GE Healthcare

MR Field Notes

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Contents

Artifacts have vexed technologists and physicians ever since diagnostic imaging became vital to medical practice.

In this issue of Field Notes we examine two new pulse sequences, PROPELLER and LAVA, designed to minimize this chronic problem in head and body imaging. Both these PSDs are available on the HD upgrade for GE Healthcare MRI systems.

We hope you find this publication interesting and informative. In future issues, we'll continue to present PSDs, software and hardware on the leading edge of clinical MR imaging applications. We want to help you get the most out of your GE Healthcare MR imaging equipment.

If you have comments you'd like to share, or if you have a particular area you would like to read about in Field Notes, please e-mail us at Mary.Zimmermann@med.ge.com.

Motion Artifact:

a new spin on an old problem

Motion artifacts in brain scans are caused by a variety of factors. They can result from "sightseeing" (a patient taking a random look around at the inside of the coil during a scan), gross motion from uncooperative patients, or subtle physiologic motion. But whatever the cause, motion artifacts in brain scanning are a chronic problem. Here are some statistics:

- Approximately 4 in every 10 brain exams show some type of motion artifact. Approximately 1 in 10 have to be rescanned.
- One in 6 pediatric patients don't respond adequately to sedation. One in 14 don't respond at all.

Short of administering some sort of sedative, it seems that motion artifact in head imaging is unavoidable.

GE Healthcare's introduction of PROPELLER (**P**eriodically **R**otated **O**verlapping Parall**EL** lines with **E**nhanced **R**econstruction) has significantly reduced the effects of motion artifact in routine T2 and T2 FLAIR scanning of the brain. And while it does not reduce motion artifacts, PROPELLER DWI significantly improves image quality in the vicinity of bone/tissue or air/tissue interfaces, or around tissue/metal interfaces prone to creating susceptibility artifacts.

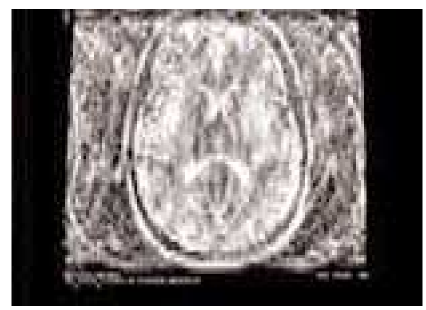

Fig. 1 - Have you ever seen one of these? Not a pretty picture, is it? Motion artifacts can set your scanning schedule back significantly. This is an FSE image of a volunteer engaged in "sightseeing."

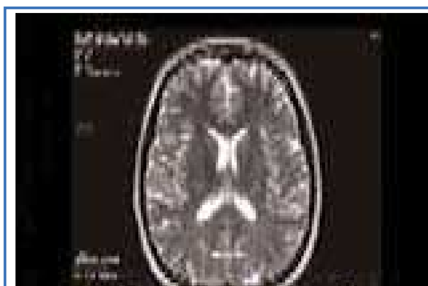

Fig. 2 - Image obtained from a "sightseeing" subject using the PROPELLER T2 PSD.

An example of PROPELLER's ability to reduce motion artifact in T2 and T2 FLAIR imaging is seen in Figs. 1 and 2. The FSE image in Fig. 1 above was obtained from a volunteer who was

 (continued from page 1)

encouraged to take an active sightseeing tour of the head coil's interior surface. Clearly, it's diagnostically useless.

Fig. 2, obtained from the same volunteer, was acquired using the PROPELLER T2 PSD, also with sightseeing activity. The image in Fig. 3 was acquired using the PROPELLER T2 PSD with minimal subject movement.

Fig. 3 - PROPELLER T2 image acquired from subject with minimal movement.

These images demonstrate that PROPELLER can make a substantial difference in scanning situations where patient motion cannot be adequately controlled.

When you use PROPELLER in T2 and T2 FLAIR imaging, you'll see a reduction in both gross- and subtle-motion artifacts. With PROPELLER DWI, you'll see less artifact from dental work and other metal, and you'll see less posterior fossa susceptibility. PROPELLER also enhances CNR, contrast interfaces, and lesion conspicuity. Not bad for a sequence that's probably on your system right now.

How PROPELLER works

First, a brief refresher on k-space.

K-space is an array of numbers whose Fourier Transform is the MR image. The values that are plugged into the k-space array come from measuring the value of each MR signal at different times. As shown in Fig. 4, rows near the center of the k-space grid correspond to low-order phase-encode steps. Rows near the top and bottom correspond to higher-order encodings.

Echo amplitudes are larger at the low-order phase-encode since there is less dephasing induced by gradients, therefore the signal values are greater near the center of the grid.

In a typical FSE acquisition, for example, multiple phase-encoded lines are collected per TR period for a "shot" (based on the ETL). The process is repeated until all lines of k-space are filled. Note that in this acquisition, only one shot is acquired in the center of k-space.

PROPELLER fills k-space in a unique way. Rather than going at it line by line (Fig. 4), it fills k-space with an arrangement of "blades" (Figs. 5, 6, 7). These blades are rotated in k-space at incremental angles. This method results in an over-sampling of the center of k-space, providing a more signal-rich image.

The blades' radial trajectory removes structured motion artifact, and redundant sampling enables the reduction of bulk patient motion artifacts.

The images in Fig. 6 illustrate how the PROPELLER PSD fills k-space and the resulting over-sampling of the center. Fig. 7 shows the difference that removal of bulk artifact from an image can make.

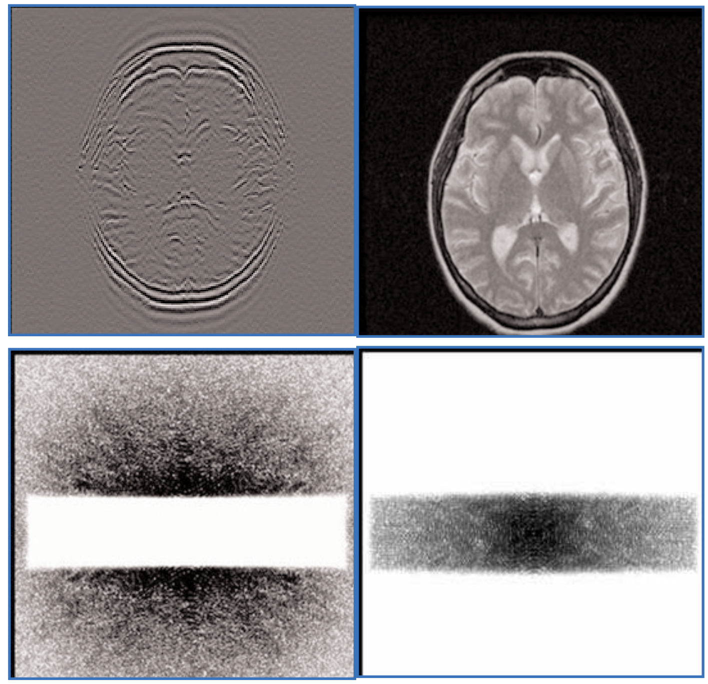

Fig. 4 - Representation of how k-space is filled in a typical FSE acquisition technique. Top and bottom left images show high-order encodings. Top and bottom right images show low-order encodings. Notice that the center, low-order encoding portion of k-space shows only a single "shot" of raw data.

