Tissue Suppression Technique

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Optimization for MR imaging

- **Contrast**
- SNR
- Resolution
- Scan time

Contrast

- Contrast was introduced in terms of the image appearance, or relative brightness of different tissues and pathology.
- Image contrast arises (or doesn't) when tissues generate MR signals which have different intensities because of their physical properties, i.e. T1 and T2 relaxation times and proton density.

Here's the maths bit

Mathematically we can define contrast as

$$C = \frac{S_A - S_B}{S_A + S_B}$$

where S_A and S_B are signal intensities for tissues A and B.

Signal-to-noise ratio (SNR) is defined as

$$\text{SNR} = \frac{signal}{noise}$$

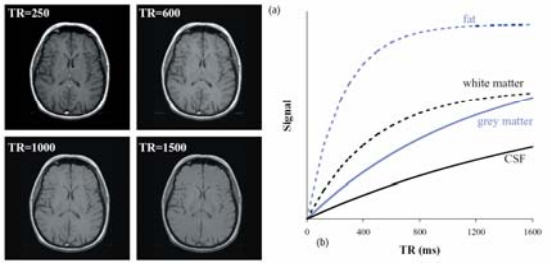
Contrast-to-noise ratio (CNR) is defined for tissues A and B as

$$CNR_{AB} = \frac{S_A - S_B}{noise}$$

In the simplest terms spatial resolution of the voxels is related to the field of view (FOV) and matrix thus

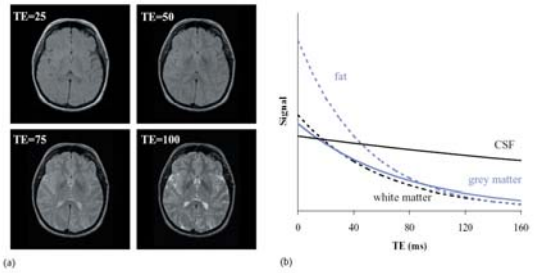
$$\Delta x = \frac{\text{FOV}}{N_{FE}} \qquad \Delta y = \frac{\text{FOV}}{N_{PE}} \qquad \Delta z = \text{slice width}$$

TR and tissue contrast



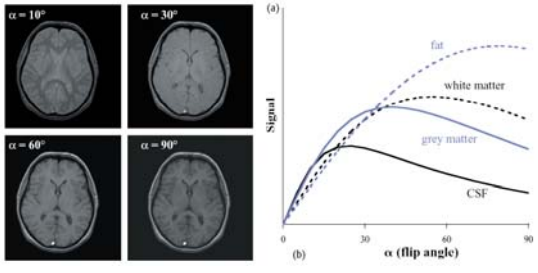
TE=10

TE and tissue contrast



TR=1500

Flip angles and contrast



TR=150, TE=4.6

Tissue Suppression

- **Fat or water**

--- Fat-Sat pulses (CHESS)
--- STIR (fat), FLAIR(water)
--- Water Excitation (WE)
--- SPIR & SPAIR
--- In-Out Phase (Dixon)
--- Double Inversion Recovery

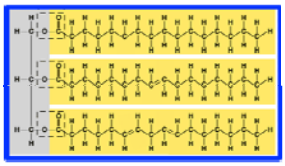
- **Flow**

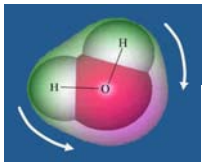
--- Black blood

Fat or Water suppression

Fat Suppression

- Fat vs. Water





These molecular structures give rise to two key differences in the magnetic properties of water and fat:
--- The T1 values for fat are much shorter than those of water
--- The hydrogen protons of water resonate slightly faster than those of fat. This difference in resonance frequency is known as the water-fat ***chemical shift***.

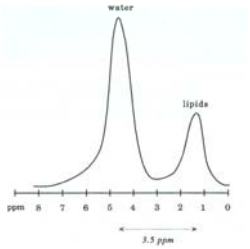
Fat/Water Chemical Shift

- The chemical shift between fat and water

--- **3.5 parts per million (ppm)**

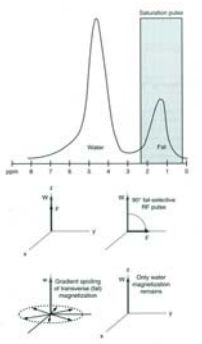
- In a 1.5T scanner (ope
  fat-water frequency di
  therefore be

