GE Healthcare

# Signa Field Notes

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## fMRI: See Where Your Patients are Thinking

A rapidly growing field within the MR industry is functional magnetic resonance imaging (fMRI), which uses MR equipment to detect changes in the cerebral metabolism, blood flow, and volume or oxygenation in response to task activation. fMRI provides the ability to see brain anatomical structure and tissue function, providing better understanding of brain organization and introducing new opportunities to assess neurological status and neurosurgical risks.

**fMRI provides the ability to see brain anatomical structure and tissue function...**

This type of imaging allows you to non-invasively observe which structures participate in specific functions and literally see where your patients are thinking.

The acquisition and detection of relative changes in the MR signal over time are believed to be tightly coupled with changes in neuronal activity. Blood Oxygen Level Dependent (BOLD) is the effect most frequently used to record signal intensities in active regions of the brain.

The brain, when activated by some means (e.g., a finger movement, feeling of a sensation, comprehending a story), reacts by increasing cerebral blood flow without a concomitant increase in oxygen consumption in that particular region. Due to the paramagnetic or weak properties of hemoglobin, we can visualize this difference with MR.

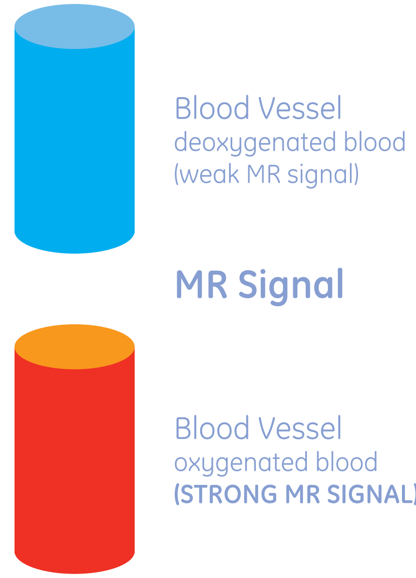


**Fig. 1**: With BOLD, blood acts as its own contrast agent. Blood's MR signal varies according to the level of oxygenation present. The higher the oxygenation, the stronger the MR signal.

Hemoglobin is paramagnetic when deoxygenated but diamagnetic when oxygenated. The MR signal of blood is therefore slightly different depending on the level of oxygenation. So with brain activation, an increase in blood flow occurs, causing an increase in oxygenated blood, which leads to an increase in MR signal (Fig. 1).

If susceptibility-sensitive MR imaging sequences are used pre- and post-stimulation, you can see areas of the brain "light up" in the regions where there is an increase in regional blood flow. So during an fMRI exam, images are taken while patients engage in a set of tasks (known as paradigms) devised to correlate functional activities with specific areas of the brain (Fig. 2).

A paradigm involves at least two repeated events used as task and rest functions. A task is the time period when the responsive stimulus is being presented. The control time period is the time between each task, also known as the rest period. For example, to map the language comprehension network of the brain, patients are given sentences of varying complexity to read and asked to answer true/false questions by pressing a finger switch during the task period of the scan. During the rest period, no stimulus is given.

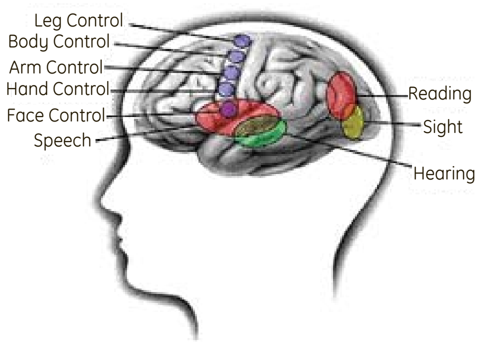


**Fig 2**: Activity areas in the brain that may be stimulated by various task activation paradigms.

Essentially, we compare a person's brain activity during a particular task with their activity level during a resting state. This resting state is then used as a baseline of the background activity of the brain since the brain works continuously.

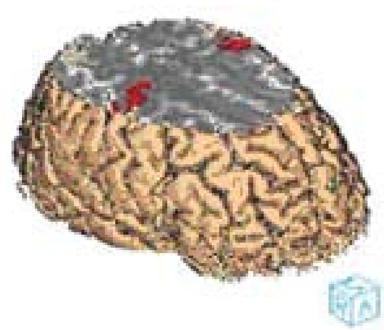

**Fig. 3**: Typical fMRI Result. 3D structural brain with the functional MR activation superimposed.

To know the value of the background signal activity and the value of the signal related to the task, we must take hundreds of images of the brain in a short time period. The best fast imaging technique for observing the blood effect is T2*-weighted Echo Planar Imaging (EPI).

After image acquisition is complete, detailed image processing needs to occur to subtract the baseline values from the activated ones. The values of activation can then be transformed into a map of colors to show the intensity levels where task activation has occurred. Finally, the colors can be overlaid on high resolution anatomical images to give the exact spatial location of the activation. The final product is commonly known as Brain Mapping (Fig. 3). Ω

## Paradigm Scan Timing Breakdown

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Still wondering what is actually happening during the fMRI paradigm scan? Let's take a closer look at what is sometimes referred to as the "task off" and "task on" procedure and a breakdown of the scan timing.

Two major components make fMRI possible. First, the BOLD technique and its effect on signal. Second, the deliberate timing of events during the acquisition and their relevance to its outcome. This timing is most often referred to as a paradigm; it outlines alternating periods of stimulus or task with periods of rest or distraction (control) at predetermined intervals.