PROPELLER, thanks to its unique acquisition technique, gathers more raw data at the center of k-space.

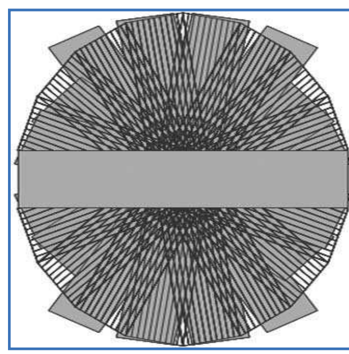

Fig. 5 - Rather than provide only a single "shot" through the center of k-space, as in a typical FSE acquisition, PROPELLER's "rotating blade" technique essentially over-samples k-space center, providing a signal-rich image. This redundant sampling allows, among other things, the removal of bulk patient motion artifacts.

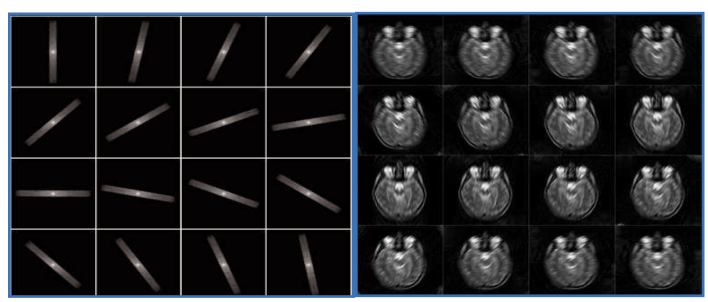

Fig. 6 - Left: As raw data is collected, it's checked for inconsistencies. Data is summed to create corrected k-space. Right: Data is transformed to image space and coil combinations are performed.

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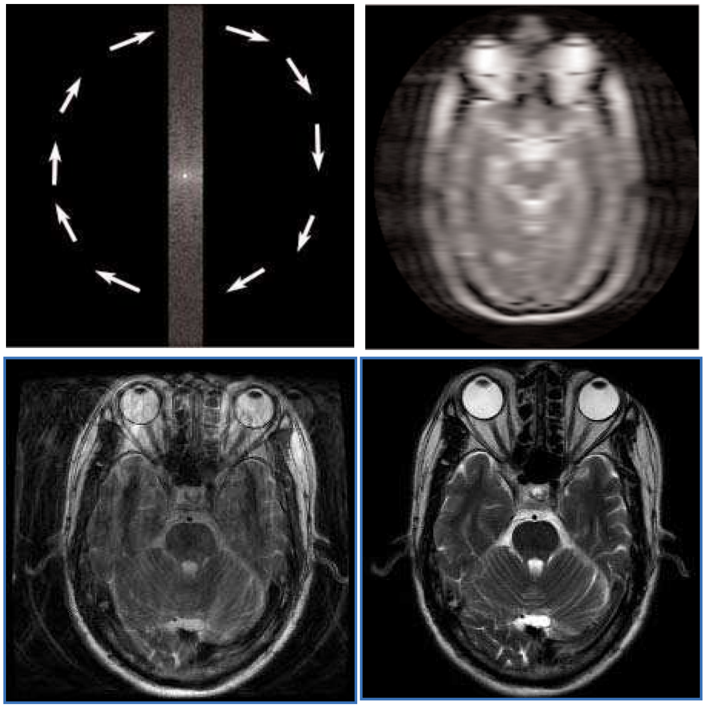

Fig. 7 - PROPELLER acquires radial blades of data (upper left). Radial trajectory removes structured motion artifact (upper right). Redundant data sampling permits reduction of bulk patient motion artifacts (seen in lower left image). Resulting PROPELLER FSE readout (lower right) shows virtually no bulk motion artifact.

DWI imaging with PROPELLER

When you call up the PROPELLER sequence for diffusion, you're presented with a customized interface for the application on which only the factors pertinent to PROPELLER scanning appear (Fig. 8). For a step-by-step guide on how to initiate PROPELLER PSDs, see PROPELLER Quick Steps at the end of this article.

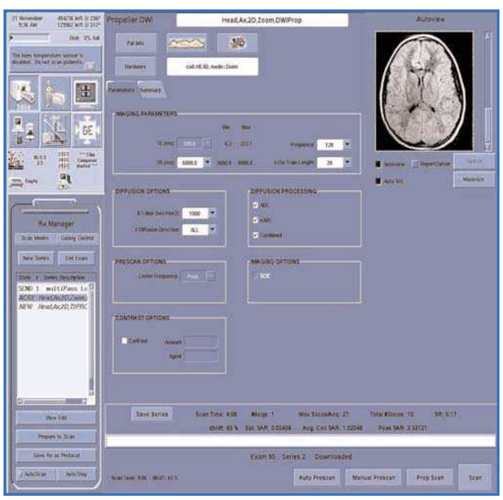

Fig. 8 - PROPELLER DWI interface window.

PROPELLER DWI addresses a major cause of artifacts in brain imaging: susceptibility. This versatile sequence improves image quality in the vicinity of bone/tissue or air/tissue interfaces, or around tissue/metal interfaces prone to creating susceptibility artifacts (Figs. 9, 10, 11, 12). PROPELLER DWI's capacity to suppress susceptibility artifacts is particularly helpful in stroke evaluation, giving your team more diagnostic confidence in the images you produce (Fig. 13).

Since there's a considerable amount of data to process PROPELLER uses intensive multi-channel image reconstruction and processing techniques, since it uses five times more processing steps than a conventional DWI acquisition.

