity (repelling). For example, in a 1.5T MR system, water has an induced magnetization of roughly 0.015 G (flux lines opposite the direction of the magnet). Paramagnetic compounds (elemental gadolinium) have an induced magnetization four orders of magnitude greater than that of diamagnetic compounds and are attracted to the applied field. Ferromagnetic substances (iron-containing alloys) have a magnetic susceptibility four orders of magnitude greater than that of paramagnetic compounds. Titanium, tantalum and aluminum are nonferromagnetic (4). Stainless steel alloys that have a high content of nickel are nonferromagnetic, however, cold working of these materials (as when they are bent to form surgical clips) can impart a mild degree of ferromagnetism (5). Ferromagnetic materials contain macroscopic magnetic "domains" in which the molecules align with the main magnetic field. These materials have high magnetic susceptibilities, that is, they strongly attract magnetic lines of force and distort magnetic field homogeneity in their vicinity. Because magnetic susceptibility is proportional to magnetic field strength, ferromagnetic artifacts worsen at high fields (6). A ferromagnetic artifact has a specific appearance, consisting of signal abnormality and geometric distortion of decreased signal intensity abutted on one side by a curvilinear region of marked hyperintensity (7-8). Spatial localization for two-dimensional Fourier transform image formation depends on the presence of a highly linear magnetic field gradient. Ferromagnetic objects distort the magnetic field in their vicinity. On one side, the field generated by the ferromagnetic object augments the applied magnetic field gradient, stretching the image as well as causing signal loss. On the other side, the increased field from the ferromagnetic object opposes the applied gradient, the MR signals from the tissue protons, over the region where the gradient is attenuated, collapse to a high intensity line. In addition to generating artifacts, larger ferromagnetic objects (such as dental plates) can worsen RF coil performance because they alter the magnetic field particularly on systems with high-quality coils. Small ferromagnetic objects in the volume imaged cause characteristic focal MR aberrations. Artifact generating ferromagnetic objects include some types of surgical clips, interventional radiological coils, steel implants such as ventriculoperitoneal shunts, dental steel in orthodontic braces and dentures, hair and safety pins, mascara and zippers. These artifacts classically consist of a central signal void and asymmetric margins of higher signal intensity in bizarre, nonanatomic configurations. Ventriculoperitoneal shunts and various clips, such as internal mammary coronary artery bypass clips and carotid endarterectomy metal clips, can all produce artifactual stenosis or occlusion of vessels on maximal intensity projections in MR angio studies. Nonferromagnetic metallic implants, such as some small surgical clips, may be invisible but can generate artifacts in the form of localized signal voids. Nonetheless, because of the different acquisition and reconstruction method employed, MR images are usually more interpretable in the presence of metal than are the radically streaked CT images (9). The severity of the artifact depends on the shape of the object and or the type of sequence that was used. Because this determines whether closed conducting pathways exist; for instance, a U-shaped clip may generate less artifact than a closed loop (Fig.: 1). The orientation of the long axis of a surgical nail relative to the readout gradient axis also influences the degree of artifact present. Rarely, nonferremagnetic metallic objects may cause focal signal loss, with the mechanism involving RF field-induced eddy currents within the diamagnetic objects (10).

Fig. 1: Coronal T2 weighted Truefisp (TR 4,8, TE 2,3, FL 70°) image of the abdomen. Linear artifact caused by ferromagnetic (arrow) foreign bodies demonstrates a linear artifact caused by a metal paper clip lodged in the scanner bore.

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Heterogeneous Fat Suppression

There are two different methods that can be used for fat suppression, 1) using a general inversion delay time (TI) to suppresses the fat signal (for 1.5T a 160 ms TI is used). The advantages of this method are a larger field of view and less sensitivity to main magnetic field distortions. The disadvantage of using inversion delay time is that the fat suppression may not always be complete since the T1 values of fat differ between patients and anatomies (Fig.: 2). 2) Fat suppression with the frequency selective suppression is a technique that involves exciting lipid protons by a radio pulse that matches their resonant frequency. If all lipid protons in the region of interest are precessing at the same frequency, they can be excited by a single radio pulse, however if the main magnetic field is heterogeneous or if the radio pulse is not transmitted uniformly throughout this region, excitation of lipid protons will not be uniform. Heterogeneous fat suppression is one of the most common artifacts, because the chemical shift between water and lipid protons is only about 3,5 ppm (parts per million).

Slight variation of the main magnetic field causes lipid protons to precess at a different frequency from that of the narrowly focused chemical shift saturation pulse. The homogeneity of even a perfect main magnetic field is disturbed once a patient lies within it. The most common cause of patient-induced magnetic field heterogeneity is air-tissue interfaces, whether within the patient or at the skin surface. Air and water have different magnetic susceptibilities and this results in different local magnetic local magnetic fields. Bone and water also have different susceptibilities, but the disturbance of magnetic field homogeneity for these tissues is less pronounced. With severe magnetic field heterogeneity, as in the presence of metal objects, most fat-suppression techniques should be avoided. As recorded above, it may happen that fat is not successfully suppressed. Basically two things may go wrong. First when the magnetic field is locally distorted and resonance frequency differences exist, water could partially be suppressed instead of fat and second when the RF fields locally distorted (Fig.: 3), the flip angle used for the fat suppression could slightly vary over the FOV resulting in unsuccessful fat suppression. Hints to improve successful fat suppression: remove all metal from the patient (dentures and dental devices), any metal in the bore will disturb the homogeneity of the magnetic field. Eye make-up should be removed before the examination because it often contains metallic particles. Use small field of view, the area of interest has to be close to the iso-center (less than 80 mm in any direction), the best shimming and therefore more homogeneous fat suppression exist at the iso-center. Avoid placing two objects (knee, ankles) in one field of view (if both objects have a slightly different resonance frequencies, the autoshim may not be successful). Avoid sandbags inside or near the field of view (sandbags may enlarge susceptibility effects). High signal intensities may disturb the autoshim. This is especially seen in the pelvis region when the patient has a full bladder. In this case only a small area is optimized and the edges of the field of view may show no fat suppression at all. Volume shimming improves field homogeneity.

