SAWA UNIVERSITY

مادة الرنين المغناطيسي/الكورس الاول

MRI SEQUENCES

Sawa University — جامعـــــــــة ســـــــــاوة الاهلية

College of health and medical techniques — كليــــــة التقنيـــــات الصحيـة والطبيـة

Department of Radiology Tech. — قسم تقنيات الاشعة والسونار

Fourth Stage — المرحلـــــــــــــــة : الرابعة

الجانب النظري — محاضرة رقم 3

Lecture No. 3. — Theoretical

تدريسي المادة : المحاضر م .م فاضل عوفي عواد

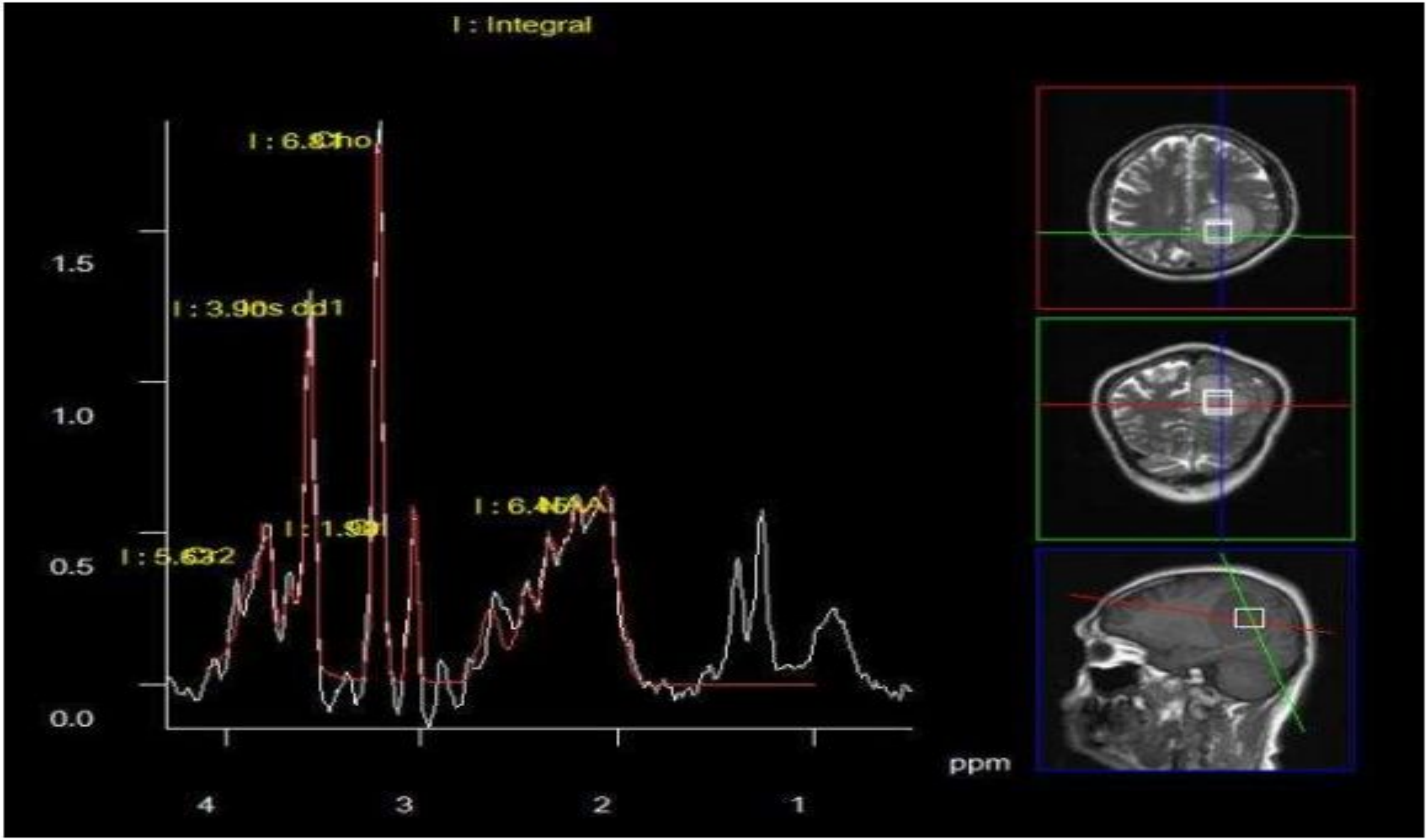
T1WI	**Provides anatomical details and helps assess tumor' s location and relationship to nearby structure.**
T2WI	**Highlights differences in tissue water content and is valuable for characterizing soft tissue tumors and tumor' s extent.**
Fat suppression	**Suppresses the signal from fat, enhancing the visibility of lesions esp. when tumor involve the skull base.**
Delayed contrast MRI	**Highlighting the tumor and assess its vascularity.**
DWI	**Measures the diffusion of water molecules in tissues, which can aid in differentiating between benign and malignant tumor.**
Post-con (T1)	**Highlight the enhancement pattern of the tumor and its relationship to nearby structures.**