After the initial signal is obtained, PROPELLER executes FSE phase correction and you get images virtually free of the susceptibility artifacts typically seen in images of patients with significant amounts of dental or other metals close to the region of interest.

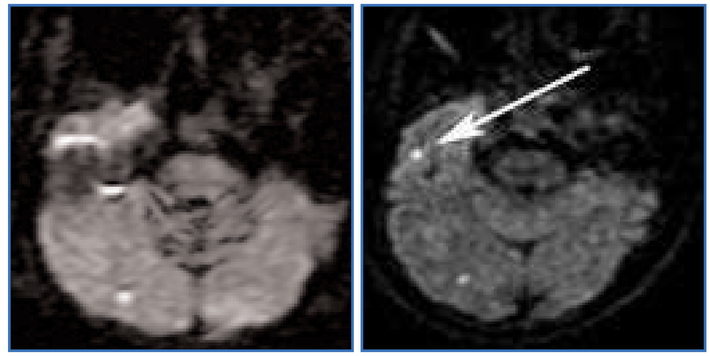

Fig. 9 - Elimination of susceptibility artifact (visible in left image) from base of skull enhances the conspicuity of a second small stroke lesion (right image, arrow).

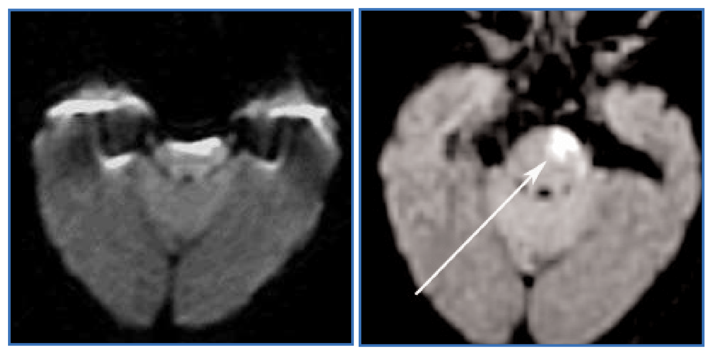

Fig. 10 - With the elimination of susceptibility artifact from the skull base (left), a brain stem infarct is clearly demonstrated (right, arrow). Without PROPELLER DWI, the infarct could not be differentiated from the artifact.

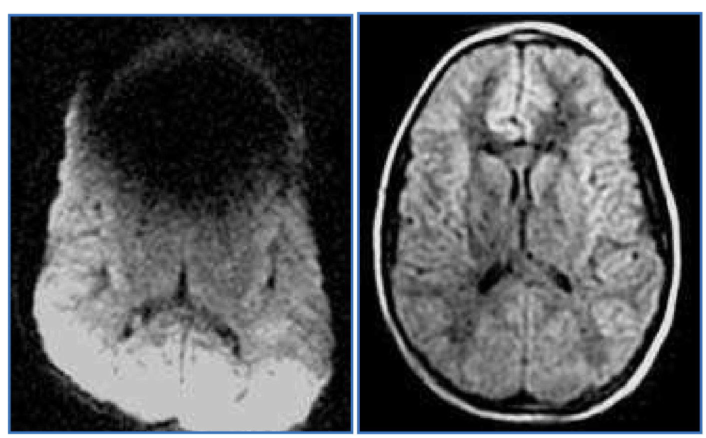

Fig. 11 - The left image shows a gross susceptibility artifact caused by metal dental work. Image on the right shows PROPELLER DWI image of the same patient.

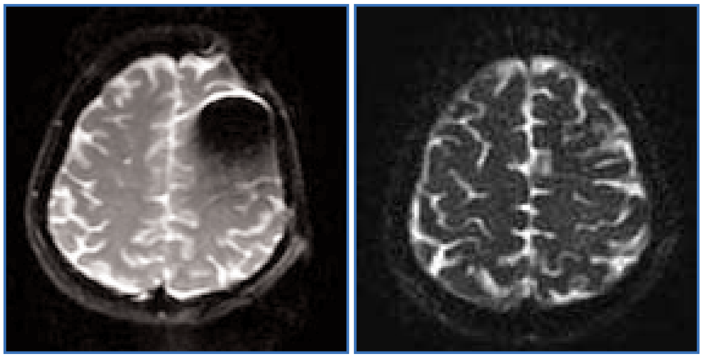

Fig. 12 - PROPELLER DWI readout is virtually impervious to susceptibility. Image on the left shows artifact associated with intervention. The PROPELLER DWI 3T image at right eliminates the artifact.

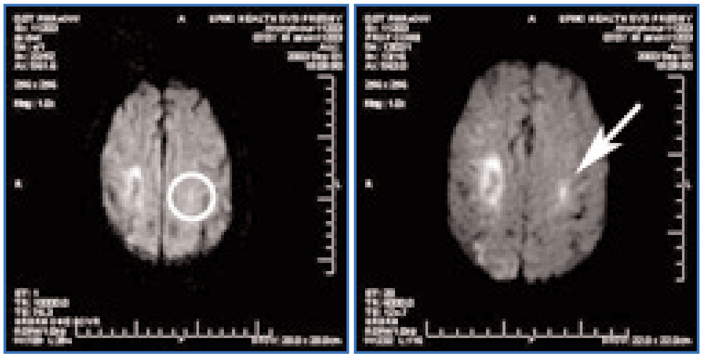

Fig. 13 - Existence of a possible lesion (left image, circle) is ambiguous. With PROPELLER DWI, the lesion is clearly demonstrated (right image, arrow), eliminating any doubt.

PROPELLER T2 Imaging

As with DWI PROPELLER imaging, PROPELLER T2 calls up a customized screen where only the factors pertinent to PROPELLER T2 appear. Select TR and echo train and center frequency. Tailored RF is defaulted. PROPELLER T2's radial acquisition technique enhances CNR, significantly improving contrast interfaces and lesion conspicuity. With HDMR, Tailored RF eliminates signal variation in early echoes and reduces SAR and echo spacing, providing more slices with less blurring and shorter scan time. Figs. 14 - 17 illustrate the advantages of PROPELLER T2 imaging.