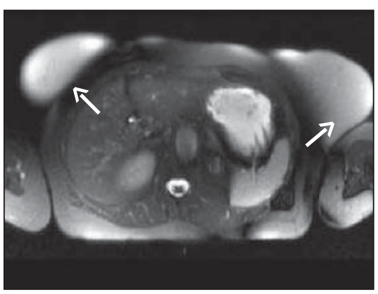

Fig. 2: Axial T2 weighted haste (Half-fourier Acquisition Single-shot Turbo spin Echo) fat suppression (TR 4.4, TE 64, FL 180°) image of the abdomen. The poor fat suppression is due to the asymmetric anatomy of this body part.

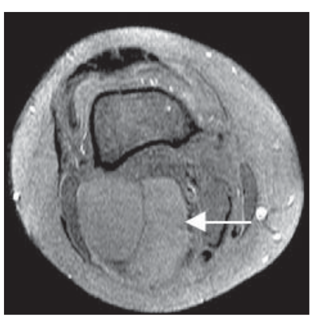

Fig. 3: Axial T1 weighted spin echo fat suppression (TR 500, TE 17, FL 90°) image of the knee, water is suppressed instead of fat due to the difference in resonance frequency (arrow).

Fig. 4: Sagittal T1 weighted spin echo (TR 600, TE 15, FL 90°) image of the knee shows a susceptibility artifact caused by screws anchoring (arrows) the reconstructed anterior cruciate ligament.

Susceptibility Artifacts

Magnetic susceptibility artifacts describe a property of matter: that of becoming magnetized when exposed to a magnetic field. The acquired magnetic moment is proportional to the strength of the applied magnetic field according to a constant susceptibility. The acquired magnetization may be concordant (parallel) or discordant (antiparallel) with the external magnetic field. In the first case, the substance has a positive magnetic susceptibility and augments the resulting magnetic field. Substances with discordant magnetization have a negative magnetic susceptibility and weaken the resulting magnetic field. Substances with a positive magnetic susceptibility are called paramagnetic; those with negative magnetic susceptibility are called diamagnetic and those with a strongly positive magnetic susceptibility are called super paramagnetic or ferromagnetic (11). Air has no significant magnetic susceptibility. Magnetic susceptibility artifacts do not usually cause serious problems in MR image interpretation. The distortion of the magnetic field produces large areas of signal void due to spatial misregistration. At the boundary between two tissues with different magnetic susceptibilities (different local magnetic field) (12), there is local distortion of the magnetic field. Spin dephasing across the slice as well as within the slice results in miscentering of the echo, when severe, this produces signal loss. Geometric distortion is also produced. The geometric distortion can be change the shape of the object, as well as by slight mispositioning of the slice. The variation in susceptibility can occur between voxels, resulting in loss of signal at the boundary between tissues or if susceptibilities vary within the voxel, loss of signal from that voxel. Hemosiderin deposits within intracerebral cavernous hemangiomas behave like a point magnetic dipole, causing intravoxel signal interference patterns that appear as a ring of enhanced signal intensity within the expected signal void around many of the individual lesions on transverse gradient-echo sequences. Knowledge of this

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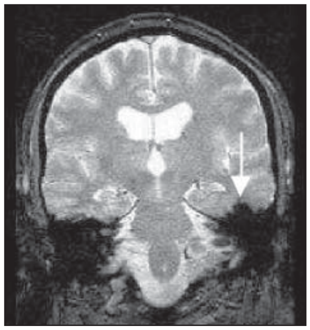

Fig. 5: Coronal T2 weighted gradient echo (TR 800, TE 26, FL 90°) image of the brain demonstrates a artifactual low signal intensity under the temporal lobes, representing a susceptibility artifact (arrow).

Fig. 6: Coronal T1 weighted spin echo (TR 600, TE 12, FL 90°) image of the sella tursica shows a focal high signal intensity "spot" at the junction of sphenoid septum with the floor of the sella (arrow) from magnetic susceptibility effect (21)

Fig. 7: Axial T2 weighted haste (Half-fourier Acquisition Single-shot Turbo spin Echo) fat suppression (TR 4.4, TE 64, FL 180°) image of the liver. The signal dropout (arrow) is due to the presence of fine ferromagnetic particles.