FLAIR	**It is necessary to assess the white matter tumor involvement and related vasogenic edema.**
SWI	**Identify blood products or classifications within the tumor.**
Perfusion	**Elevation of CBV is generally related with a high-grade tumor.**
MRS	**Metabolic peaks characterization**

Perfusion = BV (blood volume), BF (blood flow), MTT (mean transit time) and TTP (time to peak)

Key Metabolites

1. **N-Acetylaspartate (NAA)**:
   - Marker of neuronal health.
   - Typically found at around 2.0 ppm.
2. **Choline (Cho)**:
   - Associated with cell membrane turnover.
   - Peaks at approximately 3.2 ppm.
3. **Creatine (Cr)**:
   - Indicator of energy metabolism.
   - Peaks at around 3.0 ppm.
4. **Lactate**:
   - A marker of anaerobic metabolism.
   - Appears at 1.3 ppm.


I : Integral
1.5
1.0
0.5
0.0
4
3
2
1
ppm

Introduction:

There are many different pulse sequences available, and each is designed for a specific purpose. The image weighting, contrast and quality is determined by the type of pulse sequence we use.

Scientific Content:

A pulse sequence is interplay of various parameters leading to a complex cascade of events **with RF pulses and gradients to form a MR image** (Fig. 1). So, pulse sequence is a time chart of interplay of—

1. Patient's net longitudinal magnetization.
2. Transmission of RF pulses (90, 180 degree or any degree).
3. X, Y and Z gradient activation for localization and acquisition of signal (echo).
4. K-Space filling with acquired signals or echoes.