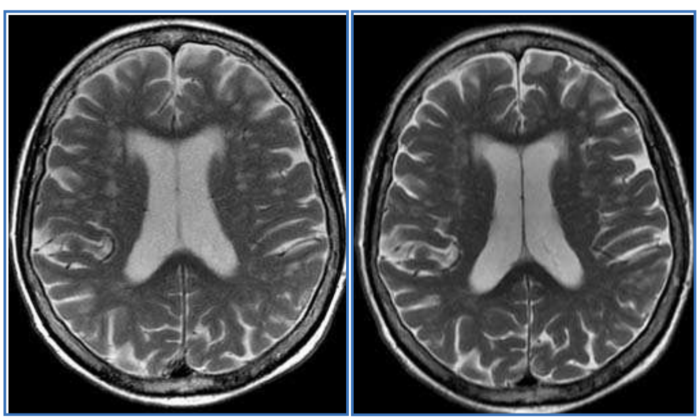

Fig. 14 - Notice how much sharper the gray/white matter interface is in the PROPELLER T2 image (right) as compared with FSE T2. The same is true for the brain/CSF interface. The margins between areas of old small vessel ischemia and white matter are also sharper.

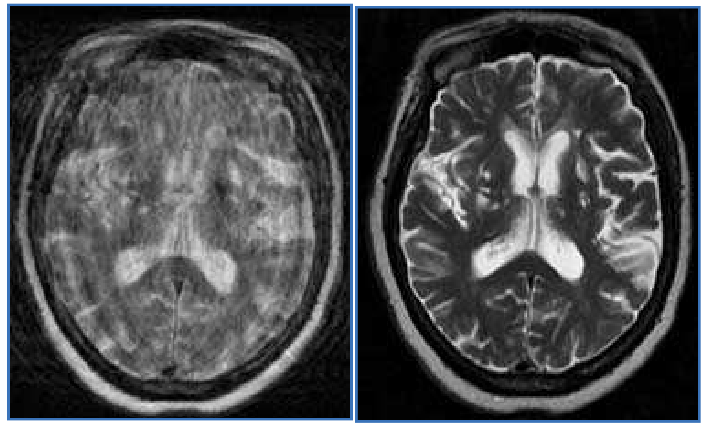

Fig. 15 - PROPELLER T2 reduces both in-plane and through-plane motion artifacts in T2 imaging. Over sampling of k-space center makes possible motion reduction algorithms, turning a compromised series into a diagnostically useful one.

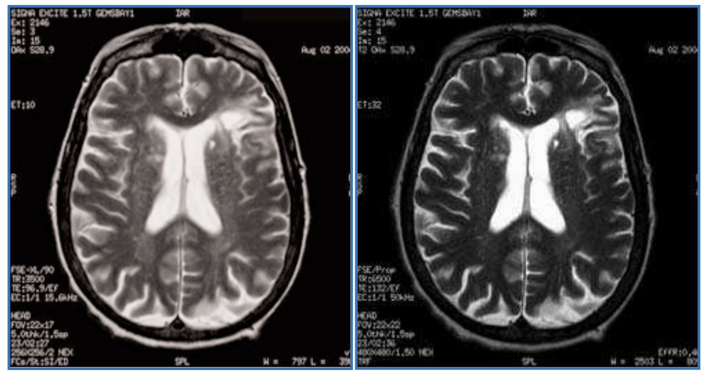

Fig. 16 - PROPELLER T2 produces higher resolution in equal or less scan time than conventional T2 imaging. Compare white matter detail in these two images for both conspicuity and edge sharpness.

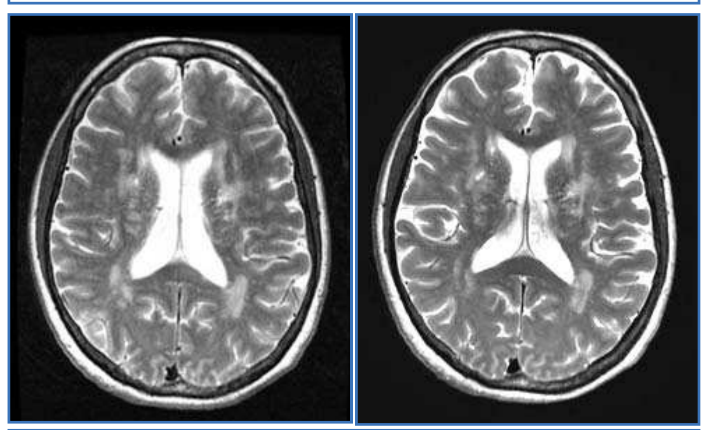

Fig. 17 - Routine 3.0T imaging. PROPELLER T2 reduces subtle motion artifacts such as pulsating CSF. Note the ghosting artifact in the FSE image (left) that has been eliminated in the PROPELLER T2 image (right).

PROPELLER T2 FLAIR imaging

PROPELLER T2 FLAIR imaging provides robust T2W imaging with CSF suppression. When CSF is suppressed, you get better visualization of gray and white matter.

A special window appears when you choose PROPELLER T2 FLAIR. Minimum TR of 8000, TI is automatically calculated based on TR/4. Figs. 18 - 21 provide examples of the difference PROPELLER makes in FLAIR imaging.

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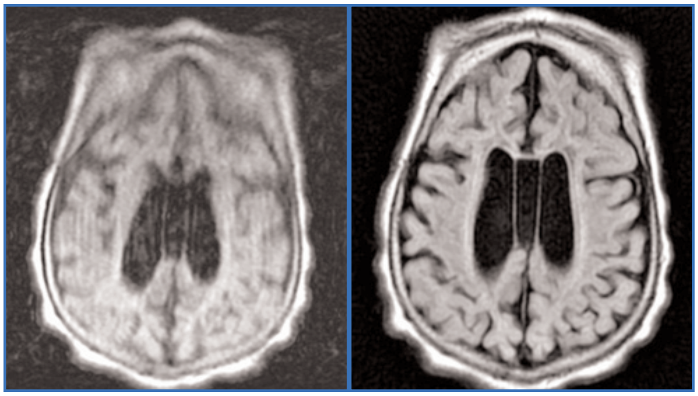


Fig. 18 -In this image pair, a pediatric patient moved during the acquisition. Note the gross motion artifact on the FSE FLAIR image (left). Motion is eliminated on the PROPELLER FLAIR image (right).