Paradigms are designed to achieve the most accurate and repeatable clinical results. However, fulfilling this clinical need creates paradigms that do not readily lend themselves to the understanding of what is happening during an fMRI series.

As a learning tool, the following 5 minute 12 second paradigm model was created with a priority on ease of use, understanding, and remembering the basic fMRI concepts. It acquires a viable motor task functional MRI with a single-shot GRE EPI pulse sequence. BrainWave is not required. This is a traditional fMRI sequence that can be done on any system with EPI.

For simplicity and to help conceptualize the events, the following basic proto-

- TR = 3000 ms
- Imaging Options = Multiphase (104 Phases, Minimum (0 ms) Inter Sequence Delay, Interleaved)
- Graphic Rx = one axial slice strategically placed bilaterally through the Motor Cortex Strip at the level responsible for Arm/Hand control
- Task = voluntary finger tapping in the region of the motor cortex

col is a single-slice prescription with the same parameters for 1.5T and 3.0T systems. (See "Got 5:12? Give fMRI a Try" sidebar on page 5 for a clinical protocol.)

In this example, a single slice will be scanned 104 times. The first 4 times (phases) or 12 seconds are sacrificial and referred to as discarded acquisitions. Discarded acquisitions help establish the scan environment for the paradigm acquisition to follow. The remaining 100 phases will be scanned over the course of the remaining 5 minutes, using the off/on paradigm, to detect small differences in signal intensity that should correlate to tasks performed by the patient in the same time frame. Beginning with a scan time of 5 minutes and 12 seconds, the scan time clock will count backwards to zero.

How is the interval time in an fMRI scan determined? For this example, we will scan our slice 100 times (phases) multiplied by a TR of 3000 ms, which equals 300 seconds or 5 minutes. Keep in mind that the total number of phases is 104, but the first 4 are discarded and nothing is required of you and the patient during this first 12 seconds (4 phases x 3000 TR). We can also say that 1 slice takes 3000 ms or 3 seconds. So if we wanted to scan our slice 10 times (phases) at rest, it would add up to a 30 second rest (control) period (Fig. 4).

After the rest period, you would then alternate scanning the slice 10 times (phases) while the patient performs a task, equaling another 30 seconds (Fig. 5). One rest period plus one task period equals a total cycle. Therefore, in this simplified example, 1 total cycle is

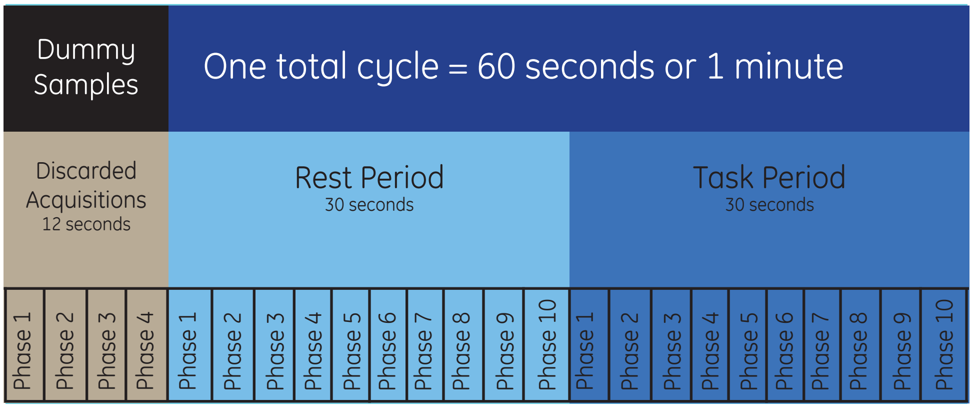



**Fig. 4**: The first 4 phases (12 seconds) are referred to as discarded acquisitions. During the Rest Period (light blue), 10 phases are acquired for a single slice at 3000 ms TR equals 30 seconds. An alternate task period (dark blue) takes place for the next 30 seconds, acquiring 10 phases at 3000 ms TR.

60 seconds or 1 minute, and will be repeated 5 times during the acquisition (5 total cycles = 5 minutes). The total cycle defines the entire exercise. It will not change and can be repeated as many times as desired or tolerated.

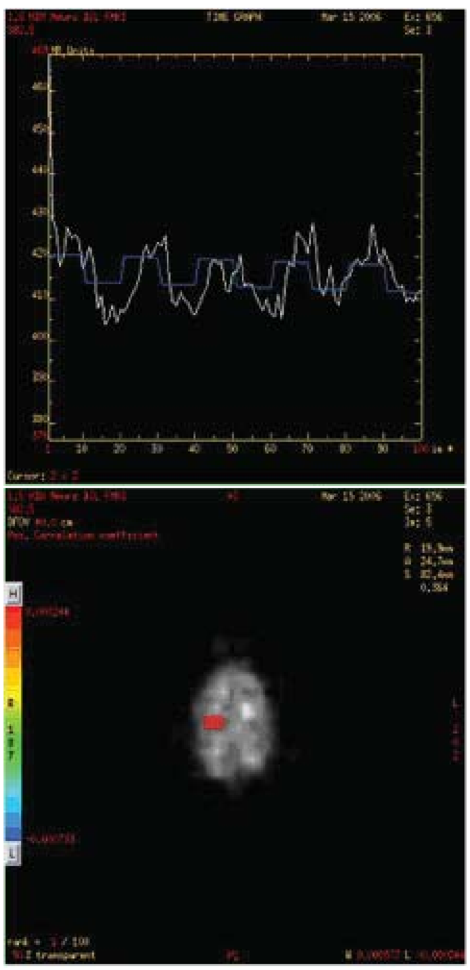


**Fig 5**: Non-BrainWave fMRI Post Processed in FuncTool. The task correlation map (top) shows the signal intensity on the vertical axis with time on the horizontal axis. Note how signal intensity (white line) increases with the increased activity (blue line). The corresponding color map of brain activity is shown below the signal intensity plot.