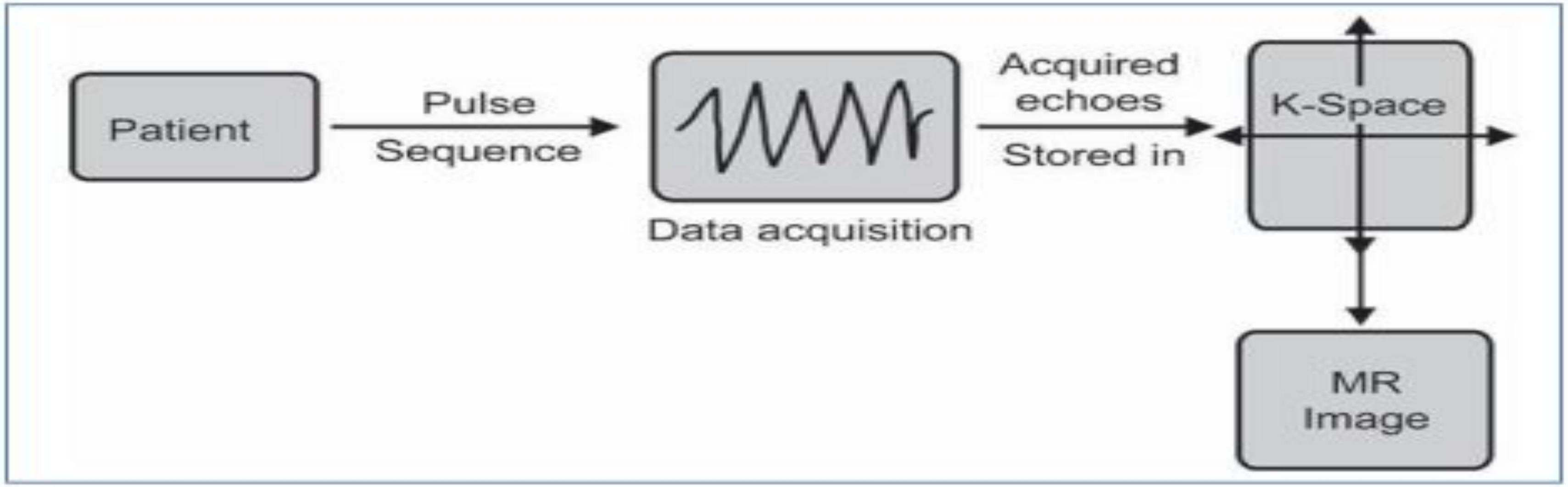
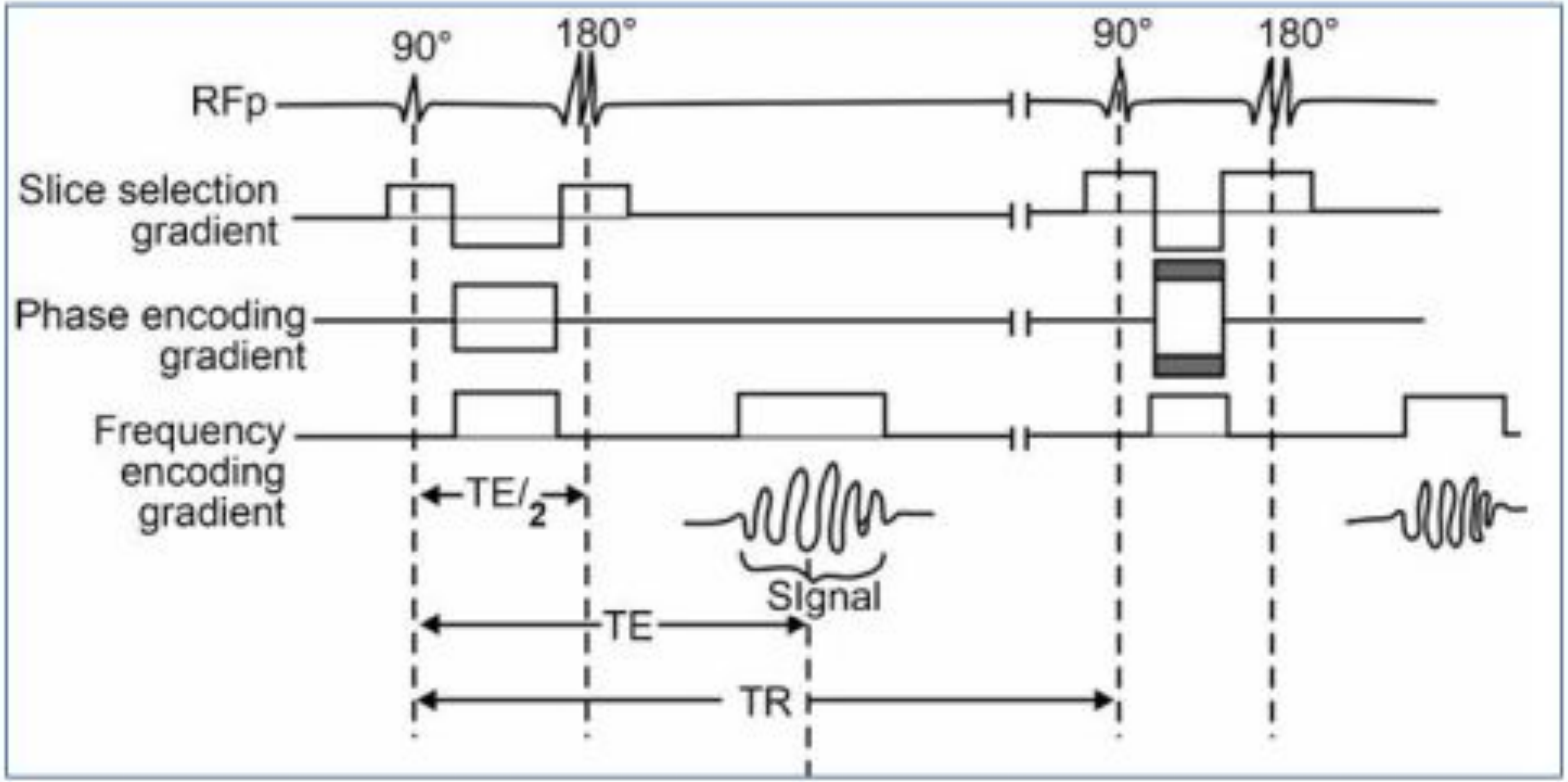