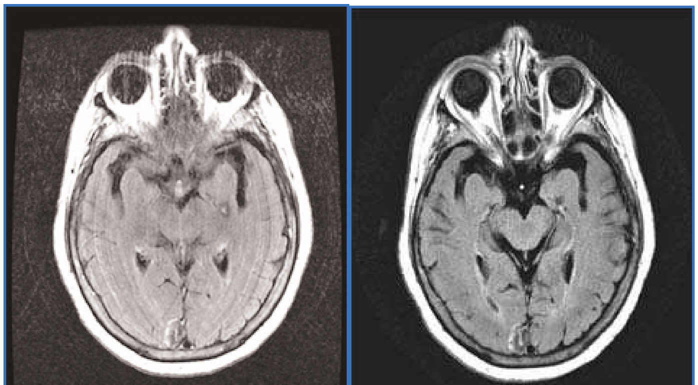


Fig. 19 - FSE FLAIR image on left demonstrates gross patient motion, eliminated in PROPELLER image on the right.

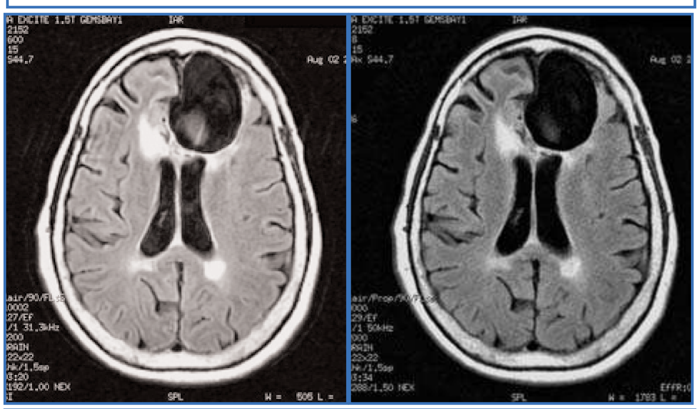


Fig. 20 -Subtle physiological movement caused motion artifact in the FSE FLAIR image (left). Artifact is eliminated in the PROPELLER image (right) done in approximately the same scan time

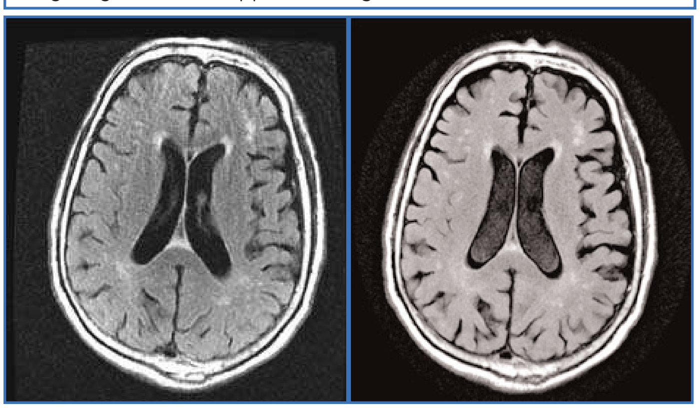


Fig. 21 - White matter lesions are enhanced in PROPELLER image (right). Subtle ghosting motion artifact is eliminated. Ω

PROPELLER FAQs

Q: When and where should I use PROPELLER?

A: Anytime, for any scan where you'd use T2 or T2 FLAIR. In fact, by using PROPELLER T2 or T2 FLAIR instead of conventional FSE sequences, you'll not only reduce motion artifact in patients where that's an issue, e.g. pediatric patients, uncooperative patients, you'll also improve the SNR and CNR.

While PROPELLER DWI does not reduce motion artifact, it significantly minimizes distortions and SNR loss found with standard EPI acquisitions in high susceptibility areas such as the base of the skull, around metal dental work, at tissue boundaries, etc. Use it whenever you suspect that such factors may compromise the diagnostic quality of your images.

Q: Why is scan time for PROPELLER DWI so long?

A: PROPELLER DWI gathers four times as much data as a conventional EPI acquisition. As you would expect, all this takes a little more time to process.

Q: Some of our PROPELLER brain images have peculiar hatch marks in them (see example). What causes these and how can they be avoided?

A: Those are wrap-around artifacts. Aliased anatomy, or wrap-around artifact, appears differently in a PROPELLER image than in other images. The hatch markings on the posterior fossa in this image are the result of nose wrap-around. To avoid this artifact, prescribe a field of view larger than the anatomy to be scanned.

Q: Can I use PROPELLER all the time?

A: Yes. Use PROPELLER T2 and T2 FLAIR instead of conventional FSE sequences. You'll find that doing so will save you a lot of time and effort spent in repairing or rescanning FSE exams of borderline diagnostic value. Use PROPELLER DWI when you suspect that metal in the patient may produce susceptibility artifacts.

Q: After performing a PROPELLER exam I can't begin another series. Why?

A: All PROPELLER images must be reconstructed before the next scan can be initiated, but this takes only a few seconds. Ω

MR Excite HD Quick Steps
PROPELLER

TiP Training Choices

Step 1: Select the PROPELLER T2, DWI or FLAIR Protocol

- Protocol listed under Head.

Step 2: Prepare and Position the Patient

- Patient entry is supine/head first.
- Choose a compatible head coil.
- Landmark to center of anatomy.
- Advance patient into the scanner.

Step 3: Acquire Localizer Images

- Select a 3-plane localizer series from the GE protocol library.
- **[Save], [Download], [Scan].**

Step 4: Prescribe PROPELLER series

- Select the PROPELLER series from the Prescription Manager (choose either T2, DWI or Flair).
- Graphically define the slice locations (only axial or axial oblique less than 45 degrees are compatible).
- Accept Graphic Rx.
- **[Save], [Download], [Scan].**

FYI — Reconstruction of all PROPELLER images must be completed before the next scan begins, but this takes only a few seconds.

FYI — Selecting PROPELLER opens a unique Scan desktop. The Scan desktop displays only parameters available with the PSD.

It may a few seconds for the Scan desktop to appear the first time PROPELLER is launched. After clicking **[Download]** from the Rx Manager, a progress bar displays at the bottom of the Scan desktop. The progress bar indicates the time it takes to download the application to be scanned. The download progress bar appears every time you switch between PROPELLER and any other PSD.

PROPELLER cannot be the first series in an exam.

GE Healthcare TiP Applications
05-2005 DC/SH Rev 1

Fuzzy Livers? LAVA's the cure.

Statistics prove that out of every ten abdominal MR exams, one is rendered inconclusive either by motion artifact or inadequate resolution. That's why we devised LAVA.