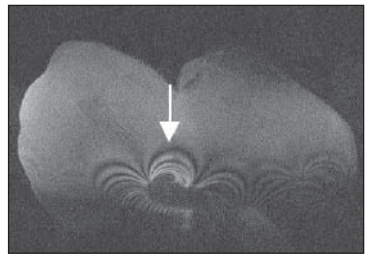

Fig. 8: Coronal T1 weighted 3D gradient echo (TR 12.0, TE 5.0, FL 25°) image of the breast. The zebra stripes are evident in regions of aliasing (arrows). This interface pattern arises from spatially differing phases that have been acquired by the overlapping (aliased) images as a result of spatial nonuniformities in the magnetic field.

artifact should allow radiologists to avoid misinterpreting a single lesion as multiple contiguous lesions. Although a ferromagnetic artifact is the extreme example (Fig.: 4), susceptibility artifacts are commonly seen at the boundary between materials with different magnetic susceptibilities, such as air, bone, brain, nonferrous metal implants and hemorrhage. Although susceptibility artifacts are less extreme than ferromagnetic artifacts, signal loss and geometric distortion are present and may mimic partial volume averaging or calcification. Susceptibility artifacts are most prominent with high-field systems, on images acquired with gradient echo (Fig.: 5) (absence of the 180° refocusing pulse), and on images obtained with a long echo time because there is more time for protons to dephase (13). The susceptibility artifact can be seen above the petrous bones and around the paranasal sinuses (Fig.: 6), as well as around bowel loops on gradient-echo abdominal images. Gradient-echo images obtained at a location remote from the magnetic iso-center also suffer from susceptibility artifacts. On gradient-echo images, bone marrow has lower signal intensity than expected for the TE. This is due to spin dephasing produced by the presence of substances with different susceptibilities (calcium, water and fat) within the same voxel (14). The characteristic appearance of a susceptibility artifact is geometric distortion of a structure shape: that is, round objects are depicted as spear or flower shaped (susceptibility flowering) (15), with alterations in pixel signal intensity caused by the overlapping displaced images. Susceptibility artifacts are larger in GE and EPI sequences which are not compensated for field inhomogeneities. Ferromagnetic metals may cause severe signal loss and image distortion, even if they are not visible on radiographs and CT scans. A common situation is at a site of previous surgery where fine ferromagnetic particles from a drilling bit or flaking off metal from surgical instruments (Fig.: 7) (16). As both bone and metal are of low signal intensity, these metal-induced artifacts may be mistaken for hypertrophic bone formation or spinal stenosis. Distortion of magnetic field due to magnetic susceptibility also reduces the efficacy of fat suppression. Susceptibility artifacts can be reduced by a variety of means. The simplest way is to identify and remove the source of artifact, particularly if it is a piece of clothing containing metal. Where the artifact source is irremovable, the artifact may be minimized by optimal positioning of patients with metallic implants, switching the orientation of the frequency- and phase-encoding gradients, using the smallest voxel size and choosing fast spin-echo sequences. Short TE values allow less time for spin dephasing than long TE values, so susceptibility artifacts are reduced. As the severity of the susceptibility artifact worsens, more phase-encoding steps are needed to correct for the local field inhomogeneity (17). Susceptibility artifacts can by reduced when the metallic screw orientation is placed as closely parallel to the main magnetic field as possible (18). The metal artifact reduction sequence, based on view angle tilting and increased gradient strength, reduces the size and intensity of susceptibility artifacts from magnetic field distortion. Sometimes, special devices may be used during imaging to reduce artifacts: for example, the placement of an attapulgite-suspension-filled pillow to create locally a more homogeneous magnetic field (19). Susceptibility artifacts can also be minimized by the use of thin slices, which reduces dephasing across the slices. For gradient echo images, three-dimensional volume methods are particularly effective for reducing dephasing across the slices (20). If enough phase-encoding steps are acquired along the selection axis, then for some values of the gradient selection the effects of local magnetic field inhomogeneities are compensated. Metal artifacts are larger on conventional spin-echo than fast spin-echo images because the time between the refocusing pulse and the echo is longer: the longer time allows more dephasing and therefore more signal loss (22,23), for the same reason, metal artifacts are larger on images obtained with later echo times.

Zebra Stripe Artifact (Moiré Fringes)

Moiré fringes are evident in regions of aliasing in a gradient echo. This interference pattern arises from spatially differing phase that have been acquired by the overlapping (aliased) images as a result of spatial nonuniformities in the magnetic field (Fig.: 8). These non-uniformities are usually due to improper shimming or environmental factors and can lead to image distortion. Wrap around artifact can produce

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a distinctive zebra-stripe “moiré fringe” artifact on gradient echo images of large body parts. They can be reduced in spin echo and fast spin echo imaging by using 180° refocusing pulses and appropriate shimming coils (auto shimming).

2) Gradient-Related Artifacts

Eddy Currents

Eddy currents are small electric currents that are generated when the gradients are rapidly switching on and off (i.e. the resulting sudden rises and falls in the magnetic field produce electric currents). These currents will result in a distortion in the gradient profile and cause artifacts in the images. Affected images show areas of reduced signal intensity that is most conspicuous at the periphery, where gradient profiles are often less adequate. Ghost artifacts in the phase direction, indistinguishable from motion, can also occur. Eddy currents can be induced in shim coils, gradient coils, magnet windings, cryosat shields or RF resonant structures. They can result in more rapid dephasing of the transverse magnetization, resulting in reduced spin-echo or gradient-echo amplitude (shortening the observed T2 decay). Eddy current problems are much more noticeable in images obtained far from the iso-center in the axial direction, because of generally longer time constants of the axial direction gradient than the sagittal or coronal direction gradients (24). Longer TE values also bring out these effects on reducing the observed T2 decay. Residual magnetic gradients can also shift the temporal position of the spin echo from the standard TE. This phase shift can become manifest in image artifact ghosts identical to motion-induced phase shift artifacts. With short TE values in spin-echo sequences, eddy currents from the dephasing lobe of the readout gradient can interfere with the 180° slice-selection gradient, resulting in an oblique plane of 180° nutation. This results in a major loss of signal from the outer edges of the image along the readout axis, similar to the intentional in-plane saturation obtained with presaturation techniques. Most manufacturers use eddy current compensation circuits in the gradient power supply. This approach does not work for all pulse sequences and all spatial locations within the magnet, because the spatial and temporal characteristics of the eddy currents vary from sequences to sequences. Other approaches include meticulous physical adjustment of the gradient coils during initial installation. The ultimate approach is to eliminate the production of the eddy currents with the use of mirror gradient coils. (25). These coils have been installed on commercial systems and have improved image quality especially in cine-sequences that are used for cardiac imaging and angio MRI.