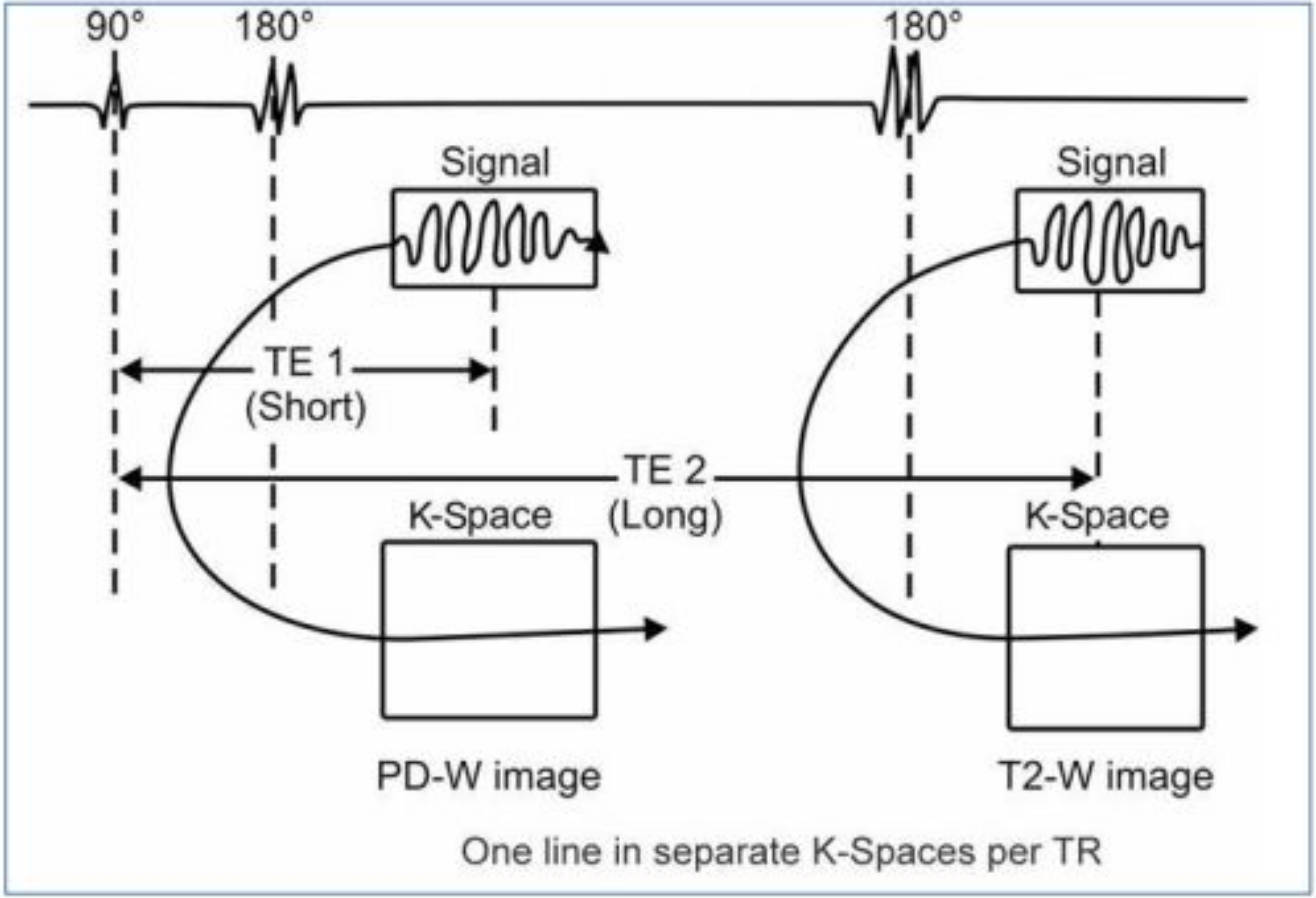
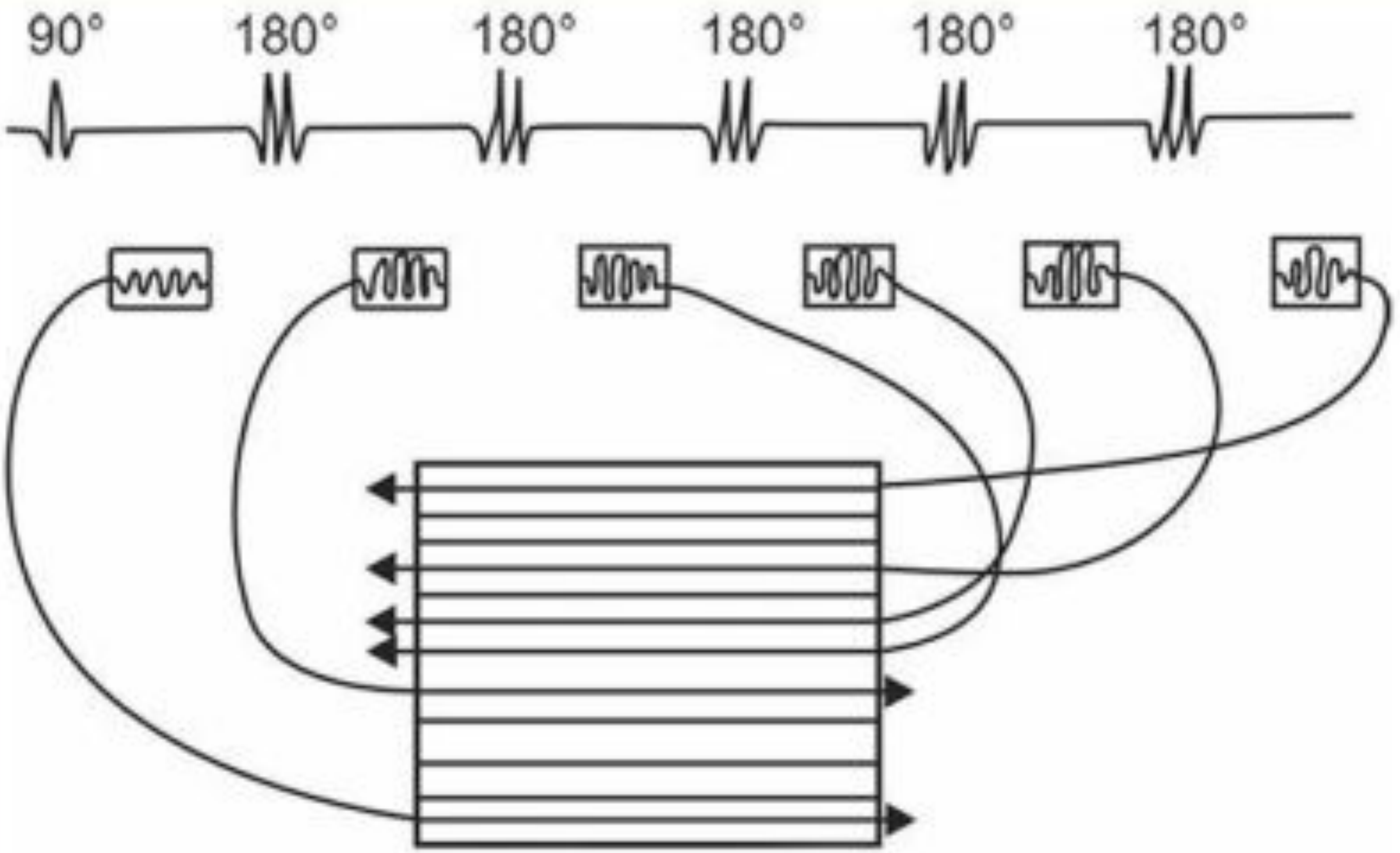