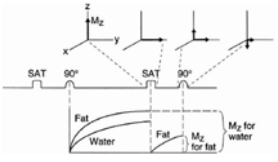
Δf = (64 MHz)(3.5 ppm) = (64 x 1

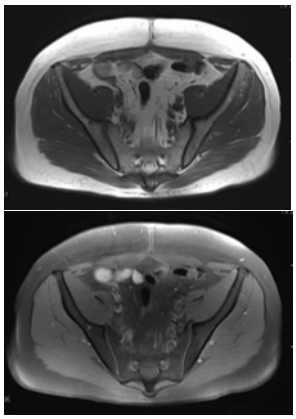


Fat-Sat pulses (CHESS)

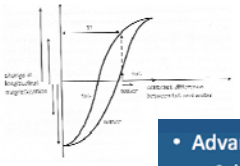
- Short-duration RF-pulses tuned to the resonance frequency of fat
- Applied immediately before the start of an MR imaging sequence





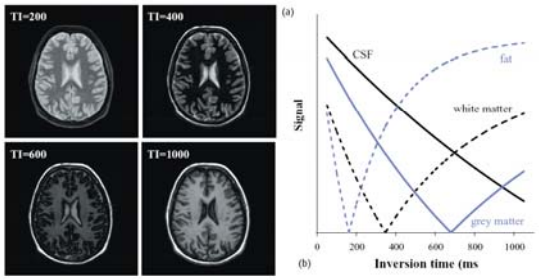


Inversion recovery (IR)



- Advantages of IR
  - Selective tissue suppression possible
  - Twice the sensitivity to T1 differences
  - Additive T1 and T2 contrast
- Disadvantages of IR
  - Longer imaging time
  - Higher energy deposition (SAR)

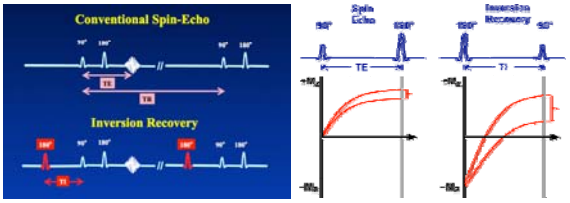
TI and contrast



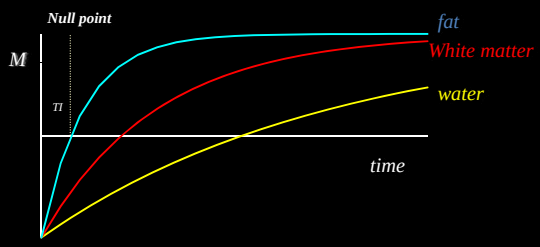
TR=4000, TE=19

STIR

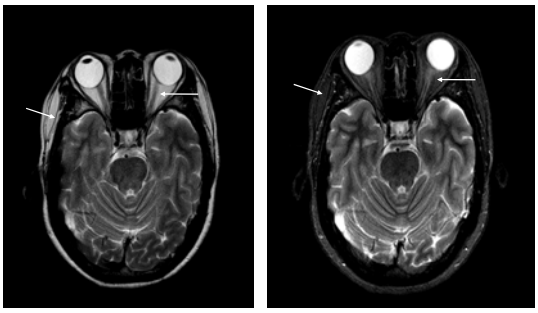
- **S**hort **TI** (Inversion Time) **R**ecovery