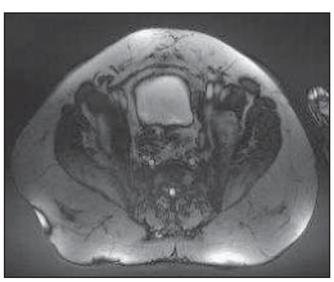

Fig. 9: Axial T2 weighted TrueFisp (TR 4.8, TE 2.3, FL 70°) image of the pelvis demonstrates a ghost-like appearance by an incorrect setting of the receiver gain.

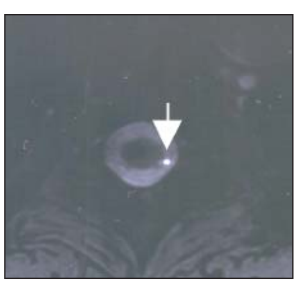

Fig. 10: Gradient Echo 2D of the cervical spine, the hyperintense signal in the center of the image represent a central point artifact (arrow).

Data Clipping

This data-clipping artifact occasionally may encounter an image with a peculiar ghost-like artifact quality, with loss of contrast between soft tissues and background (Fig.: 9). The artifact results from having signal intensity that is outside the digitization range (saturation) of the analog-to-digital converter. The artifact may be encountered on some sections and not others in a multi-slice acquisition. The problem is more severe on surface images, where subcutaneous fat contributes high signal intensity, in obese patients and in techniques that use large numbers of slices or thick slices. Normally, the receiver adjustment is performed using the zero-phase line (i.e. no phase-encoding gradient), because this data line produces the highest signal intensity. However, interaction between the magnetic field of a surface coil and the main field can change the line that produces the maximal signal. As a result, the maximal signal occurs a few lines away from zero rather than at the zero line. If the automatic receiver adjustment results in clipping, the receiver gain can be manually reduced, typically by a few decibels. Operator maladjustment of the receiver attenuation has diminished in frequency with the advent of automatic adjustment procedures on most commercial systems. Several sources of artifacts do not clearly fit into the categories. Asymmetric brightness, described previously as a result of nonuniform slice thickness secondary to slice-selection gradient inhomogeneity, can be due to low-pass filters that are too narrow for the signal band. This leads to inappropriate rejection of a portion of the signal emitted by the protons in the section of interest. The characteristic appearance is a uniform decrease in signal intensity on one side of an image. The problem may be corrected by widening the band pass of the frequency filter.

Central Point Artifact

The central point artifact (Fig.: 10) is a central bright or dark area of signal intensity and occurs generally in the exact center of the image (3). It results from a constant direct current offset in the level of the receiver voltage of each phase-encoding step. If the direct-current level of each phase-encoding step is variable, a line parallel to the phase-encoding axis can result. This artifact can be reduced by phase alternation of two RF excitation pulses at each phase-encoding step, resulting in cancellation of the two averaged extraneous signals.

3) RF Related and Signal Processing

Central Aliasing (Wrap-Around Artifact, Back Folding)

Spatial resolution of an image can be improved by decreasing its field of view. Often the field of view is smaller than the body part being imaged. These situations can lead to wrap-around artifacts, in which image data outside the field of view are wrapped around and represented on the opposite side of the image (Fig.: 11) (pseudolesions). Aliasing artifacts can be evident in any direction in the imaging volume. This artifact disrupts the image but does not pose particular hazard to diagnostic interpretation. The effect is known as an aliasing artifact and arises from the fact that when a signal is sampled at a number of discrete times or at fixed frequency (nyquist frequency), signals with a frequency greater than one-half the nyquist frequency will be indistinguishable from signals with a frequency much less than one-half the nyquist frequency. Thus a frequency