Fig. 1: Steps in image acquisition

For the localization of the signal, slice selection gradient is turned on when RF is sent. Phase encoding gradient is turned on between excitation (90 degree) pulse and signal measurement. Phase encoding gradient has different strength for each TR. Frequency encoding (read out gradient) is turned on during signal measurement.

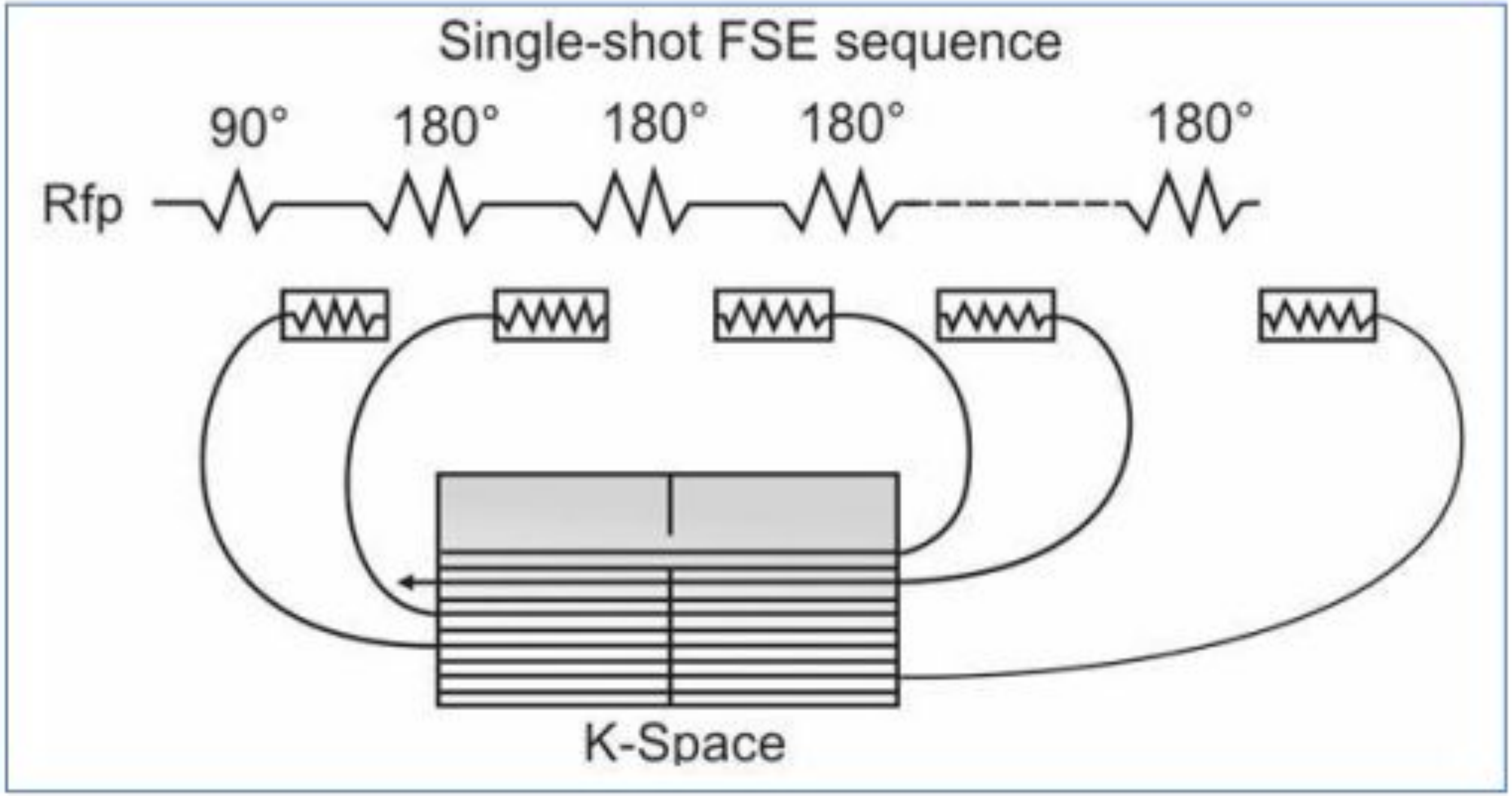



90°
180°
180°
Signal
Signal
TE 1
(Short)
TE 2
(Long)
K-Space
K-Space
PD-W image
T2-W image
One line in separate K-Spaces per TR