STIR

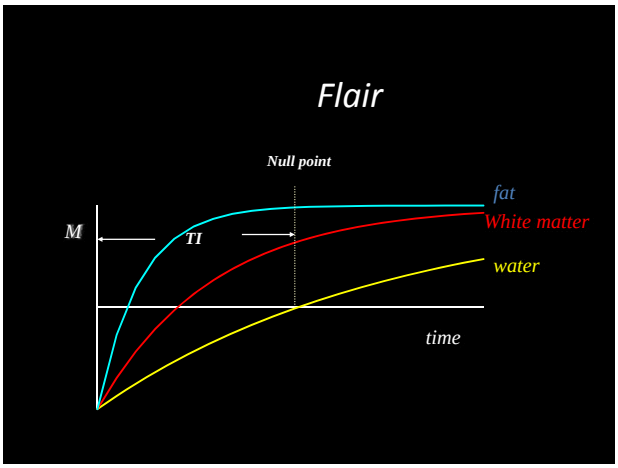


STIR image

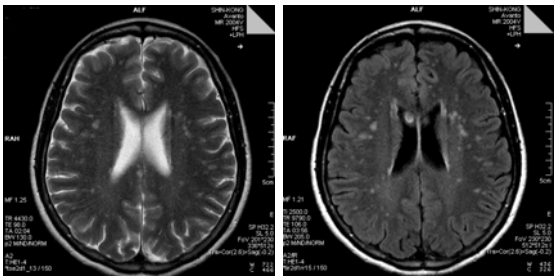


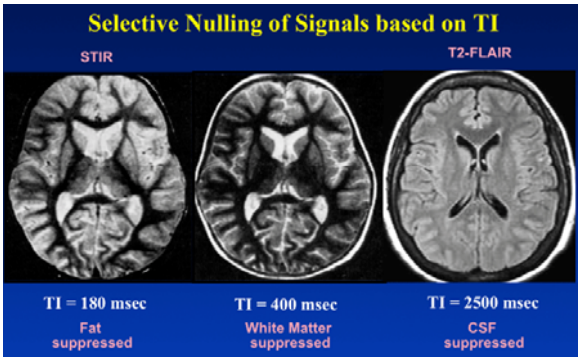
The limitations of STIR imaging

- Cannot be used as a fat suppression technique post-gadolinium.
- Improve contrast-to-noise for certain lesions, but overall signal-to-noise may be poor.
- The multiple 180°-pulses cause deposit extra energy and may result in tissue heating.



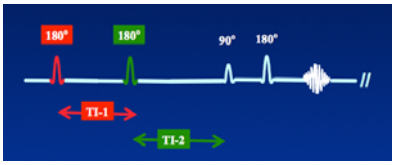
FLAIR in Brain MRI





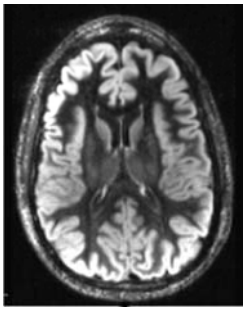
Double Inversion Recovery

- An inversion recovery variant that uses two nonselective 180°-inverting pulses
- To suppress two different tissues in one imaging sequence



Clinical applications

- Brain imaging: for detection of multiple sclerosis plaques and lesions of the cerebral cortex
- first 180°-pulse suppresses CSF and the second suppresses white matter



Disadvantages of IR

- Longer scan times
- Increase in flow-related artifacts
- Signal-to-noise can decrease as tissues are suppressed
- Higher specific absorption rate (SAR) due to additional 180° pulses

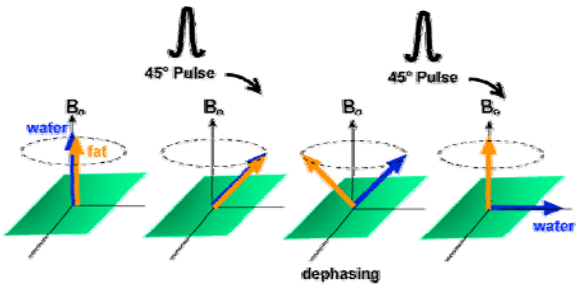
Water Excitation Pulses

- Compared with Fat-sat pulse:

--- Both based around the use of chemically selective RF-pulses

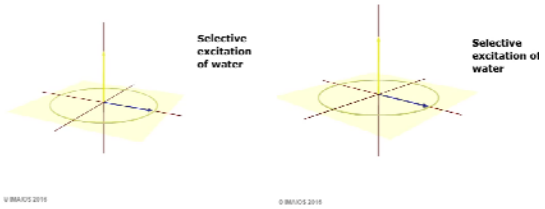
--- In Fat-Sat, fat protons are selectively excited and then dephased with a spoiler gradient

--- In WE, fat protons are left alone and water protons are selectively stimulated for image generation. No spoilers are used



Water Excitation

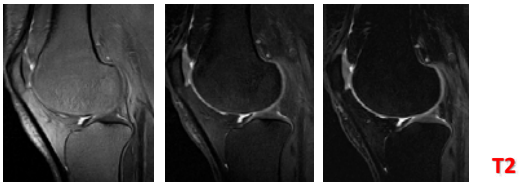
1-1 **1-2-1**



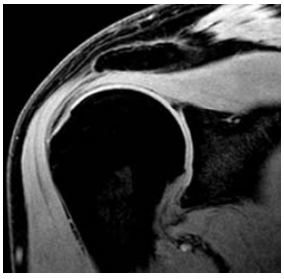
https://www.imaios.com/cn/node_50437/e-MRI/Improving-MRI-contrast-Imaging-water-and-fat/selective-excitation