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beyond the edge of an image reappears within the opposite boundary of the image. For example: On television, wagon wheels from an old westerns can appear to rotate slowly backward when in actuality the wagon is moving rapidly forward, a wagon wheel appears to turn the way it does because the movie frames are acquired at less than twice the rotational frequency of the wheel, resulting in aliasing to a lower rate of rotation. Aliasing can occur in the frequency-encoding direction, in the phase-encoding direction and in the case of three-dimensional acquisitions in the slice-direction. In the frequency-encoding direction aliasing can be eliminated by filtering out signals with frequencies that exceed one-half the nyquist frequency using a reduced bandwidth filter. If this is done where the nyquist frequency is exactly matched to the field of view of the image, the reduced bandwidth results in diminished intensity at the edges of the field of view. If instead the nyquist frequency is increased in what is described as oversampling and the data are oversampled in the frequency-encoding direction, an increase results and the signal intensity drop-off beyond the boundaries of the image can be discarded to give a uniform and nonaliased final image. Such anti-aliasing techniques are standard on commercial imagers. Wraparound along the frequency-encoding direction can also be prevented by matching the receiver bandpass filter to the reciprocal of sampling time and by over sampling along the frequency-encoding direction (e.g. acquiring 512 rather than 256 samples). Aliasing in the phase-encoding direction presents a somewhat more difficult problem, since there is no analog to the reduced bandwidth filter that can be used in the phase-encoding direction. If two averages per acquisition are acquired to improve the signal-to-noise ratio, these acquisitions can be interleaved in the phase-encoding direction, resulting in twice the field of view. When this is done, an anatomic image extending beyond the image FOV can be cut off and discarded. This reduction of phase wrapping is accomplished with out penalty in signal-to-noise ratios. Reducing the strength of the phase-encoding gradient reduces wraparound but also reduces spatial resolution. Wraparound along the phase-encoding direction can also be reduced by over sampling along the phase-encoding direction (26,27). Over sampling doubles the phase-encoding steps and doubles the FOV along the phase-encoding direction. This technique is effective but minimal acquisition time is increased. The inner volume method can eliminate wraparound by limiting the RF excitation to a restricted volume of tissue (28). With this method, slice selection is performed sequentially along two intersecting planes to define a limited central volume. However, inner volume imaging is essentially a single slice technique, which reduces its efficiency for 2D Fourier transformation imaging. Presaturation of signals from tissues outside the region of interest is a more practical method and does not have any significant drawbacks other than a slight increase in the minimal TR per slice, typically a few milliseconds (29). Aliasing in the slice-selection direction can occur with three-dimensional volume imaging. In this case, a slab is selectively excited and subsequently partitioned into multiple slices. When excited beyond the boundary of the stack of slices in the three-dimensional volume, signal from tissue outside of this stack of slices will be aliased onto inner slices. Alternatively, saturation pulses can be used to suppress signal intensity from outside the volume of interest. Even so, because exactly sharp cut-off profiles cannot be achieved, it is usually necessary to discard two slices at each end of a volume acquisition (3D acquisitions) to avoid aliasing. Using short repetition times so that there is no time for the saturation pulse to recover can eliminate aliasing along the slice-selection direction.

Chemical Shift Artifact

Clinically, the chemical shift is a complicated, probably the oldest and best-characterized artifact, or more precisely, notorious for its ability to cause spatial misregistration of MR images. Recently, chemical shift has been recognized as a diagnostic aid in the diagnosis of lipid-containing lesions of the brain (lipoma, dermoid and teratoma) or the body (adrenal adenoma, focal fat within the liver and angiomyolipoma) possibly as a result of the growing experience with faster gradient-echo pulse sequences or of the increased clinical use of MR imaging. When pulse sequences are modified to be sensitive to chemical shift effects, MR imaging can be used to confirm the presence of fat within lesions, a finding that can result in a definitive diagnosis. The chemical shift artifact can improve the evaluation of peripheral tumors for possible extra visceral extension or the visualization of visceral contours (liver and kidney) (30). The inherent differences in precessional frequencies between fat and water protons have several implications in clinical imaging. Frequency and phase components of MR signal arising from a tissue are used to encode the sagittal and coronal direction spatial coordinates of two-dimensional section (31). Because the frequency displacement caused by chemical shift cannot be differentiated from intended spatial frequency encoding, misregistration of the resultant signal may occur along the frequency-encoding direction (readout axis). If the MR imager is tuned or centered to the frequency of water, fat will be shifted or spatially mismapped relative to its true spatial location. This mismapping occurs throughout the image, although it is most apparent between regions that are primarily fatty and those that are composed of water or fluid (30). When the chemical shift misregistration is greater than or equal to the size of an individual pixel, a dark or bright band of signal intensity will occur at the lipid-water interface in the frequency-encoding direction of the image. This pixel-by-pixel misregistration along the frequency-encoding direction visibly manifests itself as a bright or dark band running perpendicular to the frequency-encoding direction. Clinically, the chemical shift artifact is most recognized at the margins of predominantly fluid-filled structures that are embedded in fatty regions, such as the bladder (Fig.: 12) and orbits (32).

Fig. 11: Sagittal proton-density-weighted (TR 2400, TE 15, FL 180°) image of the cervical spine demonstrates a hyperintense artifact, pseudo lesion (arrow). The patient's nose was outside the field of view (phase-encoding direction) and is superimposed over the cervical cord.

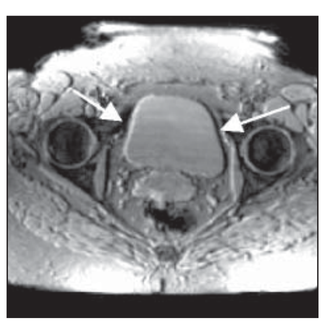

Fig. 12: Axial T1 gradient echo (TR 145.0, TE 4.2, FL 75°) image of the pelvis demonstrates a chemical shift artifact around the bladder. The left border of the bladder has a bright signal intensity (arrow), where as the right border of the bladder has a dark band (arrow). The severe lipid-water interface between the bladder and the pelvic fat produces a strong shift of the protons at the margin of the bladder, which makes it difficult to evaluate the integrity of the bladder wall.

