How to Learn MRI
An Illustrated Workbook

Exercise 4: Scanning the Brain Using a Protocol

Teaching Points:

- What is T1 and how to get a T1 weighted images.

- What is T2 and how to get a T2 weighted images.

- What is T2 Flair and how to get T2 Flair images.

- What is Susceptibility SPGR and how to get Susceptibility SPGR images.

Exercise 4: Scanning the Brain with a Protocol

Through the first three exercises, you have mastered how to scan a phantom and how to scan a live person with a pre-programmed protocol. In this exercise, you will learn to scan the brain with a protocol and to make some protocol changes. The basic steps are almost the same as in knee scan, but you will now learn to do more than a routine protocol, that is, tune the parameters. It is exciting to see how you can change the imaging contrast on your own!

Before going into the scanning room, it is important to go over some basic knowledge of MRI. In previous exercises, we always see TR, TE, and flip angle. So how do these parameters affect the images? How should we tune these parameters to get high contrast brain images? To answer these questions, we need to introduce some very important terms in MRI: T1, T2, and flip angle. Table 4.1 shows typical T1 and T2 relaxation times of different tissues at 1.5T

Table 4.1 T1 and T2 relaxation times at 1.5T

Tissue	T1 (ms)	T2(ms)
Cerebrospinal fluid	2400	600
White matter	780	90
Gray matter	920	100
Fat	270	80
Muscle	860	50
Kidney	650	60
Liver	490	40
Heart	1030	45
Spinal Cord	750	75
Cartilage	1030	40

 The time interval between successive excitations is called the Repetition Time (TR) (Fig 4.1). At the beginning of each TR, longitudinal magnetization is tipped down to the transverse plane using an RF pulse. Then the longitudinal magnetization recovers according to T1 relaxation time. The next TR tips down the recovered longitudinal magnetization and the process continues.

So TR directly determines how much the longitudinal magnetization can recover in between pulses. Thus TR directly determines the T1 contrast. For a T1 weighted image, use a TR long enough so that some tissue can fully recover in between pulses and show up bright but some tissue will not fully recover and appear darker. You are about to learn how this works in the brain.

TE is the echo time, that is, the time between giving the RF pulse and the peak of the echo signal (Fig 4.1). During this time interval, the transverse magnetization decays, eg, signal decays, due to the T2 relaxation effects. So TE directly determines how much the transverse signal decays. For a T2 weighted image, use a TE that is longer than the T2 of some tissues but shorter than the T2 of other tissues.

Fig 4.1
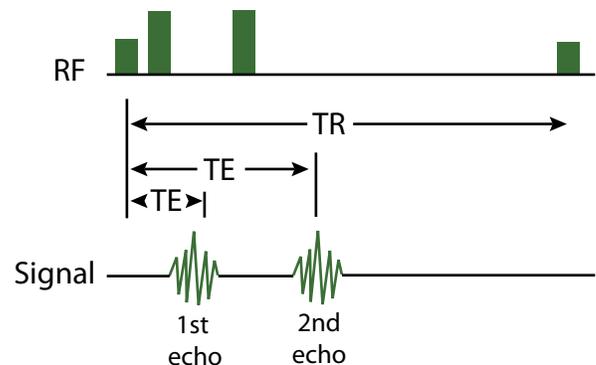
What is T1? T1 is spin-lattice relaxation time which relates to the recovery of the magnetization along z direction after RF pulse. I like to think of this as the time it takes tissue to recover from an RF pulse so you can give another pulse and still get signal.

What is T2? T2 is spin-spin relaxation time which relates to the decay of magnetization in transverse plane after RF pulse. I like to think of T2 as the time the signal lasts after giving an RF pulse.

Flip angle: The angle which longitudinal magnetization is tipped towards the transverse plane.

Now let's see how you can get perfect brain images by manipulating TR and TE.

STEP 1: Prepare the Head Coil in the Scanner Room

The typical brain coil is a bird-cage like coil. It has two parts: the cage portion and the base. First place the cage portion of the head coil on the trolley. Then place the base of the head coil assembly on the cradle and align the notches. As we use head-first position, the coil base should be close to the magnet bore. Lock the base by turning the knob clockwise until tightened. Remember to put a cushion in the coil for comfort and a sanitary liner on top of it.