How does the patient know when to tap their fingers and when to stop? The same intercom used to communicate with patients during exams can be used to instruct the patient when to start and stop tapping. Sound system intercoms may also work but only the instructions should be broadcast.

Consider this: we know the periods must alternate every 30 seconds and we will begin with the patient in a rest state. So we prep the series and start the scan with 5:12 minutes of scan time:

- 5:12 – Discarded acquisitions take place (4 phases at 3 seconds = 12 seconds).
  >12 seconds pass (do nothing)
- 5:00 - Patient and operator do nothing, as there is no need to instruct the patient in this initial state of rest.
  >30 seconds pass (task off)
- 4:30 – Loudly and clearly instruct the patient to **BEGIN!**
  >30 seconds pass (task on)
- 4:00 – Loudly and clearly instruct the patient to **STOP!**
  >30 seconds pass (task off)
- 3:30 – Loudly and clearly instruct the patient to **BEGIN!**
  >30 seconds pass (task on)
- 3:00 – Loudly and clearly instruct the patient to **STOP!**
  >30 seconds pass (task off)
- 2:30 – Loudly and clearly instruct the patient to **BEGIN!**

Repeat this task off, task on sequence with the patient until the scan time reaches zero.

**A pattern should be recognized in the sequence.** In addition to aiding in understanding the components of the paradigm, this timing should ease instructing the patient, as when watching the scan time clock for reference.

00s in the seconds' place indicates to instruct **STOP**

30s in the seconds' place indicates to instruct **BEGIN**

This is invaluable in keeping track of the current state or next required.

To summarize, the anatomy of this example paradigm consists of the following:

- 4 discarded acquisitions
- 5 total cycles
- 10 on/off states
- 104 phases
- 1 slice
- 104 images/series Ω

## fMRI Made Easy with BrainWave

GE Healthcare's powerful BrainWave™ software makes functional imaging easy and practical to perform in clinical, technologist-driven settings. BrainWave extends functional imaging beyond motor strip paradigms (finger tapping) and makes post-processing simple. It has an integrated paradigm delivery device so you can routinely apply more complex paradigms, such as verb generation, without the assistance of advanced neuroscientists. BrainWave also provides automatic segmentation, where the skin and bones on the image are removed automatically by the software so you can readily see what parts of the brain "light up" during mental activity. You can easily transport the data through your online network and retrieve it at a later date, making fMRI images PACS friendly.

### BrainWave Tools

BrainWave consists of three basic tools with which to acquire, analyze, and generate fMRI data, and it can be used with or without external stimulation hardware.

BrainWaveRT (real time) (Fig. 6) is the


**Fig. 6**: With BrainWaveRT, task correlation is in real time, displaying the color task activation images without post processing.

primary tool that allows you to see the changes in relative blood flow in real time without the need for image post processing. The real time image processor calculates the statistical differences between the baseline images and the images acquired while the patient is performing a specified task. Images are displayed in real time as color parametric images and may be overlaid on anatomical images.

If you also have BrainWaveHW Lite equipment, BrainWaveRT automatically invokes, sets up, and triggers the paradigm to be played out into the patient environment.

BrainWavePA (post analysis) (Figs. 7 and 8) is the processing and analysis package that is used to analyze the EPI data set acquired with BrainWaveRT.

BrainWavePA determines activation, uses this activation in color onto a 3D anatomical data set, and produces pixel-mapped images for surgical planning.

BrainWaveHW (hardware) Lite, used with BrainWaveRT, comprises equipment used to create custom paradigms and play them out into the patient environment. This equipment consists of a stimulus computer mounted in a rack in the MR equipment room. NeuroActivator software on the stimulus computer is used to create custom audio and visual paradigms. NeuroActivator software is carried to the patient bore using third party equipment (e.g., Avotek, Resonance Technologies) purchased separately. Cedrus patient response pads are also included in the BrainWaveHW Lite package.

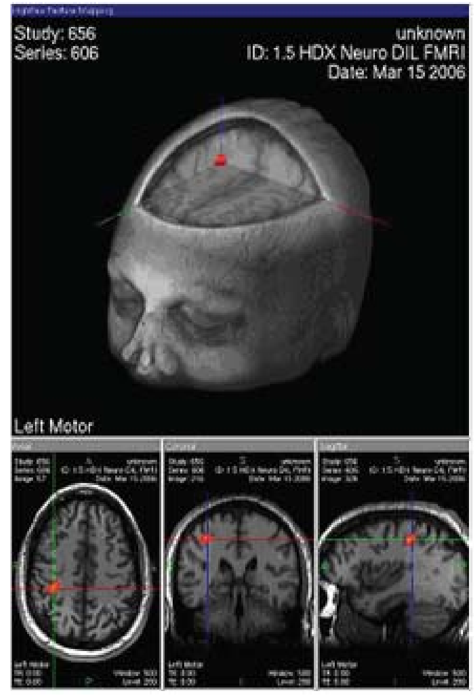



**Fig. 7**: BrainWavePA. Volume rendering view (top) displays a 3D view of the fMRI data and the image display views (bottom) present 2D views of orthogonal slices of the 3D volume.