The formal name for this 3D FastSPGR+Fat Suppression acquisition technique is **L**iver **A**cquisition **V**olume **A**cceleration. Luckily, that converts nicely into the acronym LAVA. Part of the EXCITE HD release, LAVA provides multi-phase abdominal imaging with enhanced fat suppression. LAVA gives you a trio of "25%" advantages:

- It's 25% faster than conventional acquisition techniques, meaning shorter breathholds for your patients.
- It has 25% higher spatial resolution for enhanced image quality.
- It provides 25% more anatomical coverage.

Figs. 1a and 1b illustrate the difference LAVA makes in axial and coronal views of the liver.

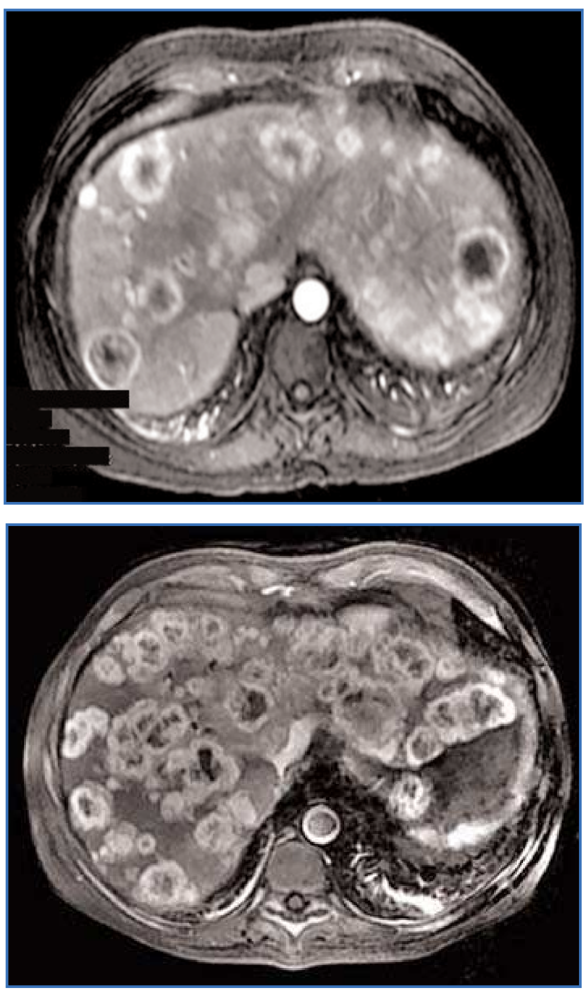


Fig. 1a - Top image is a standard MR axial image of the liver with 1.5mm resolution acquired in a 23sec breathhold. Bottom image is a LAVA image with 1.2mm resolution acquired in a 17sec breath-hold.

Fig. 1b - Top image is a standard MR coronal liver image with 1.5mm resolution acquired in a 23sec breathhold. Bottom image is a LAVA image with 1.2mm resolution acquired in a 17sec breath-hold.

LAVA provides better 3D T1 imaging

Because LAVA enables liver imaging in patients who have trouble holding their breath, it is radically changing the way abdominal MR imaging is performed.

With LAVA comes a new fat suppression technique called segmented SPECIAL, which calculates the optimum "on the fly" TI based on the number of slices and resolution.

LAVA enhances ASSET performance by a factor of 2.5 on 1.5T systems and 3.0 on 3.0T systems. With LAVA, RF pulses are optimized for shorter TR/TE, and the datasets can be used for enhanced multi-planar reformatting as well.

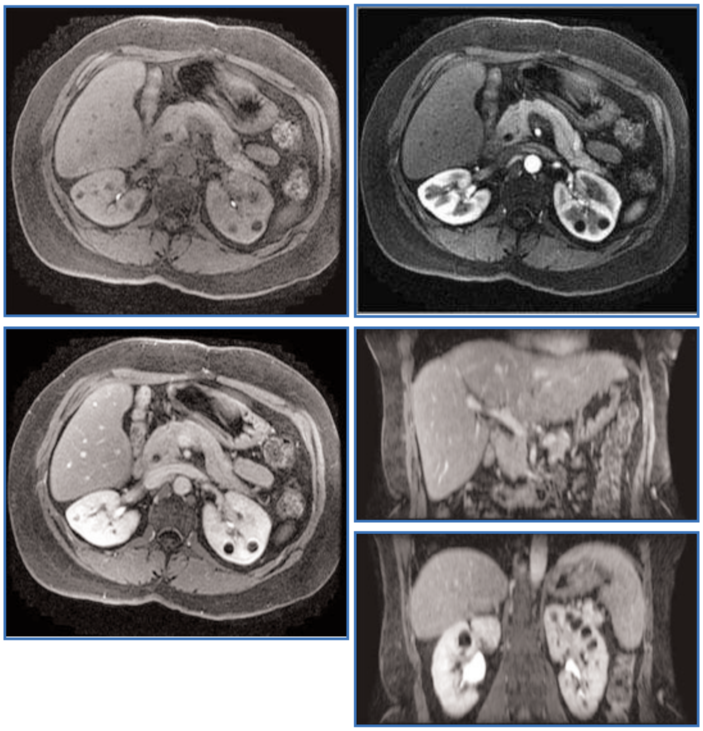
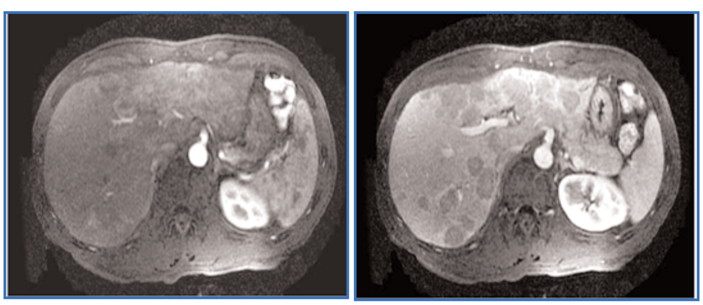


Fig. 2 - This multi-phase LAVA study was done at 1.5T. The acquired axial images and coronal reformatted images demonstrate non-enhancing renal cysts. Note the superior fat suppression.

Among the many advantages LAVA presents in imaging of the liver and adjacent structures is the ability to capture early arterial and early venous phases and late venous phases with high resolution and full organ coverage.

Figs. 3 - 4 illustrate the ability of LAVA to clearly demonstrate the liver and the vessels that supply it.