STEP 2: Place your Friend on the Scanner Table

Lower the table and ask your friend to lie down on his/her back, i.e., in the supine position with the head in the head cradle and shoulders resting against the head cradle. Use cushion and straps to immobilize the patient's head. Sometimes we use medical tape to immobilize the head further (See fig 4.4). Slide the cage portion over patient's head. Place a cushion under your friend's knees to take pressure off his/her back. Ask them if they are comfortable or if they need blanket to stay warm since the fan inside the scanner is very strong. Lift the table by stepping on the 'up' pedal. Remember to give your friend ear plugs and the alarm squeeze-ball.

STEP 3: Landmark the Brain

Plug in the coil to the scanner and press 'Align on' to activate the positioning light. As in the knee scan, ask your fiend to close his/her eyes. Move table in slowly and align the light to the superior edge of eyebrows and press 'Landmark'. Press 'Advance to Scan' before going back to the console room. Shut the door firmly behind you.
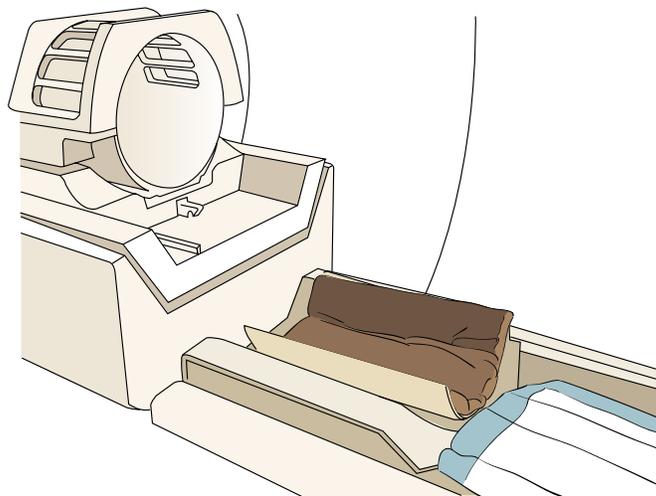
Fig 4.2 Head coil
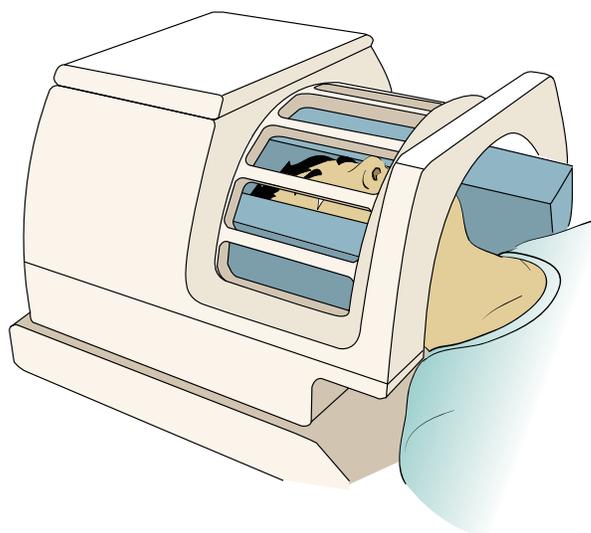

Fig 4.3 Friend's Head in coil

Fig 4.4 Tape Technique (Note: You can also tape the chin for even better prevention of motion.)

Fig 4.5 Patient Protocol

STEP 4: Choose Protocol

For this exercise, we are going to learn how to do a basic brain scan and learn about T1 and T2 images. Enter all the necessary information in 'Patient Information'. Click 'Head' on Patient Protocols. Choose **'Stroke-Trauma'** from the popup menu and then **Accept**. All series of this scan will appear in the Rx Manager window, but we'll just use 3 plane localizer, axial T1, and axial T2.

In Patient Position column, change coil to 'currently connected' then Apply all.