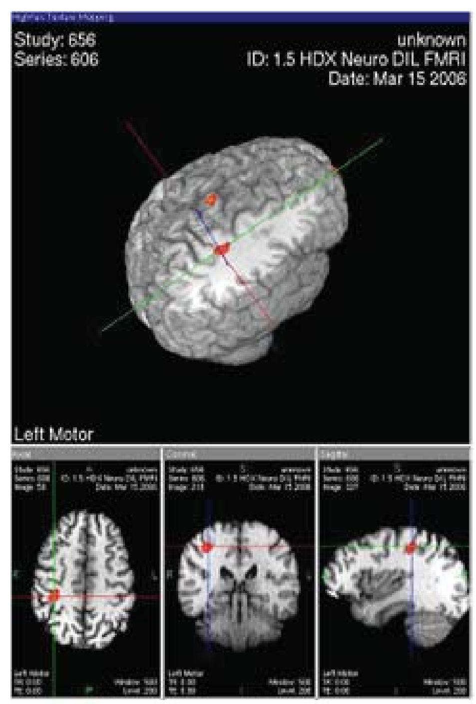



**Fig. 8**: BrainWavePA images showing activation after segmentation, with the brain free of skull and tissues. Note the activity in the left motor cortex shown in red.

## Functional Workflow

A typical fMRI exam consists of a structural scan and task activation scans, which use BrainWaveRT and some means of playing a visual, auditory, or sensory stimulus into the patient environment. These scans last 5 to 10 minutes, depending on the paradigm and the scan protocol parameters. The structural scan, generally a high resolution 3D anatomical series, is acquired either before or after the paradigm scans. This image set is to be used with BrainWavePA to render activation on the brain in a 3D visualization for diagnostic purposes.

The following example workflow provides a practical guide to help optimize the tasks associated with fMRI operations.

1. Set up the patient and components for paradigm delivery.
2. Acquire a localizer scan.
   - You can select the fMRI GE protocol from GE Library > Head > fMRI. This protocol has a localizer, structural, and fMRI series.
3. Acquire a high resolution structural scan of the whole brain.
   - Typically acquired with a 3D SPGR pulse sequence or BRAVO application.
   - This image data is later segmented and used to overlay the task activation color maps, therefore, it is important this scan be of sufficient resolution.
   - If a different background image is desired during functional data acquisition as opposed to the mean EPI scan, acquire an additional matched structural scan. This structural scan is for the background image, which is separate from the structural data used for automated segmentation.
4. Acquire the fMRI data with BrainWaveRT.
   - Acquiring fMRI data involves the scanning of the task areas of the brain with a single-shot Gradient Echo (GRE) or Spin Echo (SE) EPI pulse sequence.
   - It is necessary that the fMRI scan be of the same graphic prescription parameters of the background scan, if acquired.
5. Perform 3D Segmentation.
   - The segmentation process in BrainWavePA involves segmenting a 3D SPGR high resolution structural scan to remove the outer layers of tissues, resulting in a 3D volume with the brain free of skin or skull tissues.
   - View the segmented results to ensure the data is satisfactory.
   - If the results of the automated segmentation are less than optimal, acquire another high resolution scan with increased resolution and SNR.
6. Continue to repeat the process of acquiring any additional fMRI paradigm scans with BrainWaveRT and viewing the results with BrainWavePA until all desired paradigms are complete.

## Paradigms

Paradigms can be performed with the aid of response equipment and/or sensory equipment, such as headphones, eye glasses, or a microphone. The equipment used depends on the paradigm being applied. BrainWave's Paradigm Manager provides a way to create new paradigms with custom graphics, sound, sequence, and timing.

Hardware or software paradigms can be used to acquire the task activation data.

Hardware paradigms are task activation procedures that use BrainWaveHW Lite for presentation of visual and auditory stimuli to the patient. Several standard hardware paradigms are available and you can also build custom paradigms. Standard paradigms include voluntary hand movement, passive listening, verb generation, rhyming, and semantic decision.

Software paradigms are task activation procedures that are not associated with the GE BrainWaveHW Lite stimulus system. Left and Right Motor standard paradigms are available and you can also customize your own software paradigms. Ω

## Got 5:12?

### Give fMRI a Try

Take 5 minutes, give fMRI a try, and see where your patients are thinking. Here is clinical GRE EPI protocol to get you started. To acquire fMRI data with a basic finger tapping paradigm, prescribe the slices through the motor cortex strip. This is a traditional fMRI protocol and can be performed on BrainWave and non-BrainWave systems. Without BrainWave, images can be post processed in FuncTool.

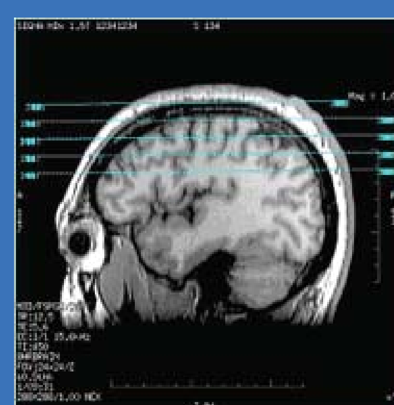
**Scan timing**
- # of shots =1
- TE = 60
- TR = 3000
- Flip angle = 90

**Acquisition timing**
- Freq = 64
- Phase = 64
- NEX = 1
- Phase FOV = 0.5
- Freq dir = R/L
- Shim = Auto
- Phase correct = On

**Scanning range**
- FOV = 40
- Slice thickness = 10
- Spacing = 2
- # of slices = 4

**Multiphase**
- Phases per location = 104
- Phase acq. order = Interleaved
- Delay after acq. = 0

**User control variables**
- Ramp sampling = 1 (on)



**GRx**

## Clinical Applications

Studies of human brain mapping have generated insights into the functional organization of various motor, sensory, visual, and language processing systems. Clinically, fMRI is used to map the brain prior to surgery and as a post-operative follow up to assess neurological function. If the surgeon can identify a patient's language or motor function centers, surgery can be planned to avoid them, protecting the abilities to speak and move.