Multiple echoes contribute (multiple k-lines filled) to single K-Space per TR

C- SINGLE-SHOT FAST SPIN-ECHO Sequence: This is a fast SE sequence in which **all the echoes required to form an image are acquired in a single TR.** Hence it is called '**single-shot' sequence**. In this sequence, not only all K-Space lines are acquired in a single excitation but also just **over a half of the K-Space is filled reducing the scan time further by half** (Fig. 5). **The other half of the K-Space is mathematically calculated with half-Fourier transformation.**



PULSE SEQUENCES

Types

1. Spin echo (SE) pulse sequences
a. Conventional spin echo (CSE) pulse sequence
b. Fast spin echo (FSE) pulse sequence
2. Inversion recovery (IR) pulse sequences
a. STIR (short inversion recovery)
b. FLAIR (fluid attenuated inversion recovery)
3. Gradient echo (GE) pulse sequences
a. Coherent gradient echo pulse sequence
b. Incoherent gradient echo pulse sequence
4. Steady state free precession (SSFP)
5. Ultrafast imaging
6. Echoplanar imaging

Conventional Spin Echo (CSE) Pulse Sequence

In this pulse sequence, a 90° excitation RF pulse is given followed by 180° rephasing RF pulse.

Uses

- **These are the most commonly used pulse sequences**
- **May be used for almost every examination**
- **Produce optimum signal-to-noise ratio (SNR) and contrast-to-noise ratio (CNR)**
- **T1, T2 and proton density weighting is possible**

Advantages

- **Good image quality**
- **True T2 weighting is possible.**

Disadvantages

- **Scan times are relatively long**
- **More RF power deposition in the body**

Fast Spin Echo (FSE) Pulse Sequence

In this type of pulse sequence, 90° excitation RF pulse will be delivered followed by several 180o rephasing RF pulses. In conventional spin echo (CSE), only one line of K-space is filled per TR. So the CSE takes longer scan time. But in fast spin echo several lines of K-space will be filled per
TR. Because of this reason, the scan times are reduced in fast spin echo. The number of lines of K-space filled per TR is referred to as Turbo Factor (tf) (or) echo train length (ETL). More the ETL, less the scan time (Fig. 1).

Uses

• Can be used as an alternative to spin echo
• Reduction in the scan time compared to conventional spin echo.

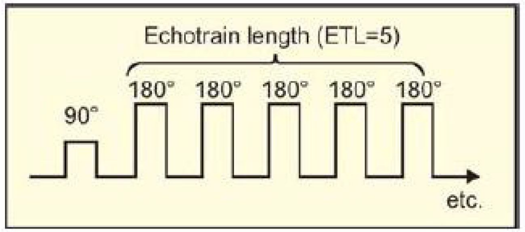
Advantages

• Scan times are greatly reduced
• High resolution matrices and multiple NEX can be used
• Improved image quality.

Disadvantages

• Fat remains bright on T2 weighted images
• Image blurring may result

Fig .(2): Schematic illustration of fast spin echo



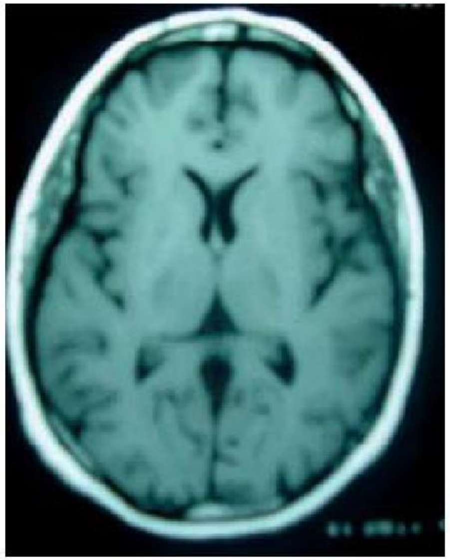


Fig. 5.2: Spin echo T1W1 CSF appears dark

Fig. 5.3: Spin echo T2W1 CSF appears bright

Inversion Recovery (IR) Pulse Sequences

These pulse sequences use 180° inverting RF pulse followed by 90° excitation RF pulse after certain time [Inversion Time (IT) or Time from Inversion (TI)].