Fig 4.6 Rx Manager
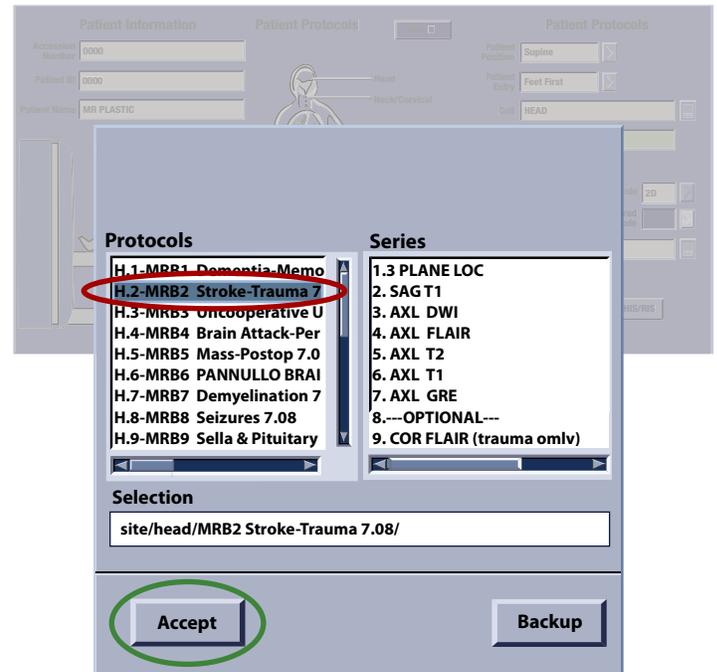
STEP 5: 3-Plane Localizer

Sometimes you may change the protocol which can change the coil selection automatically. So before running the 3-plane localizer, verify the selection of currently connected coil.

3 Plane Localizer is important for every protocol. As with the knee scan in Exercise 3, this is also the first sequence in the brain protocol. Select **3 PLANE LOC** from the Rx manager, click View Edit, Save Series, Download, and Scan. Wait until the 3-plane is finished to go on to graphically prescribe the other series.
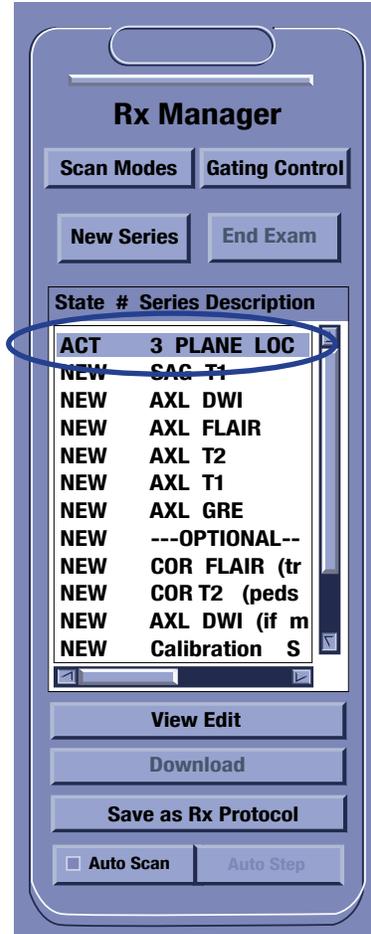
STEP 6—Series in protocol

6.1 Axial T1 Scan

T1 is the relaxation time for the recovery of magnetization along the z axis and we use a short TR to get T1-weighted images. Let's see what happens if we acquire several spin-echo (SE) images with different TRs but the same TE.

In Rx Manager, select AXL T1 and click View Edit. Exit out of the graphic Rx window, change series description to AXL T1 25 and change TR to 25. Go to Graphic Rx window and adjust the localizer to 3 slices (See fig 4.7). Click Save Series, Download, and Scan.