### Preoperative Planning

The following case study from New Jersey Neuroscience Institute - Edison Imaging demonstrates the advantage of functional plus anatomical information for surgical treatment of brain tumors that are located near active processing areas of the brain. Preoperative conventional MR imaging demonstrates an extensive low grade glioma (Fig. 9). To assist surgical resection of the tumor, a functional MR study was acquired on the patient before surgery.

The fMRI study with BrainWave (Fig. 10) showed activation of the central sulcus and supplementary motor cortex, identifying the lesion as clearly anterior to the motor cortical strip.

Further imaging was done with Diffusion Tensor Imaging (DTI) (Fig. 11) to visualize the white-matter fiber tracts in the central nervous system. FiberTrak seeded off the posterior limb of the internal capsule, confirming the lesion as anterior to the patient's sensorimotor pathways.

With this information at hand, the surgery was carefully planned and the patient's glioma was removed while preserving the patient's motor and sensory functions. Ω

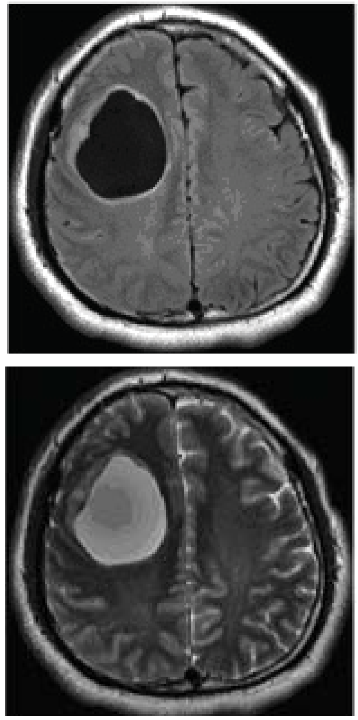


**Fig. 9**: PROPELLER FLAIR (left) hypointense and PROPELLER T2 (right) hyperintense mass lesion in the right lobe of the brain.

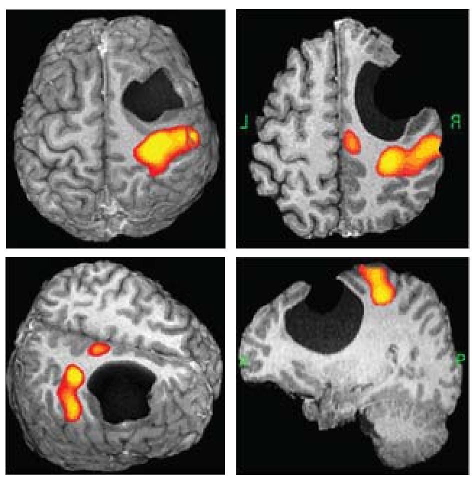


**Fig. 10**: fMRI BrainWave Images. 3D volume rendered and 2D orthogonal slices of the motor cortex activation.

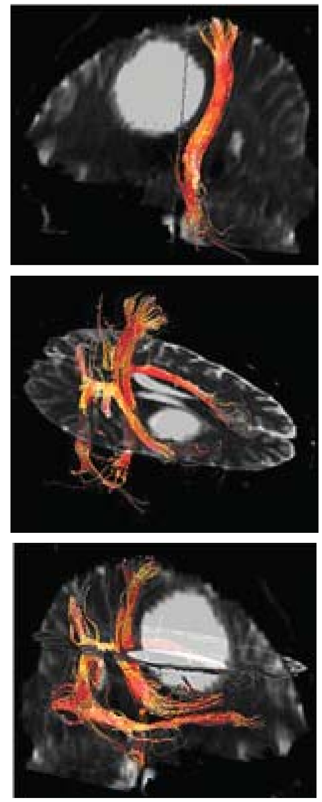


**Fig. 11**: DTI Fibertrak Images. FiberTrak delineates the superior and inferior longitudinal fasciculi as well as the cingulum and corticospinal tracts displaced by the lesion.

## BrainWave FAQs

**Q: Our site does not have the BrainWave software, can I still do fMRI?**

**A:** Yes, the basis of an fMRI scan is a multiphase GRE EPI sequence with careful attention to chronology relative to a patient paradigm. The resultant series can be post processed in FuncTool. However, BrainWaveRT has several key benefits that elevate fMRI capabilities to new levels, and it's a great tool with which to learn and develop entry-level to more advanced fMRI practices.

- It increases the amount of available slices to 20k per series.
- With use of real-time visualization, it allows assessment of data quality so you may intervene if it is unacceptable, forgoing scanning a long series to its completion only to discover that it's inadequate.
- The interface is truly more interactive during the acquisition, and despite being more capable it has a sensible logic that aids both learning and understanding of set-up procedures and fMRI data acquisition.