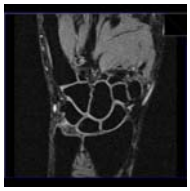
The type of Water Excitation

- 1:1 (45° : 45°)
- 1:2:1 (22.5° : 45° : 22.5°)
- 1:3:3:1 (11.75° : 33.25° : 33.25° : 11.75°)

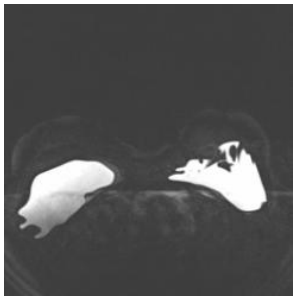


1:1 1:2:1 1:3:3:1





Silicone Implant Imaging



- **Water Saturation +STIR**

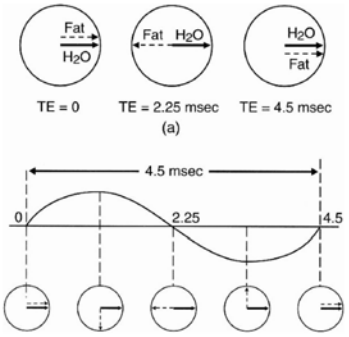
In-Phase vs. Out-of-Phase

- Chemical misregistration

--- Chemical Shift of the "Second Kind"

- Also produced as a result of the processional frequency different between fat and water.
- Caused because fat and water are in phase at certain times and out of phase at others.

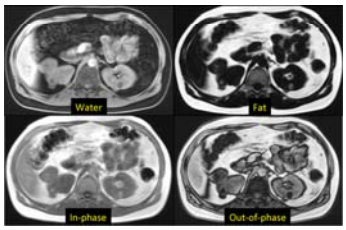
The phase VS. echo time



Dixon method

IP = W + F ***OP = W – F***

½ [IP + OP] = ½ [(W+F) +(W–F)] = ½ [2W] = W → Water only image
and
½ [IP – OP] = ½ [(W+F) – (W–F)] = ½ [2F] = F → Fat only image

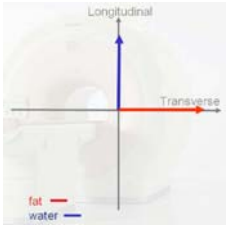


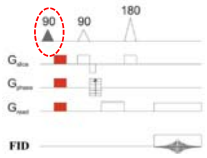
- Modern Dixon methods combine 3 echoes acquired at different TE's to create water-only and fat-only images
- Relatively insensitive to both B_o and B_1 inhomogeneities
- Most useful in abdominal imaging at 3T

Spectral Presaturation with Inversion Recovery (SPIR)

- Combines a fat-selective RF-pulse and spoiler gradient (similar to CHESS) together with nulling of the residual longitudinal fat magnetization through an inversion delay mechanism (similar to STIR).

How does SPIR working??





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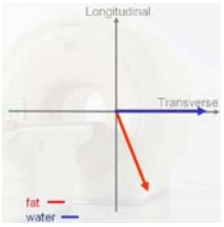
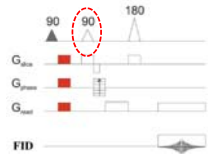
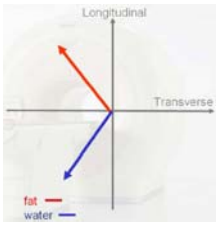
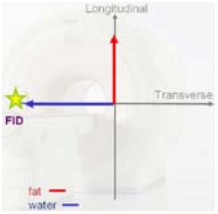


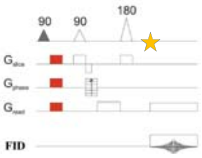


How does SPIR working??

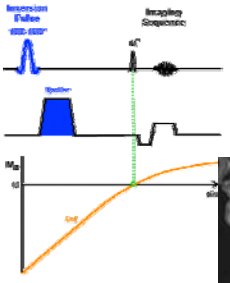


How does SPIR working??

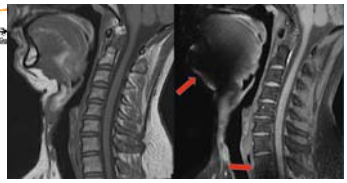




About SPIR



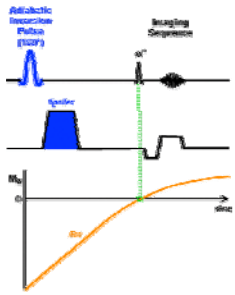
- SPIR is a *hybrid* fat-suppression technique that combines features of CHESS and STIR:
  - Selective RF-saturation of fat, and
  - Nulling of residual fat by inversion delay
- Sensitive to B_0 and B_1 inhomogeneities