Fig 4.7 Axial T1 imaging
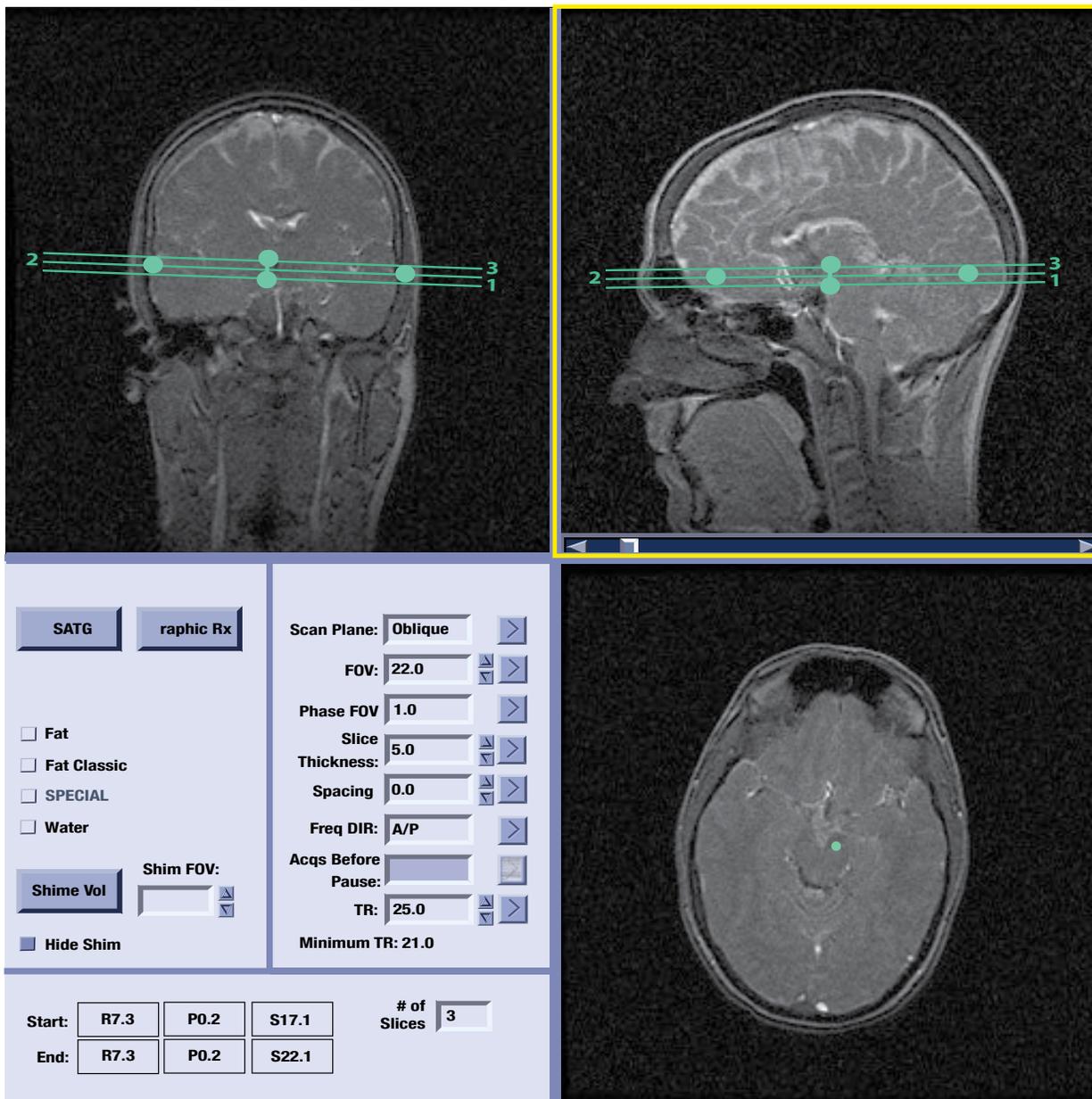
Copy and paste AXL T1 25 on the Rx Manager, click View Edit, change series description to AXL T1 100, and change TR to 100. Make sure that you prescribed 3 slices in the Graphic Rx. Click Save Series, Download, and Scan. Repeat the same procedure to create AXL T1 500 with TR equal to 500 and AXL T1 2000 with TR equal to 2000. You can also click Auto Scan to run prescribed series in order automatically.

To compare the images with TR 25 and 100, go to Display Desktop and click Browser. Click the name of volunteer on the examination list, click AXL T1 25 on the series list, and then click Viewer. Click Compare, click AXL T1 100, and then click Viewer again.

Axial brain images with different TR are shown in fig 4.8.