Continued on page 15 ➠

The misregistration of signal along the frequency-encoding direction results from the erroneous mapping of the signal of the fatty elements relative to that of the fluid-filled structures. This misregistration results in the production of dark or bright band at the lipid-water interface. The dark bands result from the shifting of the lipid proton signals to a lower frequency, away from the actual lipid-water interface, which cause a signal void. The bright bands result from the overlapping of water signal with "shifted" lipid signal on the high-frequency side of the interface. The bright bands, although present, may be more difficult to appreciate when the object being imaged has a curved surface (33). There are several ways to minimize the spatial misregistration caused by the chemical shift artifact, including choice of frequency-encoding direction, field of view and receiver bandwidth and the use of fat-suppression techniques. The size (width of dark and bright bands) and location of the chemical shift artifact are influenced by a number of factors. Most important is the selection of the frequency-encoding direction. Choosing the frequency-encoding direction in the plane with the narrowest lipid-water interface can reduce the clinical significance of the chemical shift artifact or by selecting a direction that minimizes the chemical shift effect over the area of primary interest. The imaging field of view is an operator variable that can easily be controlled and has strong influence on the size of the chemical shift artifact seen in an image. The artifact can be minimized by decreasing the field of view (34). Receiver bandwidth is another imaging parameter that may affect the amount of chemical shift artifact seen in routine MR images. The artifact is usually not readily apparent in spin-echo images unless the receiver bandwidth is too narrow (Fig.: 13).

When a narrow bandwidth is used, the strength of the gradients along the frequency-encoding direction is reduced (35). The readout (frequency-encoding direction) window must remain open proportionally longer to preserve the field of view; thus, the apparent shift in resonant frequencies between lipid and water protons becomes more widely separated spatially. The effect of bandwidth on chemical shift is directly proportional to the static magnetic field strength. When using an MR imaging unit with 1.5 T magnetic field strength, the operator must be very careful when narrowing the bandwidth to image anatomic areas with lipid-water interfaces because this action will increase the degree of chemical shift artifact in the resultant images (36). Chemical shift artifact can also reduced by minimizing the signal contribution from lipids with the use of fat-suppression techniques.

Fig. 13: Coronal T1 weighted spin echo (TR 560, TE 14, FL 90°) image obtained at a midline level of the orbit. Crescent moon area of high signal intensity above the muscle refers to a chemical shift artifact (arrows).

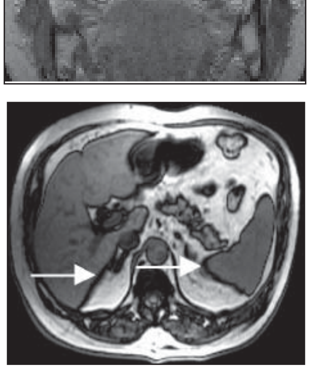

Fig. 14: Axial T1 weighted gradient echo (TR 170, TE 2.3, FL 80°) out-of-phase image of the abdomen, artifactual delineation of the contours of the organs (arrows).

Black Boundary Artifact

Sometimes well-defined black contours following anatomic structures are seen. These artifacts are another class of chemical-shift artifact. These contours are often esthetically pleasing because they have apparent sharp definition between neighboring tissues. They are, however, artifactual because nothing in the object corresponds to these black boundaries. Interpreting the boundaries in terms of anatomic structures is incorrect. In each case, the black boundary lies at the interface between two regions of tissue where real images have opposite sign. On presenting this image in magnitude form, the two regions have positive intensity but a black boundary persists, corresponding to the area of transition in the real image. Black boundaries can occur on gradient-recalled echo images at TE times for which the fat and water images are 180° out of phase. The hydrogen nuclei in lipid have a frequency that is 3.5 ppm less than water protons; the precessional frequency of the hydrogen nuclei in lipids is related to the precessional frequency of water. The chemical shift is approximately 3.5 ppm, corresponding to approximately 147 Hz at 1.0 Tesla. For a pulse sequence with a readout bandwidth of 78 Hz/pixel, there is a shift of 2 pixels. Gradient recalled echo sequences with a TE that is a multiple of 2.25 ms (6,75;11,25;15,75ms and so on) on a 1.5T, fat and water protons will be out of phase and a dark boundary will be seen (Fig.: 14), this result is called the boundary effect, which is the result of chemical shift of the "second kind". This type of imaging is referred to as "out of phase" scanning, referring to the fact at these TEs , fat and water spins will be 180° out of phase. This phenomenon does not just occur along the frequency-encoding axis (like the chemical shift artifact of the first kind) (37). To avoid artifactual contours from chemical shift, TE times of 4.5, 9.0,13.6 and 18.1 ms should be used (also called "inphase" scanning). Alternately, spin echo images avoid this fat and water interference since all frequency shift are refocused at the spin echo. Black boundary artifacts can also appear at shear interfaces. Where two adjacent tissues have a significant motion shear, pixels along the boundary will show intervoxel dephasing and an artfactual boundary on the magnitude-reconstructed image. Shear boundary can be eliminated using gradient moment nulling techniques to desensitize the motion.

Boundary effect does not occur in conventional spin echo techniques because of the presence of the 180° refocusing pulse, which is absent in gradient-echo techniques. As shown in Fig. 15 not all black boundaries are artifacts. The dark contouring around the lesion looks similar to the boundaries described, but it is in fact an evidence of a pathologic condition. Hemosiderin salted out along the lesion, resulting in considerably reduced T2 and hence signal loss. In this case, the boundary is real and not an artifact.

Fig. 15: Axial T2 weighted gradient echo image of the brain. Dark contours along the lesion look initially like black boundary artifact (arrow). However, in this case, they are due to hemosiderin deposition from blood, which has significantly shortened T2 relaxation time along the brain.