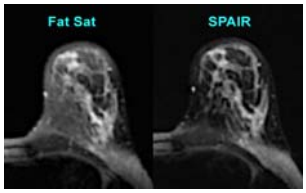
Spectral Attenuated Inversion Recovery (SPAIR)

- Like SPIR, is a hybrid technique combining features of both CHESS and STIR
- With a 180º-inverting pulse tuned to the fat resonance
- Nulling of the residual longitudinal fat magnetization through an inversion delay mechanism (similar to STIR)

About SPAIR



- SPAIR is identical to SPIR except SPAIR uses a full 180° adiabatic inversion pulse
- Adiabatic pulses are less sensitive to B_1 non-uniformities
- SPAIR provides better fat suppression than SPIR or CHESS, but with time penalty



SPIR vs. SPAIR

SPIR

SPAIR

Flow signal suppression

Normal Appearance of Flowing Blood

- Time of flight (TOF) effects

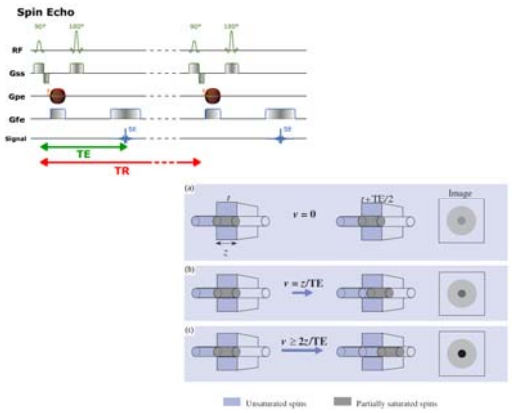
--- Signal loss (*high-velocity signal loss or TOF loss)*

--- Signal gain (*flow-related enhancement [FRE])*

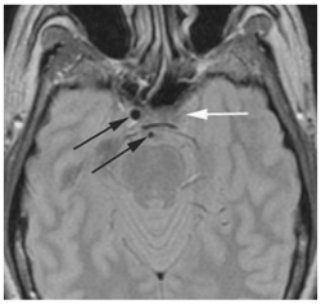
- Motion-induced phase changes

High-Velocity Signal Loss "black blood"

- In spin-echo (SE) imaging, the protons must be exposed to both a 90^0 and a 180^0 radio frequency (RF) pulse to give off a signal.
- High-velocity signal loss or time-of-flight (TOF) loss occurs when flowing protons do not remain within the selected slice long enough to be exposed to both RF pulses.

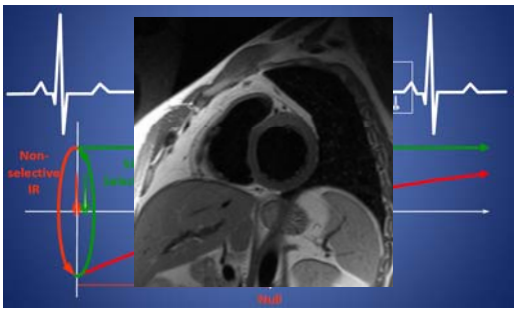


PDW axial image



"black blood" imaging

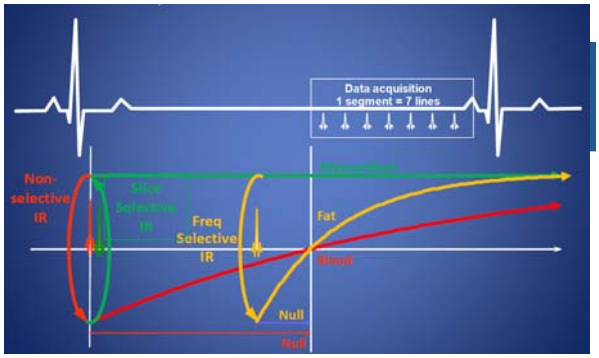
- Commonly used in cardiovascular MRI
- The first 180°-pulse is nonselective, inverts the magnetization for all slices within the imaging volume
- The second 180°-pulse, following immediately on the heels of the first 180°-pulse, is slice selective, returns the magnetization of all tissues *in that slice only* back to the +*z*-direction



How about *"Triple IR"* ?

- It is possible to use a third (or even fourth) 180°-pulse in conjunction with a black blood DIR technique. This third pulse is commonly used to suppress pericardial fat, producing a ***triple inversion recovery (TIR)***sequence, that is a combination of STIR plus black blood DIR.

Clinical applications



休息一下，喝口水吧!!