Fig 4.8 Axial brain images with different TR

| TR = 25 | TR = 100 | TR = 500 | TR = 2000 |
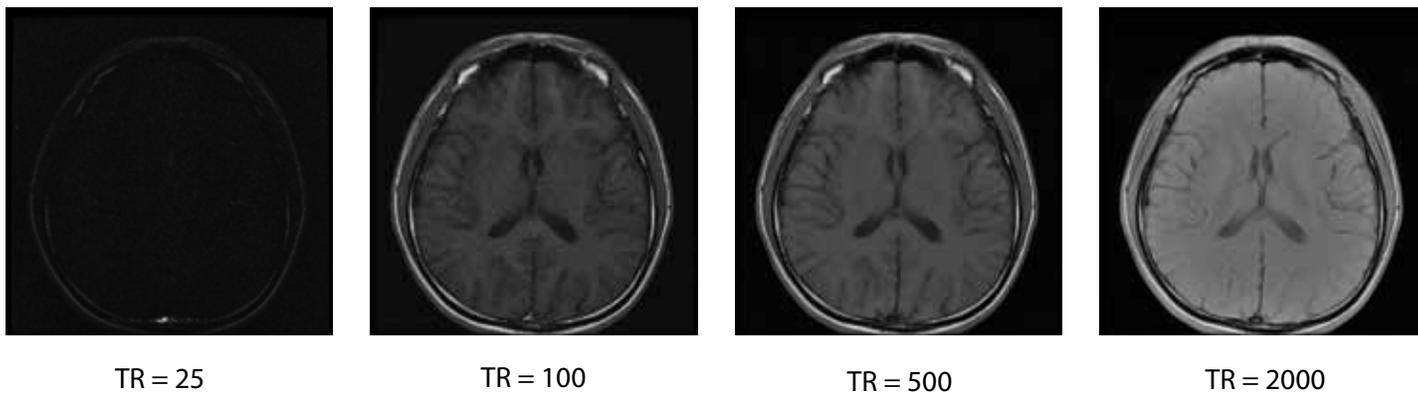
With long TR, there is very little signal difference between gray and white matter, but with a shorter TR, the contrast is improved. That's why we get T1-weighted images at short TRs.

6.2 Axial T2 Scan

We can also have brain tissue images based on T2 contrast. To get T2 contrast images, we set the TR to a big value to allow longitudinal magnetization to fully recover for all tissues in between pulses which eliminates T1 contrast. In this exercise, we fix TR at 4000ms and set TE to different values-- 10ms, 30ms, 100ms and 400ms respectively.

Select AXL T2 in the Rx Manager and click View Edit. Change series description to AXL T2 10, change TR to 4000ms, and change TE to 10ms. Go to Graphic Rx and adjust the localizer to 3 slices (see fig 4.9). Click Save series, Download, and Scan. Repeat the same procedure to create AXL T2 30 with TE equal to 30, AXL T2 100 with TE equal to 100, and AXL T2 400 with TE equals 400.

In AXL T2 400, you may have to change Echo Train Length (ETL) to achieve a long TE. TE is usually short and has an upper limit in the Scan Timing module in clinical protocols. For really long TE like 400ms, increase your echo train length (ETL) to 64. Since the echo span is about 10ms, your effective TE=320ms. In this way you can set a longer TE.

Run these four series of T2 weighted images sequentially and compare. Fig4.10 shows the mid-slice of axial axis of the brain with different TEs.

Fig 4.9 Axial T2 imaging
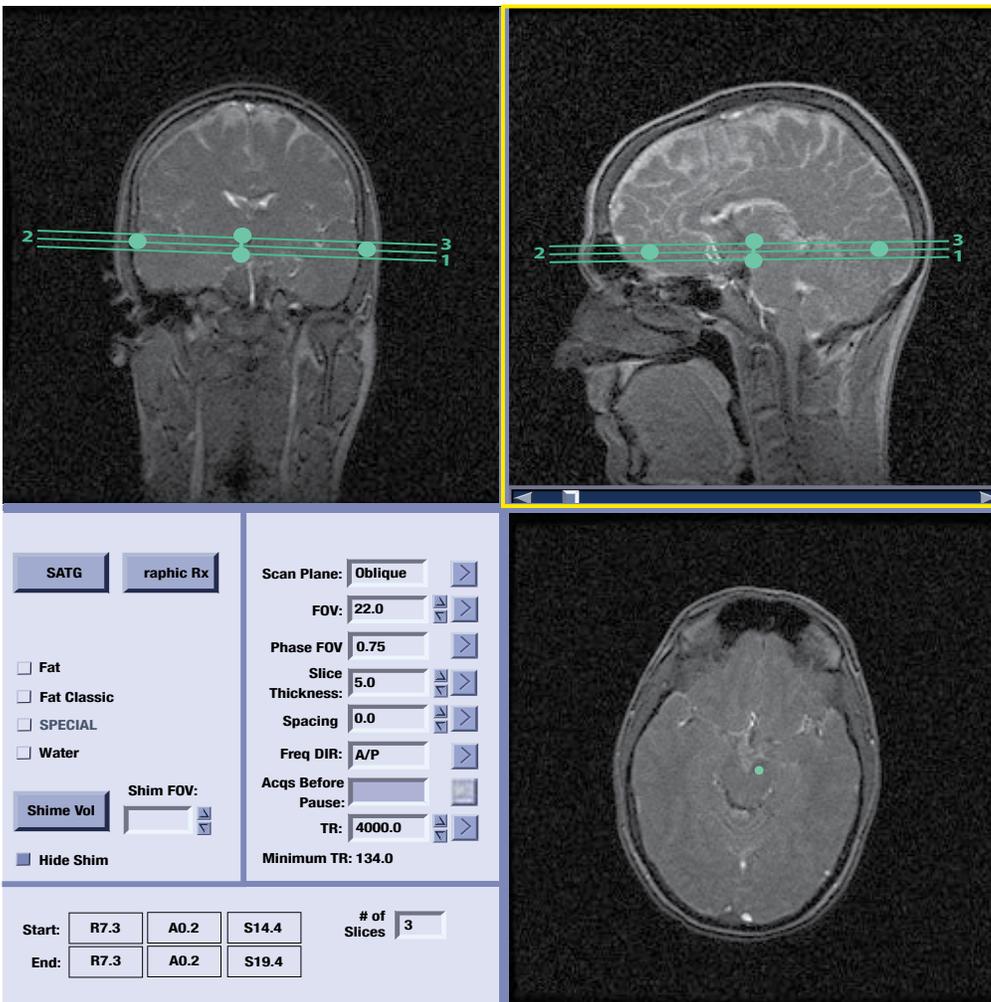
The echoes around the TE time are placed in the center of k-space and they determine the image contrast. Echoes away from the echo time are placed in the edge of k-space so they determine the spatial resolution. Usually in the brain, we like to use a TE of about 100ms to get the best balance between contrast and optimal SNR.