**Q: I have a 1.5T scanner, can I still do functional imaging or is it best done on a 3.0T system?**

**A:** At 1.5T, the signal change in blood is 1 to 3%; blood signal change is 5 to 10% in a 3.0T environment. BOLD signal increases at 3.0T because the higher field strength is more sensitive to the oxygenation of blood so the signal is larger. However, relevant research and clinical fMRI have been done for many years on 1.5T. fMRI can be pursued on all preexisting or new MR systems at either 1.5T or 3.0T field strength.

**Q: Our MR system has the BrainWave software. Do we need external stimulus hardware to use it?**

**A:** No. fMRIs can be categorized based on the components involved in their acquisition. If there is no hardware, such as goggles and viewing screens, to deliver stimulus to the patient, or response mechanisms, such as touch pads or microphones, it can be referred to as a "Software Paradigm." If accessories are used, an fMRI can be referred to as a "Hardware Paradigm".

**Q: Which coil is best suited for fMRI?**

**A:** fMRI can be performed on several coils depending on field strength, software version, configuration or accompanying exams. For example, if an NV Array coil was necessary for additional evaluations, it wouldn't warrant the change to an alternate coil for the fMRI. It would make more sense to just use the current coil. Ω

## fMRI Terminology

**BOLD:**
Blood-oxygenation level dependent functional magnetic resonance imaging that relies on intrinsic changes in hemoglobin oxygenation.

**Color Map:**
Demonstrates the intensity levels where task activation has occurred by transforming activation values into a map of colors.

**Control Period:**
The time between each task, also known as the rest period.

**Functional Scan:**
A scan during which the patient performs cognitive tasks while many images are taken to capture changes over time. Provides information related to the function of the brain, also known as a task activation scan.

**Paradigm:**
A way to conduct an fMRI scan that is defined by patients being engaged in a set of cognitive tasks devised to correlate functional activities with specific areas of the brain based on theoretical background.

**Segmentation:**
The process of automatically removing the outer layers of tissues for the 3D volume to locate the area of activity which may be depicted in the image. The end result is a 3D volume with the brain free of skin or skull tissues.

**Structural Scan:**
A high resolution image (typically sagittal, T1-weighted) of the brain, showing the anatomical structure, that serves as a reference for subsequent anatomical labeling. This image set is to be used with BrainWavePA to render activation on the brain in a 3D visualization for diagnostic purposes.

**Task Period:**
The time the responsive stimulus is being presented and the patient performs an action or activity in order to produce a particular activation in the brain. Ω

# What's New in Neuro Imaging?

GE Healthcare launches its second generation of the Signa HDx 1.5T and Signa HDx 3.0T systems, offering new technologies and breakthrough advances to increase clinical performance. Here is a look at what's new in neuro imaging.

## BrainWave Enhancement

A new enhancement to BrainWave gives you more capabilities and provides a more integrated solution to paradigm management. A new Additional Parameter screen (Fig. 12) appears when prescribing an fMRI scan that allows you to change the fMRI prescription parameters during scan prescription, essentially giving you on-the-fly paradigm control. You can edit the parameters and change an existing paradigm or make a copy of the edited version to save as a new paradigm.

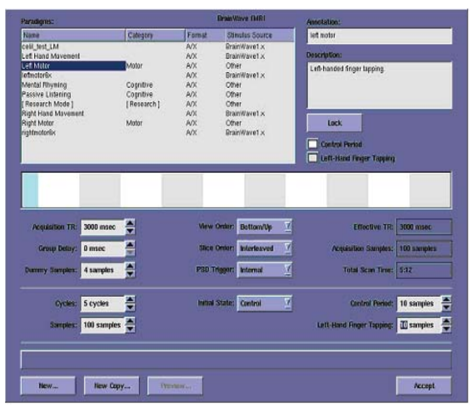


**Fig. 12**: BrainWave fMRI Additional Parameters Screen.

## BRAVO

BRAVO (BRAinVOlume) Imaging complements fMRI as a rapid 3D high-resolution T1-weighted sequence. This technique provides whole-brain isotropic volumes acquired in 3 to 4 minutes, reducing the total fMRI exam length by as much as 40%.

BRAVO is an IR-Prepared FSPGR pulse sequence that uses self-calibrated, 2D-parallel imaging with a new parallel imaging reconstruction algorithm. 2D parallel imaging allows higher acceleration factors. Self-calibration ensures that the coil sensitivity measurements are automatically co-registered with the imaging data, regardless of inter-series patient movement. The reconstruction method, known as GEM (Generalized Encoding Matrix), is an iterative reconstruction approach that improves SNR and offers a reduction in the residual aliasing artifacts that can be possible with parallel imaging (Fig. 13).

**Fig. 13**: BRAVO 1.5T Sagittal Brain.

## COSMIC

COSMIC (Coherent Oscillatory State acquisition for the Manipulation of Imaging Contrast) is a powerful new 3D sequence used to image axial cervical spines. COSMIC uses a segmented multi-shot centric k-space technique that improves the CNR and SNR of C-spine tissue, including the spinal cord, vertebral disks, nerve root canal, and contrast between cerebral spinal fluid and nerve roots (Fig. 14).