Continued on page 16

Truncation Artifact (Ringing Artifact, Gibbs Phenomena)

The presence of truncation artifacts is well known in MR imaging and occurs at high-contrast interfaces (e.g. skull/ brain, cord/CFS, meniscus/fluid in knee) and causes alternating bright and dark bands. A common manifestation of this artifact occurs frequently in images of the brain and is caused by the thin band of fat in the scalp or the high contrast between the calvarium and the brain (Fig.: 16). This manifestation is easy to recognize because the structures from which the artifact emanate (the subcutaneous fat or edge of the brain) are of different shapes than those of the structures of the brain on which they are imposed. However, other manifestations, such as the artifactual intensity modulations may stimulate a syrinx (Fig.: 17) in the spinal cord (38), spinal cord atrophy (39), disc abnormality (40) and a tear in the knee meniscus (41). Recently, truncation artifacts have been identified to produce a false laminar appearance and apparent alternation of width in cartilage imaging (42). Digital pictures are only approximations of analog pictures because they contain a finite number of pixels each with a finite number of brightness levels. The difference between the original image and the reconstructed image is the truncation error (43). This artifact arises primarily: because of data interpolation (zero filling), when a smaller acquisition matrix (128x256) is interpolated into a larger display matrix and near edges where there are abrupt transitions in signal intensity along relatively linear portions of tissue interfaces. Truncation artifacts occur in both directions (frequency- and phase encoding) and are always present to some degree in MR images. On images obtained with short TR and TE, a ring of high signal intensity at the periphery of the cervical spinal cord can be found because of truncation artifact.

Truncation artifacts are clinically most likely to be present along the phase-encoding direction, because throughput and economic pressures often constrain imaging time to the least number of phase-encoding steps possible (e.g. 128), this is known as the phase matrix. It must by emphasized that with greater sampling of the higher frequencies in K-space (256), the spacing of the gibbs lines is cut in half but the amplitude is not diminished (2). Decreasing the field of view can also reduce truncation artifact. The Gibbs phenomenon is often used as a synonym for truncation error but the Gibbs phenomenon refers only to the lack of convergence of the Fourier integral at a point of discontinuity of a function. The image reconstructed with Fourier transform overshoots or undershoots, the original function at a point of discontinuity by a certain amount. The Gibbs phenomenon describes the ringing artifacts that occur in proximity to the discontinuity. These artifacts cannot be eliminated even if an infinite number of spectral components are used. (44). The periodicity of the ringing is proportional to the size of the matrix or the number of spectral components. The use of a larger matrix makes the ringing less visible but does not eliminate it. Only removing the discontinuity of the function, that is, by smoothing or lowpass filtering the image, can eliminate the Gibbs phenomenon. Numerous data extrapolation algorithms have been proposed to estimate the truncation errors (45). These techniques are laborious and have limited success when the signal to noise is low or in complex images (46).

Fig. 16: Axial T1 weighted spin echo (TR 600, TE 15, Fl 90°, Ma 144x256) image of the brain. The fine lines visible are due to undersampling of the high spatial frequencies (arrows). Sharp edged borders between areas of high contrast are represented by high spatial frequency data.

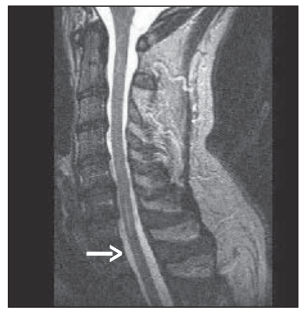

Fig. 17: Sagittal T2 weighted fast spin echo (TR 4500,TE 128, FL 90 °, Ma 128x256) image of the cervical spine shows a band of increased signal intensity (arrow) within the spinal cord. This mimics a syrinx and is due to the truncation error.

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2006 Annual Meeting Update

Todd Frederick, R.T.,(R)(MR),
Program Committee Chair

The SMRT Program Committee is busy planning for the 2006 Annual Meeting in Seattle, Washington. We are striving for a mix of clinical and research topics with lots of information, motivation, and fun!

Be sure to check the SMRT Website for up-to-date program information and for the "Call for Papers." Posters and proffered papers are an important part of the Annual Meeting. They allow Technologists/Radiographers to communicate research and clinical findings, and show off all the hard work they have been doing. The Poster Exhibit and Walking Tour Reception will be on Friday evening 5 May 2006. The work that Technologists/Radiographers put in to the proffered papers and abstracts is amazing. Please plan to arrive on Friday and take part in this important activity.

The SMRT Annual Business meeting will take place during lunch on Saturday, 6 May. At this meeting you will be able to learn about the work that the Section has been doing throughout the year. The Annual Meeting is just one of many things the Section is doing on your behalf, and the business meeting is one way you can learn more about these activities and take part in valuable discussions regarding your profession. New officers are also introduced and installed at this meeting.

The educational program will be held on Saturday and Sunday. The 2005 program resulted in a great mix of topics and speakers. The 2006 Program Committee is reviewing valuable feedback from the very successful 2005 meeting in Miami so that we can provide another quality meeting to the membership.

Registration for the SMRT Annual Meeting also includes an invitation to the ISMRM/SMRT forum on Monday afternoon, 8 May. This forum is a collaboration between both organizations, and brings together information from Technologists, Scientists, and Physicians. Please plan on staying through Monday to participate in this forum.

Start planning now to attend. We hope to see you in Seattle in May, 2006!

Dear SMRT Members and List Serve Subscribers,

Many technologists and other MR professionals have inquired how best to help our healthcare community colleagues affected by Hurricane Katrina and the resulting aftermath, by posting messages via the Technologist List Serve.