Fig 4.10 Axial brain images with different TEs

TE = 10   TE = 30   TE = 100   TE = 400
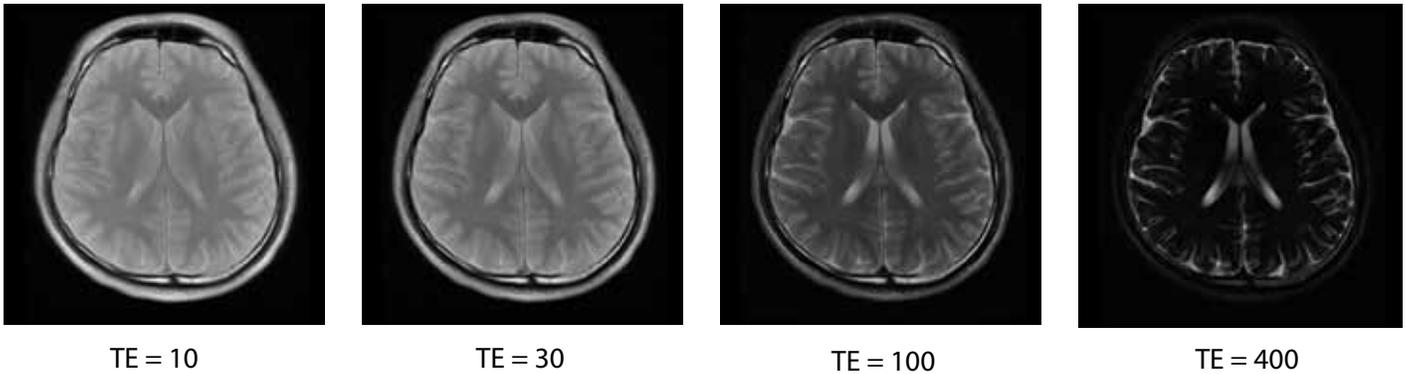
At short TE there is little contrast between gray and white matter, white matter, and CSF. Longer TEs improve the T2 weighting of the images.

Comparing T1 and T2 Images
You can compare your T1 and T2 images by going to the Display Desktop and click Browser. Click the volunteer's name on the examination list, click AXL T1 100 on the series list then click Viewer. Click Compare, click AXL T2 100, and then click Viewer. What is the difference between the two images?

T1-weighted Images
Fluids are very dark, water-based tissues are mid-grey and fat-based tissues are very bright. Clear boundaries between the different tissues are seen, so they are known as the 'anatomy scans'. We can predict that pathology which has edema or a lot of capillaries will be darker than the surrounding normal tissue, while fatty lesions will have higher signal intensities.

T2-weighted Images
Fluids have the highest intensity, and water- and fat-based tissues are mid-grey. Abnormal collections of fluid are bright against the darker normal tissue, so they are known as 'pathology scans'.