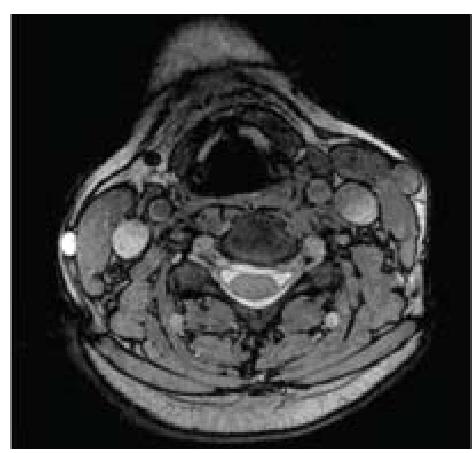


**Fig. 14**: COSMIC 1.5T Axial C-Spine.

## MERGE

MERGE (Multiple-Echo Recalled Gradient Echo) is a fast GRE pulse sequence designed for axial T2* weighted C-spine imaging. It acquires multiple echoes at several different TEs and then averages those echoes to form a single T2* weighted C-spine image. MERGE uses a larger receive bandwidth (31.25 kHz), which reduces chemical and susceptibility artifacts while improving image quality. MERGE provides excellent gray/white matter conspicuity in the spinal cord and improves visualization of cord compression and parenchymal disease (Fig. 15).

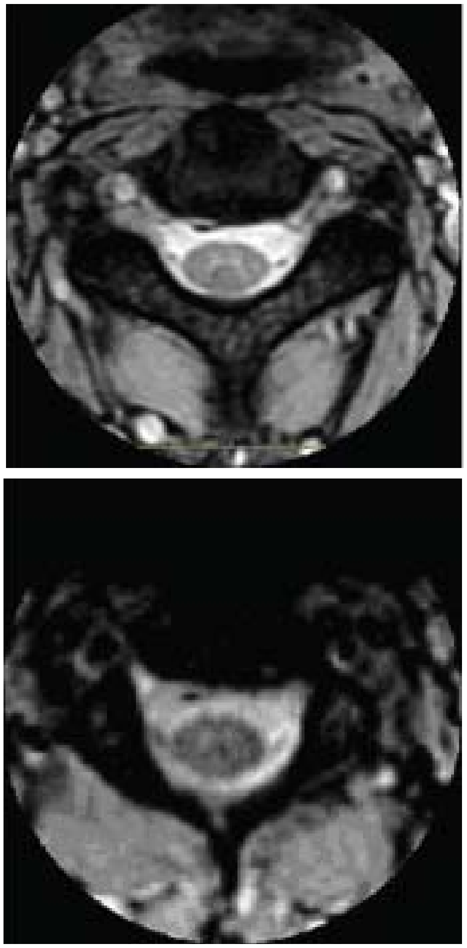


**Fig. 15**: MERGE 3.0T Oblique Axial C-Spine (top) vs. FGRE 3.0T Oblique Axial C-Spine (bottom).

## 1.5T & 3.0T 16-Channel Head, Neck, and Spine Array

The 16-Channel Head, Neck, and Spine Array is a receive-only coil designed to give an optimum signal-to-noise ratio and uniform coverage of the head and spine (Fig. 16). This rigid coil incorporates soft, flexible components that conform to patients' anatomy to accommodate various body contours, while minimizing patient discomfort.

This coil enables the clinical user to collect high resolution images of the head, neck, and spine.

**Fig. 16:** Signa 16-Channel 1.5T and 3.0T Head, Neck, and Spine Array.

## Signa HDx 1.5T and 3.0T On-System Help

Do you ever wish that answers to your software/hardware/protocol/procedure questions were right at your fingertips instead of in a book, on a shelf, somewhere in the department, miles from where you are? Help is at hand … literally. The HDx platform for both Signa 1.5T and Signa 3.0T incorporates a comprehensive help feature containing all of the answers and information you'd typically go to the printed manual to find … now available at the click of a mouse (Fig. 17).

Besides concise explanations of hardware, software, protocols and everything else you need to know to get the most out of your GE Healthcare Signa MR system, this searchable data base contains plenty of illustrations, pictures, and movie files for added

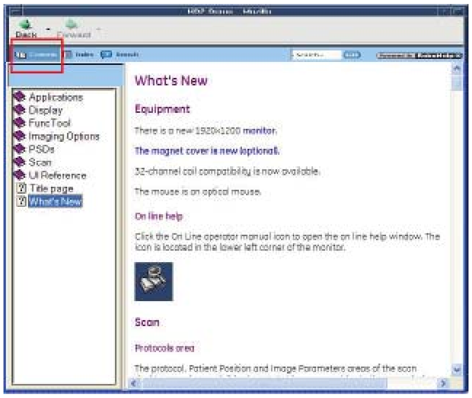



**Fig. 17**: On-System Help available on Signa HDx 1.5T and 3.0T systems.

## Useful Links

Wikipedia Encyclopedia is a great resource to learn more about fMRI. It includes thorough background information, a discussion on its value, scanning practices, related techniques, all illustrated with images. Be aware that the Wikipedia is open to contributions from anyone, so carefully evaluate any information you find here before you implement it.

http://en.wikipedia.org/wiki/Functional_magnetic_resonance_imaging

The Columbia University Functional MRI Research Center website contains general functional imaging information and discusses the future roles of fMRI in medical applications. Check out the reference links on this site to find recent fMRI abstracts, publications, and recent media coverage.

http://www.fmri.org/fmri.htm

The Centre for Functional Magnetic Resonance Imaging of the Brain at the University of Oxford's website includes an introduction to fMRI, an abstract, physiological background, and an overview of data analysis. The abstract, titled "fMRI: A window into the brain" is loaded with great information and case studies. It examines how we learn, how the brain repairs itself and even fMRI's ability to provide greater understanding of the neurobiological basis for problems of drug addiction or gambling. Check it out!