In response to these inquiries, the SMRT has set up a message/jobs board, via the SMRT Homepage **www.ismrm.org/smrt/** for those wishing to help their colleagues find employment, housing, etc.

Policy board member, Vera Miller, has volunteered to tackle the task of approving postings on the new message/jobs board. Please contact Vera directly at **bvdmiller@comcast.net.**

Those wishing to make a financial donation, please visit **www.charitywatch.org/hottopics/hurricane_katrina.html.**

Sincerely,

The SMRT Executive and Policy Board

ISMRM/SMRT CALENDAR

ISMRM Workshop on Real-Time MRI: Dynamic Interactive Imaging and Its Applications
23-24 February 2006
Santa Monica, California, USA

SMRT President's Regional Seminar
18 March 2006
University of Virginia, Charlottesville, Virginia, USA

SMRT 15th Annual Meeting
5-7 May 2006
Seattle, Washington, USA

ISMRM 14th Scientific Meeting and Exhibition
6-12 May 2006
Seattle, Washington, USA

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... is published by the International Society for Magnetic Resonance in Medicine, 2118 Milvia Street, Suite 201, Berkeley, CA 94704, USA

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Monday, November 28, 2005

RC941 8:30 AM – 10:00 AM
Capital Asset Management: From Acquisition to Replacement Strategies
Susan K. Vannoni, MS, RT(R)(T), *Moderator*
Ed Mercado, MBA
Sheila M. Sferrella, MAS, RT(R)

RC942 10:30 AM – 12:00 PM
Development of the Radiologist Assistant: An Education and Certification Update
Paula Maramonte, MEd, RT(R), *Moderator*
Salvatore Martino, MEd, EdD
Jerry B. Reid, PhD

RC943 1:30 PM – 3:00 PM
HIPAA: Ongoing Impacts and Re-inventions in Radiology
Kathryn J. Canny, *Moderator*
Patricia Kroken, FACMPE, CRA
Claudia Murray

RC944 3:30 PM – 5:00 PM
Joint Commission on Accreditation of Healthcare Organizations National Patient Safety Goals
Jordan B. Renner, MD, *Moderator*
JoAnn Belanger, RN

Tuesday, November 29, 2005

RC945 8:30 AM – 10:00 AM
PET/CT and SPECT/CT Fusion Imaging: Technical and Clinical Highlights
Barbara A. Whitefield, RT(R)(CV), *Moderator*
Steve Bujenovic, MD

RC946 10:30 AM – 12:00 PM
The Art and Science of Radiology Planning and Design
Morris A. Stein, FAIA, FACHA, *Coordinator*
Bill Rostenberg, FAIA, FACHA
Steven C. Horii, MD

RC947 1:30 PM – 3:00 PM
Digital Radiography: A Comparison of Cassetteless and Cassette-based Systems
Elaine Dever, *Moderator*
Charles B. Burns, MS, RT(R)
Kerry T. Krugh, PhD

RC948 3:30 PM – 5:00 PM
Controversies in Image-based Screening
Karen J. Finnegan, MS, RT(R)(CV), *Moderator*
Reuben S. Mezrich, MD, PhD
Charles S. White, MD
David J. Vining, MD

AAPM/RSNA BASIC PHYSICS LECTURE FOR THE RADIOLOGIC TECHNOLOGIST:

PET/CT

Monday, 1:30 PM – 2:45 PM
Anne C. Chapman; Beth A. Harkness, MS; Lei Xing, PhD

ASSOCIATED SCIENCES SYMPOSIUM

(Approved for 3 category 1 credits)

Wednesday, 8:30 AM – 12:00 PM

Radiology's Leaders: Challenges of the Future

Bobbi Miller, BA, RT(R)(M), CRA, FAHRA, *Moderator*; Judy LeRose, BS, RT(R), CRA, *Moderator*

8:30 AM – 9:30 AM
Tomorrow's Leader: The Radiology Business of the Future
Patricia Kroken, FACMPE, CRA

9:40 AM – 10:40 AM
Radiology in the Clinical Setting: The Final Frontier
Suzanne K. Ramthun, MBA, RT(R)
Carrie E. Abendroth, MBA, MHA

10:50 AM – 11:50 AM
Education: The Amazing Race
Carole South-Winter, MEd, CNMT, RT(R)

11:50 AM – 12:00 PM
Questions

Registration Information for the RSNA Annual Meeting

Sunday, November 27 – Friday, December 2, 2005.

Advance registration for the RSNA annual meeting ends November 11, 2005. Onsite registration begins at 12:00 PM on Saturday, November 26, at McCormick Place. RSNA shuttle bus service to McCormick Place will be available beginning at 11:00 AM on Saturday. Registration is required to attend the Associated Sciences programs.

Onsite registration fees are $100.00 higher than advance registration fees.

Advance registration and housing information can be found at *RSNA.org*.

If you would like a copy of the published Associated Sciences Proceedings, please call (630) 571-7874.

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- American Healthcare Radiology Administrators (AHRA)
- American Institute of Architects – Academy on Architecture for Health (AIA-AAH)
- American Radiological Nurses Association (ARNA)
- American Society of Radiologic Technologists (ASRT)
- Association of Educators in Radiological Sciences, Inc. (AERS)
- Association of Vascular and Interventional Radiographers (AVIR)
- Canadian Association of Medical Radiation Technologists (CAMRT)
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- Section for Magnetic Resonance Technologists (SMRT-ISMRM)
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