Module 12: Spin Echo
Spin Echo

Objectives

…Review the SE PSD.
…Review the concepts of T2, T2’, and T2*. 
Spin Echo PSD

RF
90

Gz

Gy

Gx

180
Spin echo is a standard pulse sequence on Signa MRI/LX and is used for T1, T2 and PD weighting in all areas of the body

- SE uses a 2D, multiplanar mode
- SE can be used to produce 1 or 2 echoes
- SE acquires one phase encoding value per repetition so long TR acquisitions take a long time
- SE is less sensitive to magnetic field inhomogeneities than GRE, but more sensitive than FSE

Variable Flip Angle for improved T1 contrast and Zip 512 now available in 9.0 release and above.
**Spin Echo**

A dual or multiple echo sequence looks like this:

- RF: 90°, 180°, 180°
- Gy: delayed
- Echo: signal response
Dual Echo Spin Echo

Conventional Spin Echo (TE 1)

Conventional Spin Echo (TE 2)
Module 13: FSE
**Objectives**

...Explain how a FSE pulse sequence speeds up scan time in comparison to a Spin Echo.

...View images to see the effect ETL has on image quality.

...View images to see the effect changing RBW has on SSFSE image quality.
A closer look at Fast Spin Echo

- Echo Space
- Echo Train Length (ETL)
- Effective TE
Fast Spin Echo

ETL=8    Eff. TE=5xESP

RF

Gy

Gx

echo
Within the 1st TR:
8 ETL and therefore 8 lines of K-space are filled.
**Contrast** SE vs. FSE

**Conventional Spin Echo (TE)**

- Conventional Spin Echo (TE)

**Fast Spin Echo (TE)**

- Fast Spin Echo (TE)
Terminology

• Echo Train Length (ETL): The number of echoes selected by the operator in the FSE sequence. It is annotated ET on the image

• Echo Spacing: multiple of the minimum TE
The time between each echo in the FSE sequence, in which a 90 degree pulse is followed by the acquisition of multiple echoes.
Echo spacing is a multiple of the minimum TE

**Scan parameters that increase Min TE:**

<table>
<thead>
<tr>
<th>FOV</th>
<th>Matrix</th>
<th>Slice Thickness</th>
<th>RBW</th>
</tr>
</thead>
<tbody>
<tr>
<td>↓ FOV</td>
<td>↑ Matrix</td>
<td>↓ Slice Thickness</td>
<td>↓ RBW</td>
</tr>
<tr>
<td>↑ MIN TE</td>
<td>↑ MIN TE</td>
<td>↑ MIN TE</td>
<td>↑ MIN TE</td>
</tr>
</tbody>
</table>
The number of echoes selected by the operator in the FSE sequence. It is annotated ET on the image.
ETL comparison

GE Medical Systems

The images show a comparison of ETL settings for two different scans.

Left Image:
- SL: 1.5T
- Sys: GE
- Ex: 1102
- Se: 3
- Im: 13
- Sag: R1.8

ET: 16

Technical Details:
- Fr: fse-xl/90
- TR: 1916
- TE: 12.2/EF
- EC: 1/2 31.2kHz
- LS: 464
- FOV: 34x34
- 3.0thk/0.5sec/I
- 32/4/159
- 512*256*2
- NEX
- St: 1a/NP/VB/TRF/SPF

Right Image:
- SL: 1.5T
- Sys: GE
- Ex: 150
- Se: 3
- Im: 6
- Dsag: L3.5

ET: 6

Technical Details:
- Fr: fse-xl/90
- TR: 2000
- TE: 12.3/EF
- EC: 1/1 15.5kHz
- CTLBOT
- FOV: 26x19.5
- 4.0thk/1.0sec
- 12/02/52
- 256x224
- NEX
- St: 5a/NP/VB/TRF
Echo Train Length

How does ETL affect other scan factors?

<table>
<thead>
<tr>
<th>T2 Contrast</th>
<th># of slices</th>
<th>scan time</th>
<th>motion artifacts</th>
<th>edge blurring</th>
</tr>
</thead>
<tbody>
<tr>
<td>↑</td>
<td>↓</td>
<td>↓</td>
<td>↑</td>
<td>↑</td>
</tr>
</tbody>
</table>

ETL
ETL for Slices
Scan time for Spin Echo

Acquisition time =
(TR) (# phase encodes) (NEX) (1/60,000)

example:  (2000) (256) (2) (1/60,000)

(2000) (256) (2) (1/60,000) = 17 minutes

Scan time for Fast Spin Echo

Acquisition time =
(TR) (# phase encodes) (NEX) (1/60,000) ETL

example:  (2000) (256/16) (2) (1/60,000)

(2000) (256/16) (2) (1/60,000) = 1 minute
**Receive Bandwidth**

Receive bandwidth influences many FSE factors

<table>
<thead>
<tr>
<th>SNR</th>
<th>Min TE</th>
<th># of slices</th>
<th>Motion Artifact</th>
<th>Chem shift</th>
</tr>
</thead>
<tbody>
<tr>
<td><img src="image1.png" alt="arrow down" /></td>
<td><img src="image2.png" alt="arrow down" /></td>
<td><img src="image3.png" alt="arrow up" /></td>
<td><img src="image4.png" alt="arrow down" /></td>
<td><img src="image5.png" alt="arrow down" /></td>
</tr>
</tbody>
</table>
**FSE and ETL**