http://www.fmrib.ox.ac.uk/fmri_intro/

There are also some great online resources for neuro anatomy. Take a look at Harvard's whole-brain atlas:

http://www.med.harvard.edu/AANLIB/home.html

The human brain slices from the neuroradiology website of The Uniformed Services University of Health Sciences (USUHS) Bethesda, MD is also worth a look:

http://rad.usuhs.mil/rad/neuroradiology.html

A Diffusion Tensor Imaging-based atlas of the brain's white matter tracts can be found at:

http://www.dtiatlas.org/ Ω

## GE MR Masters Series

### *The GE Healthcare MR Master Series Helps Clinicians Draw Maximum Return on MR Investment*

Advances in GE Healthcare MR imaging technology continually increase the capabilities of GE MR products. Faster computers, more advanced protocols and magnet upgrades allow unprecedented imaging techniques. With proper training in these latest applications and software, a site will be able to draw on the full potential of its MR scanner. GE has pioneered the creation of specialized education to enable physicians to fully utilize their GE MR equipment.

A unique offering of GE Healthcare, the MR Masters Series gives physicians an avenue to learn about the latest MR techniques to help them deliver better patient care while maximizing productivity.

### Learn with experts

At GE MR training centers throughout the United States, the world's top radiologists train physicians from around the globe on how to maximize the clinical benefits of the most advanced MR techniques.

Offered throughout the year, each Masters Series course is taught by a renowned radiologist who has mastered specific procedures that maximize a particular MR application.

After participating in a Masters Series course, physicians will be fully equipped with the knowledge and skills needed to use new applications in their own facilities. Attend three GE MR Masters Series courses and receive certification of your accomplishment. The GE MR Masters Series is fully accredited for CME credits. For more information, including complete faculty biographies, course descriptions, locations and dates for 2006, visit the GE Healthcare website at:

http://www.gehealthcare.com/usen/mr/education/products/physiciantrain.html

## Course Listing

**Physics and Clinical Applications**
*William G. Bradley, MD., Ph.D., FACR, San Diego, CA*
Attendees will understand MRI physics; when gradient echo, conventional spin echo, fast spin echo and echo planar imaging should be used; major applications of MRI; when MRI is preferred over CT.

**Understanding and Applying Clinical MR Physics**
*Emanuel Kanal, M.D., FACR*
*Pittsburgh, PA*
This course provides a deeper understanding of basic physics and the contrast mechanisms of MR imaging and how to apply them in a busy clinical practice. It also provides an overview of MR angiography, diffusion weighted imaging, perfusion weighted imaging, parallel, multichannel imaging (such as ASSET), and many other clinical imaging techniques and parameters.

**Breast MR Imaging**
*Constance D. Lehman, M.D., Ph.D.*
*Seattle, WA*
This practical, interactive course includes lectures on the technical aspects of performing breast MRI with VIBRANT™, clinical indications for Breast MRI, practical guidelines for Breast MRI interpretation, and hands-on training in interpreting clinical breast MR studies.

**Beyond MRI: MR Spectroscopy for the New Millennium**
*Dr. Brian Ross, M.D., Alexander Lin B.S.*
*Pasadena, CA*
Participants will learn the fundamental information needed to use and interpret MRS. The course includes diagnostic examples describing the clinical utility of MRS and its impact on patients.

**Advanced High Field MR Practicum: 3.0T – 1.5T**
*Lawrence N. Tanenbaum M.D., FACR*
*Edison, NJ*
The course covers essentials and advanced diffusion imaging at 3.0T and 1.5T. Participants will master fast spin echo and optimize their MR scanning with ASSET, PROPELLER and TRICKS. Also covered are clinical spectroscopy; core protocol design for neuro, MSK and body; issues in neuroimaging at 3.0T and 1.5T; MR of the spine; image processing and display; scanning on the Signa Interface; and managing an advanced imaging practice.

**Clinical fMRI at 1.5T and 3.0T**
*Keith Thulborn, M.D., Ph.D.*
*Chicago, IL*
This course features lectures and hands-on training for brain imaging on 1.5T and 3.0T Signa LX systems. Emphasis on functional imaging protocols using diffusion and blood oxygenation level dependent (BOLD) contrast. Conventional anatomic and angiographic sequences at both field strengths will be compared in clinical application.

**Cardiovascular MRI**
*Steven D. Wolff, M.D., Ph.D.*
*Cindy R. Comeau, BS, RT (N) (MR)*
*New York, NY*
Workshop focuses on cardiac MRI and vascular MRA with didactic lectures, small group tutorials, case reviews and hands-on time to scan human volunteers.

**MSK Imaging: Applications, Techniques & Interpretation. Emphasis on Joint Imaging**
*Michael Zlatkin, M.D., Timothy Sanders, M.D., Paul Clifford, M.D*
*Weston, FL*
The course covers MR arthrography, injection techniques, acquisition and interpretation of joint images. Also provides overview of MR coil techniques, pulse sequences/parameters, techniques for imaging wrist, ankle and foot, etc. Protocols for MR arthrography, meniscal disorders and body parts – from rotator cuff to the hip – are discussed. Bone and soft tissue tumors are covered as well. Ω

Contact your GE representative for the most current information.

For more than 100 years, scientists and industry leaders have relied on General Electric for technology, services and productivity solutions. So no matter what challenges your healthcare system faces – you can always count on GE to help deliver the highest quality services and support.

For details, please contact your GE Healthcare representative today.

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