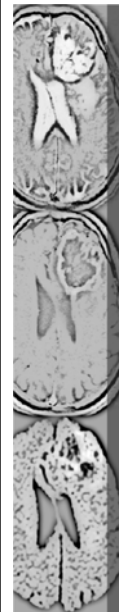




磁振影像學MRI 磁振假影

盧家鋒 副教授

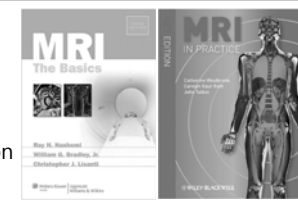
國立陽明交通大學
生物醫學影像暨放射科學系
alvin4016@nycu.edu.tw



本週課程內容 <http://cflu.lab.nycu.edu.tw>

- 磁振假影

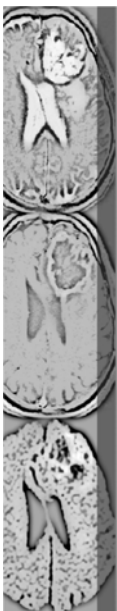
- MRI The Basics (3rd edition)
 - Chapter 18: Artifacts in MRI
- MRI in Practice, (4th edition)
 - Chapter 7: Artefacts and their compensation



<http://cflu.lab.nycu.edu.tw>, Textbook: MRI The Basics, Hashemi et al.

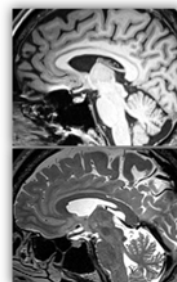
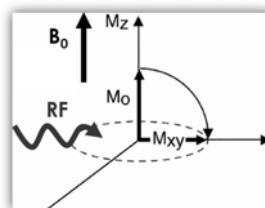
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Procedure of MRI

- Alignment (magnetization) B_0
- Precession $\omega_0 = \gamma B_0$
- Resonance (given B_1 by RF with ω_2) $\omega_1 = \gamma B_1$, $\nu_1 \perp \nu_0$
 - The most effective resonance is produced when $\omega_0 = \omega_2$
- MR signal (EMF, relaxation time)
- Imaging (Pulse sequencing: SE, GRE, EPI)
 - Tissue Contrast: Image weighting
 - Spatial localization: Slice selection & Spatial Encoding
 - Data space/K space
- Tissue Suppression Techniques
- Artifacts in MRI



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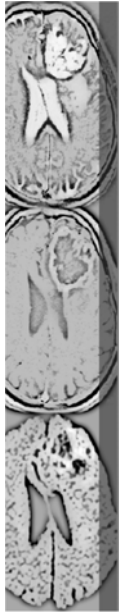
磁振假影

Artifacts in MRI

<http://cflu.lab.nycu.edu.tw>, Textbook: MRI The Basics, Hashemi et al.

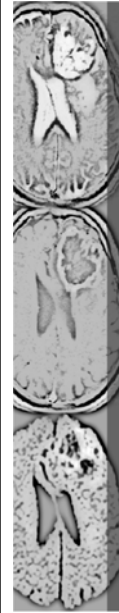
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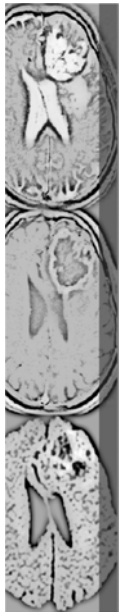
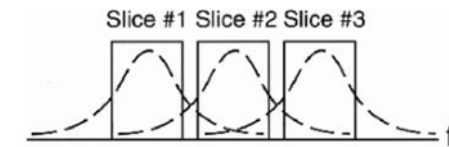
Hardware-related Artifacts

- **Radio frequency (RF)-related artifact**
 - Cross-talk
 - Zipper artifacts
- **External magnetic field artifacts**
 - Magnetic inhomogeneity
- **Gradient-related artifacts**
 - Eddy currents
 - Nonlinearity
 - Geometric distortion



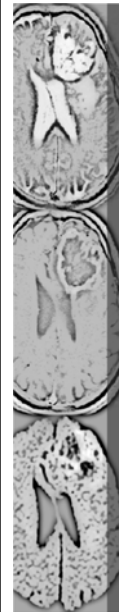
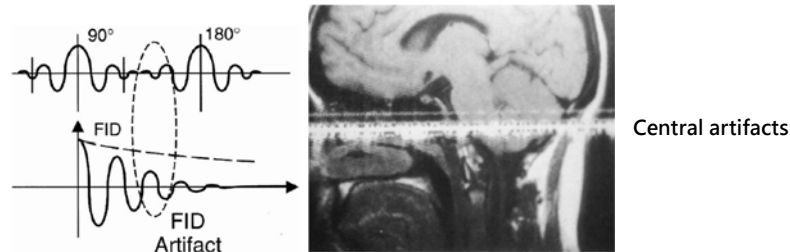
RF-related artifacts: Cross talk

- An imperfect rectangle of the FT of the RF pulse
- Decrease TR due to saturation of protons by the RF for adjacent slices.
- T1 weighting \uparrow and SNR \downarrow
- Remedy: interleaving, increase gap, rectangular wave