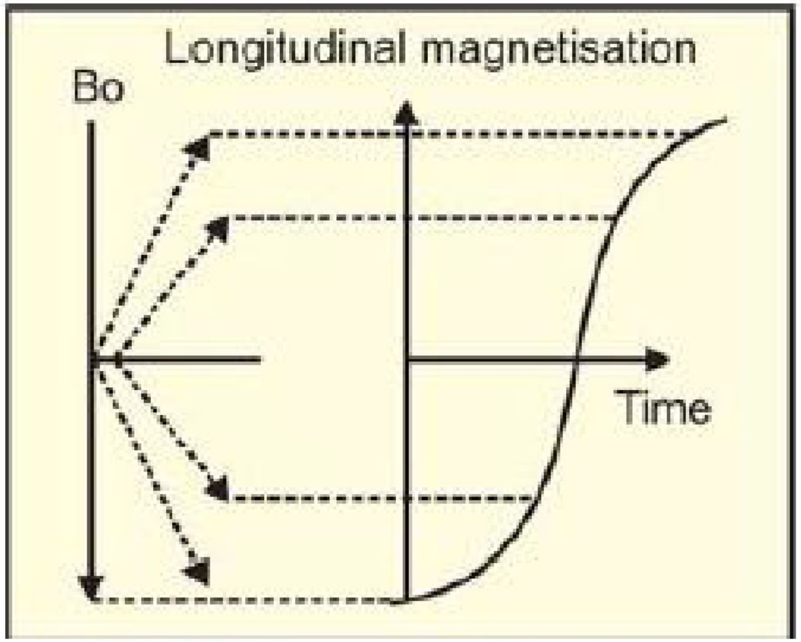


Fig. 5.5: Recovery from inversion

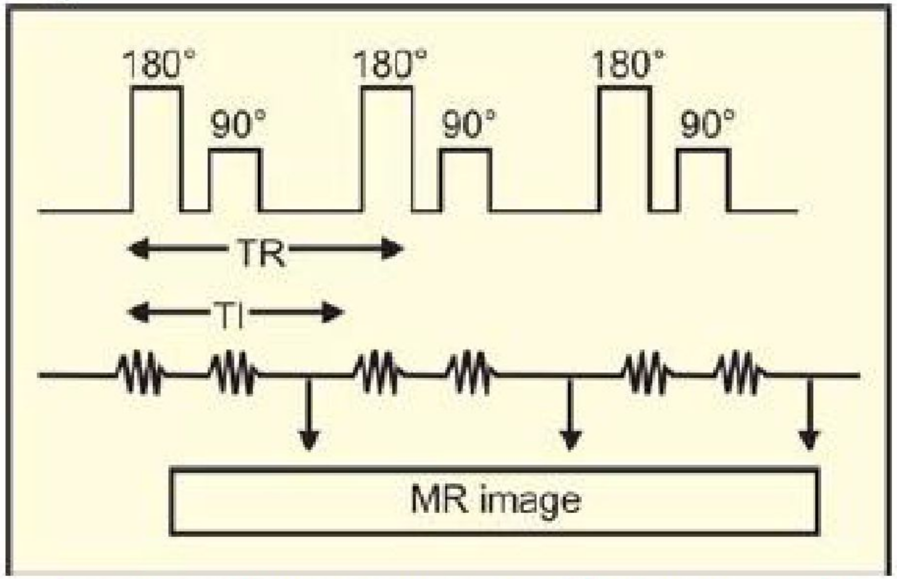


Fig. 5.6: Schematic illustration of the inversion recovery (IR) pulse sequence

Depending on the TI value, we can classify the IR sequences into:
1. Short inversion recovery (STIR)
2. Fluid attenuated inversion recovery (FLAIR)
If we apply 180° inverting RF pulse, the NMV (net magnetic vector) will be
inverted through 180° into full saturation. When we remove the inverting pulse, the
NMV begins to relax back to Bo (static external magnetic field) A 90° excitation
pulse is then applied at a time from the 180° inverting pulse known as the TI time
(Time from Inversion). The contrast of the image depends on the TI value (Fig. 3&4).
These sequences are used to generate heavily T1 weighted images bringing large
difference between fat and water.

Advantages

- Produces heavily T1 weighted images
- Very good signal-to-noise ratio (SNR).

Disadvantage

- Long scan times.

STIR (Short Inversion Recovery) Pulse Sequence

This sequence is used to suppress the fat signal from the anatomy of interest. Here we use a TI value that corresponds to the time it takes fat to recover from full inversion to the transverse plane so that there is no longitudinal magnetization corresponding to fat. When the 90° RF excitation pulse is applied, the fat is flipped 90° to 180°, so there will not be any fat signal. It will suppress the fat in STIR. Generally, a TI value of around 100-200 ms is used. This TI value may slightly vary depending on the field Strength.

Uses

• Used to suppress the fat signal in T1 weighted image.

Disadvantage Should not be used with contrast enhancement.

Parameters

FLAIR (Fluid Attenuated Inversion Recovery)

It is another variation in the IR pulse sequence which uses a TI value around 2000 ms. Usually, this sequence is used to suppress the signal from CSF containing areas.

Gradient Echo (GE) Pulse Sequences

These sequences use variable flip angles and lesser repetition time (TR). The gradients are used to rephase the protons. We can apply the gradients quickly to

rephase the protons (unlike 180° rephasing pulses in spin echo which takes
some
time to apply) (Figs 6 and 7). Because of the quicker application of gradients
and
reduced repetition time and smaller flip angles, the scan times are greatly
reduced
in gradient echo pulse sequences. With this sequence, we can get T1
weighting,
proton density weighting and T2* weighting.

Fig.(7): Image obtained with gradient echo pulse sequence .blood vessels appear bright on gradient
echo
pulse sequences

Fig.(8): schematic illustration of gradient echo pulse sequences.

Since the gradient does not compensate for magnetic field inhomogeneities,
we
will get T2* weighting (Fig. 8).