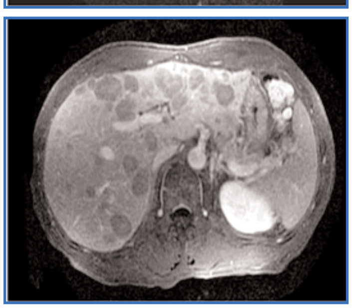


Fig. 3 - Three-phase LAVA scan demonstrating early arterial (upper left), early venous (upper right) and late venous (left) phases with full coverage of the liver.

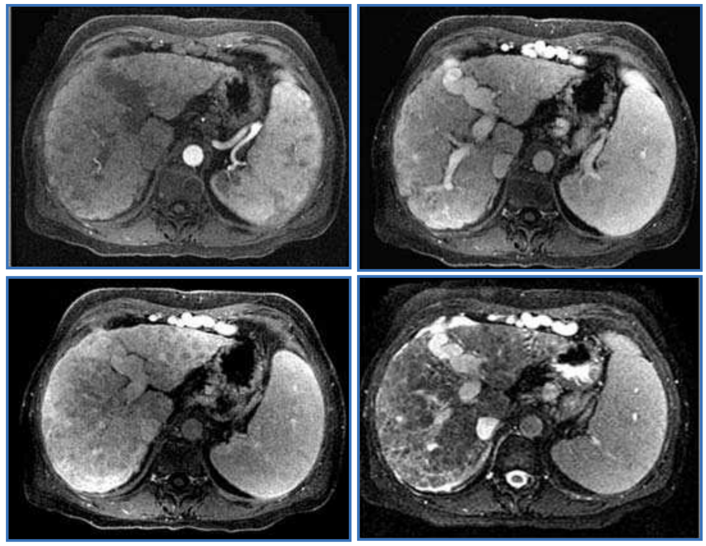


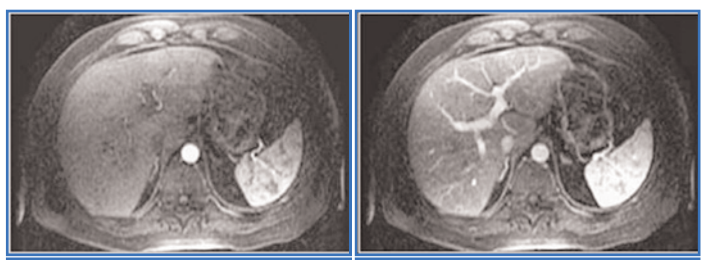
Fig. 4 - Multi-phase liver study (top left and right, and bottom left) demonstrates diffuse liver enhancement with multiple tortuous vessels. The 2D Fat Sat FIESTA image (bottom right) complements the LAVA study and clearly demonstrates the tortuous vessels and unusual liver texture.

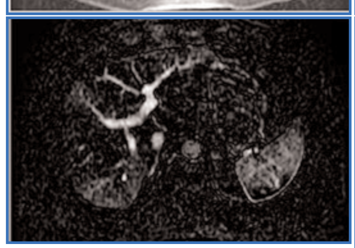
LAVA imaging with Dual Arterial Phase

LAVA's speed allows you to perform Dual Arterial Phase imaging in a single breathhold.

Early and late arterial phase in the same breathhold eliminates misregistration and enables subtraction of phases one and two (Fig. 5).

This ability also enhances scanning sensitivity to hepato-cellular carcinomas.





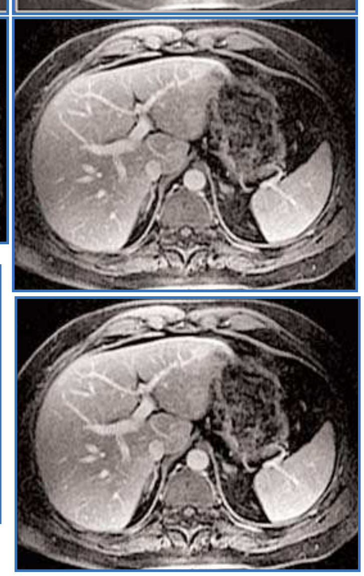


Fig. 5 - Dual arterial phase images in single breathhold. Top left = phase 1; top right = phase 2. middle left = subtraction of phases 1 and 2, middle right = phase 3, bottom right = phase 4.

3.0T LAVA imaging with Dual Arterial Phase

Since scanning at 3.0T inherently gives you two times the SNR, you're able to achieve higher ASSET acceleration without compromising the quality of the images you obtain. The images in Fig. 6 are Dual Arterial Phase images obtained in a single breathhold at 3.0T.

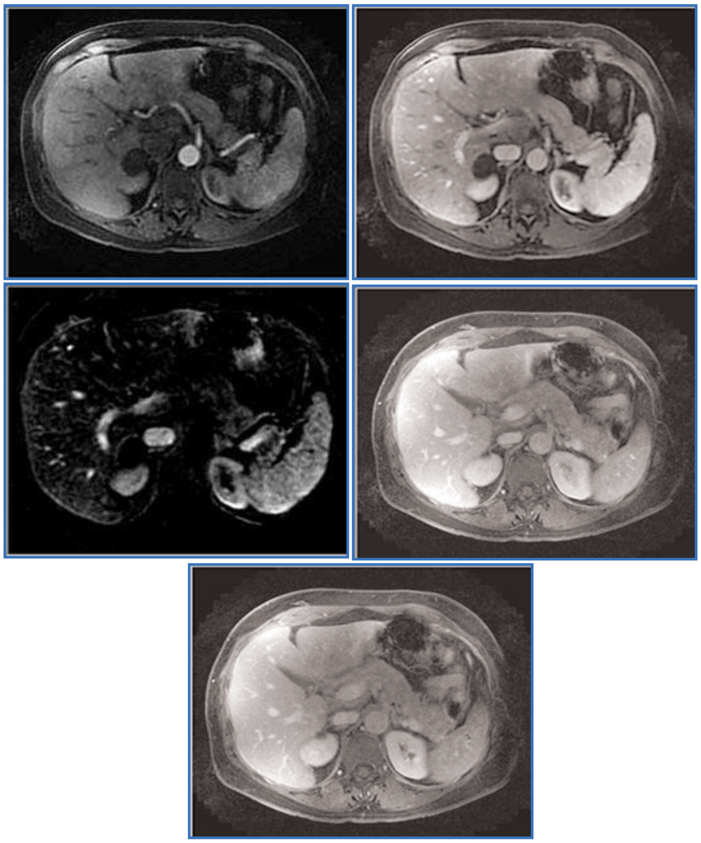


Fig. 6 - 3.0T dual arterial phase images in single breathhold.
Top left = phase 1
Top right = phase 2.
Middle left = subtraction of phases 1 and 2
- Matrix 192x160
- 132 2mm slices (ZIP 2)
- ASSET factor 3
- Scan time 9sec/3D

Middle right = phase 3
Bottom = phase 4
- Matrix 288x288
- 132 2mm slices (ZIP 2)
- ASSET factor 3
- Scan time 18sec/3D Ω

LAVA FAQs

Q: What are my coil choices when using LAVA?