Echo train affects scan time, contrast, and image blurring

- The number of echoes in the echo train and the spacing between each echo affect the overall echo train length
- The longer the echo train the more the T2 decay curve affects image contrast and image blurring
- Increase the bandwidth to decrease the echo spacing and ETL

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**Parameters Ranges**

- For T1 use FSE-XL, minimum TE, TR, TRF and ETL 2-3
- For PD use FSE-XL, minimum TE, TRF, and reduce ETL to 4-6
  - Reduce TR to 2000 (to decrease CSF brightness)
- For T2 use FSE, FSE-XL or FRFSE-XL, increase TR, TE and extended ETL to 8 or more
FSE, FSE-XL + FRFSE-XL

Comparison

• FSE-XL is an enhanced FSE sequence that allows longer ETL’s with less blurring by using RF pulses with a higher amplitude and shorter duration to reduce echo spacing and blurring.

• FRFSE-XL uses additional RF pulses after the acquisition window to drive the recovery of longitudinal magnetization. This produces images with more T2 contribution.
**FSE-XL**

- An enhanced FSE sequence that allows longer echo trains with less geometric distortion and intersecting slice prescription.

Select *Sequential group (1)* in User CV to get multi-groups with no cross talk.
FR Fast Spin Echo Contrast

• With an appropriate choice of timing parameters, signal from fluid can be dramatically enhanced in these images.

• SNR is improved and can be traded for spatial resolution at the operator's discretion. TR can be reduced at no expense to contrast to noise.

• The Fast Recovery FSE pulse sequence can be used to create highly T2-weighted images with decreased acquisition times.
Gated High Resolution
3D FRFSE MRCP

High resolution and high SNR enable the definition of the entire biliary system including the pancreatic duct and small hepatic branches.
SSFSE

- Single Shot FSE acquires all data for one slice in one excitation—each image takes less than 1 second. 0.5 NEX and ETL is determined by phase matrix and FOV.
- Use it for uncooperative or pediatric patients.
- Use it for ultra-long TE studies:
  - Choleopancreatography
  - Urography
  - Myelography
  - Enterography
- SSFSE is less sensitive to geometric distortion than EPI.
3D FSE

• 3D FSE allows 3D volume acquisition by using a multi-slab technique

• 3D FSE provides high resolution like 3D GRE and 3D SPGR but with less sensitivity to inhomogenieties

• Use it for high resolution imaging, reformatting and 3D modeling of the spine, brain, IAC, and knee
Progress Check

1. What scan parameter on your system indicates the echo space?

2. What happens to the number of slices as the echo space increases?

3. Would a 8 ETL or a 32 ETL produce a more PD-weighted image? Which would produce a more T2 weighted image?

4. Provide at least three scan parameters that would reduce the echo space:

5. Does increasing the ETL increase the number of slices in the acquisition?
Progress Check

ETL PD contrast change

Image A: ETL = 3
SNR:
Contrast:
Spatial resolution:
Time:

Image B: ETL = 6

Image C: ETL = 12

Image A: ETL = 3
SNR:
Contrast:
Spatial resolution:
Time:

Image B: ETL = 6

Image C: ETL = 12
SNR:
Contrast:
Spatial resolution:
Time:
Spin Echo/ Fast Spin Echo

FSE scan time formula:

$$\text{TR} \times \text{NEX} \times \text{phase} \times \text{ETL}$$

Divide the product by 60,000.

K-space is centrically filled, not sequentially.

Echo space - min TE
Module 14: FSE-IR T1 / T2 FLAIR
Objectives

…Identify scan timing parameter that controls image contrast with an FSE-IR and T1/T2 FLAIR PSD.
FSE-IR or FLAIR

\[ \text{ETL}=8 \quad \text{Eff. TE}=5\times\text{ESP} \]
Time Interpulse

- $M_z$
- $T_{\text{STIR}}$
- $T_I$
- Fat
- Water

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Training in Partnership
TI Ranges

T1 FLAIR
1.5T = 860
T2 FLAIR
1.5T = 2500

STIR
1.5T = 145-160
1.0T = 120-130
0.5T = 90-100
0.2T = 70-90

T2 FLAIR
1.5T = 2200
0.5T = 2000
0.2T = 1500
Progress Check

1. What scan parameter controls the contrast in an Inversion Recovery pulse sequence?

2. Is it advisable to decrease the TI or TR to gain more slices or speed up the scan time in your T2 FLAIR protocol?

3. FSE-IR is designed to reduce the signal from what tissue?

4. T2 FLAIR is designed to reduce the signal from what tissue?
FSE-IR & T2 FLAIR are tissue suppression PSDs.

The TI time determines the tissue to be suppressed.

STIR = 120-170
FLAIR = 2200-2500