STEP 7 Axial FLAIR Scan

FLAIR (Fluid Attenuated Inversion Recovery) produces heavily T2-weighted images with a suppressed CSF signal. It uses inversion recovery technique, removing the signal from CSF which has a much longer T1. This technique is more sensitive than simple T2-weighted imaging for multiple sclerosis lesions and for lesions closed to the ventricles.

Fig 4.12 axial Flair

Select AXL FLAIR in the Rx Manager, click View Edit and prescribe 3 slices in the the Graphic Rx. Click Save Series, Download, and Scan.

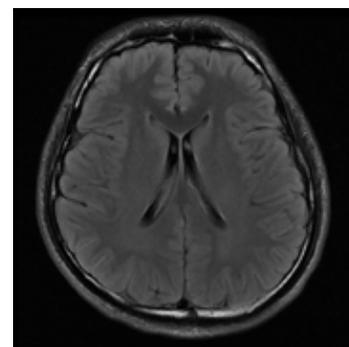## Step 8 Gradient echo sequence to show susceptibility differences

In gradient echo sequence, we usually use a short TE such as 2ms. If we use a very long TE like 40ms to eliminate T2 effects, the magnetic field inhomogeneity can act as contrast in the image. As blood iron concentration can affect the local magnetic field, a gradient echo sequence with a long TE is able to indicate micro-hemorrhage in the brain.
Select AXL GRE in the Rx Manager, click View Edit, prescribe 3 slices in the the Graphic Rx, change series description to SPGR TE 5 and set TE to 5. Click Save Series, Download, and Scan.
Copy and paste SPGR TE 5, click View Edit, prescribe 3 slices in the Graphic Rx, change series description to SPGR TE 10 and change TE to 10. Click Save Series, Download, and Scan. Repeat the same procedure to create SPGR TE 20 with TE equal to 20 and SPGR TE 40 with TE equal to 40.

Fig 4.13 Susceptibility weight images with different TE's

TE = 5   TE = 10   TE = 20   TE = 40
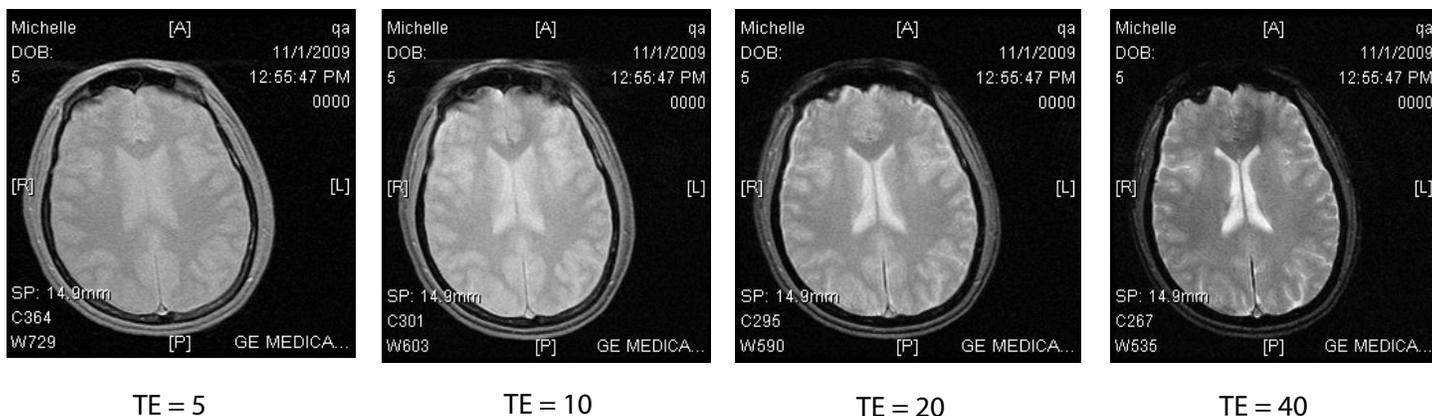
Signals from substances with different magnetic susceptibilities compared to their neighboring tissue will become out of phase with these tissues at sufficiently long TEs. There's good contrast between gray matter and white matter, iron-laden tissues, venous blood vessels, and other tissues with susceptibilities that are different from the background tissue.

Clean up
Restore room to its original neat, clean, organized condition.