A: The following coils are compatible with the LAVA PSD:
- 8ch Body Array by GE
- 8ch Cardiac Array by GE
- 4ch Torso Phased Array by GE
- 12ch Body Array by GE

Q: How does LAVA produce better fat suppression?

A: LAVA uses an asymmetric k-space zero fill in the slice direction followed by a SPECIAL inversion pulse and alpha excitation pulses. The technique of applying a small number of alpha pulses (labeled views per segment) after the inversion pulse limits the amount of fat recovery and thus results in better fat suppression, with less scan time used for the inversion pulse.

Q: Do I have to acquire a calibration scan first?

A: LAVA automatically turns on the ASSET imaging option, so you have to acquire a calibration scan before you acquire a LAVA scan. Note that you can also deselect the ASSET option.

Also, LAVA automatically sets the flip angle used in the SPECIAL pulses so that fat is nulled when the center of k-space is filled.

Q: What is the optimum body coil configuration to use with LAVA?

A: Using an 8 channel body coil produces the best results. However, it's important to use either 8 channel body upper or 8 channel body lower, depending on your ROI. The image in Fig. 7 was acquired using LAVA and the 8 channel upper selection. The image in Fig. 8 was obtained using the full 8 channel body array. The ring artifact (arrow) was most likely caused by wrap-around in the slice direction. To avoid artifacts spoiling the image, use either 8 channel body upper or lower. Use the full 8 channel body array only if absolutely necessary. Ω

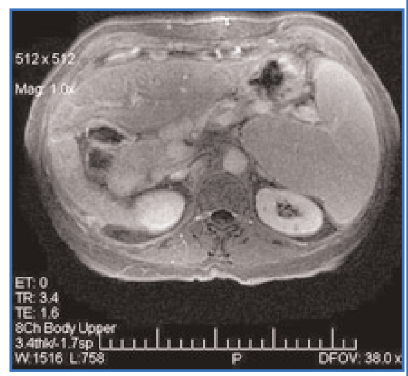


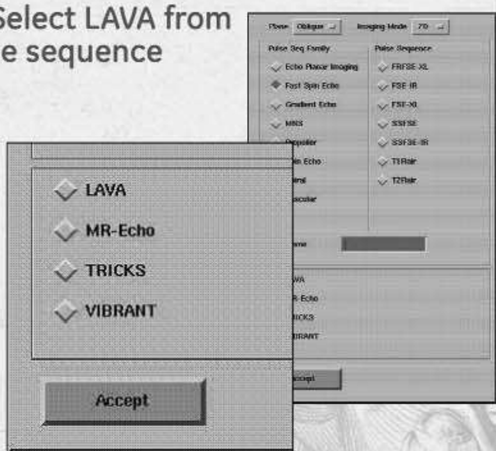
Fig. 7 - Image obtained with LAVA using 8 channel body array, upper selection only.

Fig. 8 - Image obtained with LAVA using full 8 channel body array. Notice ring artifact (arrow) most likely caused by wrap-around in the slice direction.

MR Excite HD Quick Steps
LAVA

TiP Training Choices

Step 1: Select LAVA from the pulse sequence screen



OR

Select the LAVA protocol from the GE Protocol Library

- Protocol listed under Abdomen/Lumbar

Step 2: Prepare and Position the Patient

- Patient entry is Supine/Feet First
- Choose a compatible coil:
  - 8ch Body Array by GE
  - 8ch Cardiac Array by GE
  - 4Ch Torso Phase Array by GE
- Landmark to center of anatomy
- Advance patient into the scanner

FYI — LAVA is only compatible with the 8 channel body array, cardiac array coils and 4 channel torso PA. The body coil cannot be used to acquire a LAVA scan.

Step 3: Perform Localizer and Calibration Scans

- Select a 3-plane localizer series from the GE protocol library
- **[Save], [Download], [Scan]**
- Select the ASSET calibration series from the GE Protocol
- Prescribe the axial calibration scanning range to extend past the anatomy by 50%

FYI — LAVA automatically turns on the ASSET imaging option, therefore you must acquire a calibration scan prior to acquiring a LAVA scan. ASSET can also be deselected.

Step 4: Prescribe LAVA Series

- Select the LAVA series from the Prescription Manager
- Graphically define the slice locations
- Accept Graphic Rx
- **[Save], [Download], [Auto Prescan], [Scan]**

FYI — Up to 10,000 images can be acquired with the LAVA application.

FYI — LAVA can be combined with Fluoro Triggering and SmartPrep.

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Useful Links

You'll find a rich vein of imaging information in the Medcyclopedia on GE Healthcare's web site. This is an on-line version of The Encyclopedia of Medical Imaging and includes all the text and images from the eight-volume print edition. It covers just about every aspect of medical imaging, including: Physics, Techniques and Procedures, Normal Anatomy, Musculoskeletal and Soft Tissue Imaging, Gastrointestinal and Urogenital Imaging, Chest and Cardiovascular Imaging, Neuroradiology and Head and Neck Imaging, and Pediatric Imaging. It is truly an invaluable resource for anyone wishing to know more about any aspect of diagnostic imaging. You'll find it at: http://www.medcyclopedia.com.

The MR Technology Information Portal, or MR-TIP (not to be confused with GE Healthcare's Training in Partnership (TiP) program), bills itself as "the web portal for the 'MRI Professional'." This comprehensive site pretty much covers the MR imaging waterfront … from basic terms, abbreviations and protocols to information on the latest equipment and software innovations and upcoming congresses and shows around the world. You'll find entries on artifacts (with illustrative case studies), PSD information, and safety guidelines to name just a few entries. MR-TIP boasts links to more than 2,100 publications and additional resource sites. There's also a Forum where you can exchange tips and ideas with MR professionals from all over the globe. You'll find this site at http://www.mr-tip.com.

For more Quick Tips sheets, or if you've missed the first few issues of MR Field Notes you can find them on-line at http://www.gehealthcare.com/usen/education/tip_app/products/mri.html

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