Uses

- **Can be used to produce T1, proton density and T2*weighting**
- **Very minimal scan times**

- Can be used for single slice breath hold acquisitions in abdomen and dynamic
contrast enhancement
- Since these sequences are flow sensitive, can be used for MR angiography/MR
myelography
- Less RF deposition into the body, i.e. less specific absorption rate (SAR).

Disadvantages

- Less signal-to-noise ratio when compared to SE pulse sequences
- True T2 weighting is not possible (T2* contrast rather than true T2)
- More work for the gradients
- More noise to the patient.

Steady State

In this state, the selected TR will be shorter than the T1 and T2 times of the tissues.

In this state, there will be coexistence of both longitudinal and transverse magnetization.Most gradient echo sequences use the steady state.

Generally, flip angles of 30° to 45° with TR of 20 to 50 ms favours the steady state.

Depending on the residual transverse magnetization in phase (or) out of phase GE pulse sequences are classified into:

1. Coherent (in phase) gradient echo pulse sequence
2. Incoherent (out of phase) gradient echo pulse sequence.

Coherent (in phase) Gradient Echo Pulse Sequences

These sequences use a variable flip angle excitation pulse followed by a frequency encoding gradient rephasing to produce a gradient echo. Here the steady state is maintained by selecting a TR shorter than the T1 and T2 times of the tissues. In this sequence, the tissue with long T2 values appear with high signal intensity.

Uses

- **Increased T2* Dependence**
- **Very fast scans**
- **Preserves the transverse signal**
- **Good for angiography**
- **Can be acquired in a volume acquisition.**

Steady State Free Precession (SSFP)

These sequences are used to attain more T2 weighting. In this sequence the steady state is maintained.

Advantages

- True T2 weighting is achieved
- Can be acquired in volume or 2D

Disadvantages

- Loud gradient noise
- Poor image quality

Ultrafast Sequences

- These sequences use coherent (or) incoherent gradientecho pulse sequences
- Only a portion of the RF pulse is used
- Only a portion of the echo is read

Because of the

Disadvantages

• More gradient noise to the patient

POOR SNR IN 2D ACQUISITIONS COMPARED TO SPIN ECHO.

• MORE MAGNETIC SUSCEPTIBILITY.

incoherent (spoiled) gradient

echo pulse sequences

these pulse sequences begin with a variable flip angle excitation pulse and use

frequency encoding gradient rephasing to give a gradient echo. these sequences

spoil (or) dephase the residual transverse magnetization so that its effect on image

contrast is minimal.

uses

• increased t1 weighting

• spoils the transverse signal

• only the longitudinal signal contributes to the next rf pulse

• good snr in volume acquisition

• can be acquired in 2d (or) volume

ECHOPLANAR IMAGING (EPI)

PERFUSION WEIGHTED IMAGING (PWI)

This is a type of dynamic MR imaging by using GRE (or) EPI sequences with
contrast enhancement to study the uptake of contrast medium by the lesion. This
technique can be used in abnormalities of brain, pancreas, liver and prostate.

DIFFUSION WEIGHTED IMAGING (DWI)

In this type of MR imaging either GRE (or) EPI sequences are used to demonstrate
the areas with restricted diffusion of extracellular water such as infarcted tissue.
High signal intensity appears at the area of restricted diffusion. DWI is mainly
useful in brain to differentiate salvageable and non salvageable tissue after brain
stroke.

FUNCTIONAL MRI (FMRI)

It is a dynamic MR imaging Technique that acquires images of the brain during stimulus and also at rest. Then the two sets of images are subtracted to demonstrate functional brain activity. This technique is called BOLD (blood oxygenation level dependent). At the activated areas of brain, there will be increased signal intensity.

fMRI is useful in evaluating the brain activity in the disorders of epilepsy, stroke and behavioural problems.

MAGNETIZATION TRANSFER (MT) CONTRAST

This is a technique used to suppress the background tissue thereby increasing the conspicuity of vessels and certain disease processes. MT contrast is useful indiagnosing hemorrhage, AIDS, multiple sclerosis and also to improve contrast in TOF-MRA images by suppressing background tissue.

MAGNETIC RESONANCE ANGIOGRAPHY (MRA)

MRA is a technique which allows us to acquire the images with high signal from flowing nuclei and low signal from stationary nuclei. This technique will allow us to see the blood vessels more clearly than surrounding. Generally, GRE pulse sequences are used to show flowing vessels as bright.

There are two types of MRA techniques available. They are: 1) Time of flight (TOF-MRA and 2) Phase-contrast MRA (PC-MRA).

Time of Flight MRA (TOF-MRA)

This technique commonly uses incoherent GRE pulse sequences in conjunction with TR and flip angle combinations that saturate background tissue but allowing moving spins to show high signal intensity. This technique is used in demonstrating arterial and venous flow in head, neck and peripheral vessels.

Phase Contrast MRA (PC-MRA)

This technique usually uses coherent GRE sequences. It provides excellent background suppression. But the scan times with PC-MRA are longer than the scan times of GE pulse sequences are flow sensitive hence used for MRA (magnetic resonance angiography).

Thank You