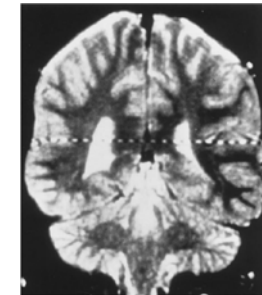
RF-related artifacts: Zipper artifacts

- Along the phase encoding axis at zero frequency
 - Cause 1, RF feed-through: excitation RF pulse \rightarrow receiver coil
- Along the frequency-encoding axis without phase encoded
 - Cause 2, Stimulated echo: imperfect RF pulses of adjacent slices, imperfect 90° - 180° - 180° pulses
 - Cause 3, FID artifact: the overlapping of 180° RF pulse with the FID



RF-related artifacts: Zipper artifacts

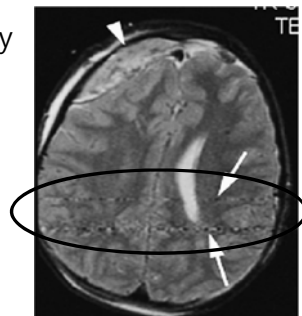
- Remedy to FID artifact:
 - Increase TE (increase the separation between FID and RF pulse)
 - Increase slice thickness (a wide RF BW narrows RF signal in the time domain)
- Remedy to stimulated echo:
 - Use spoiler gradients
 - Adjust the transmitter



Central artifacts

RF-related artifacts: Zipper artifacts

- Unwanted external RF noise (TV, radio station, electronic monitoring equipment)
- Occurs at the specific frequency
- Remedy: improve RF building, shut the door of MR room



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External magnetic field artifacts

- Improper shimming, environmental factors, far extremes of short bore magnets
- Remedy: auto shimming

Moire fringes (zebra pattern)

T2 fat-suppressed image

Upper slice

Lower slice

Distortion & lack of effective fat suppression

T1 image

ortion

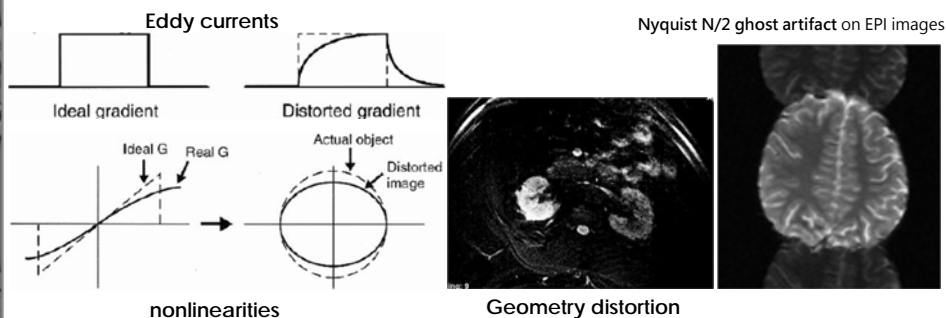
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Gradient-related artifacts

- Eddy currents are generated when the gradients are rapidly switched on and off, resulting in a distortion in the gradient profile.



Nyquist N/2 ghost artifact on EPI images

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Software-related Artifacts

- Image processing artifact
 - Aliasing
 - Chemical shift
 - Truncation
 - Partial volume

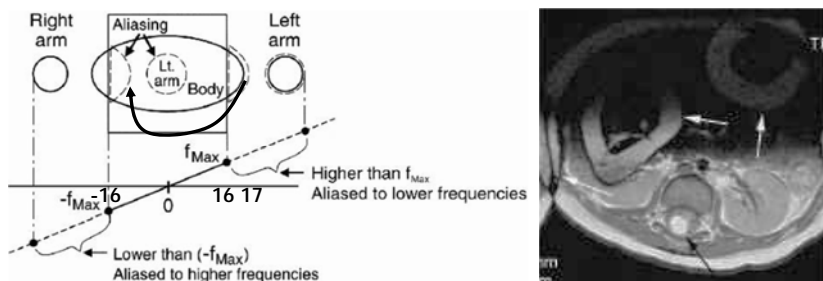
<http://cflu.lab.nyu.edu.tw>, Textbook: MRI The Basics, Hashemi et al.

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Image processing Artifacts: aliasing

- Any frequency higher than the maximum frequency allowed by the gradient cannot be detected correctly.
- $f(\text{perceived}) = f(\text{true}) - 2f(\text{max})$



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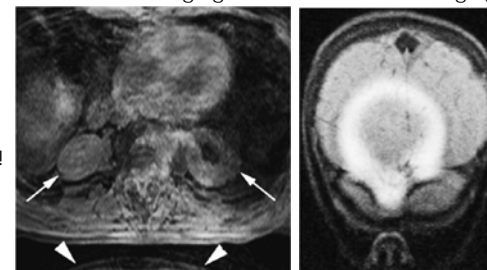
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Image processing Artifacts: aliasing

- 2D imaging: along frequency-encoding or phase-encoding directions
- 3D imaging: in all three directions

3D axial imaging

3D coronal imaging



Kidneys in lungs!

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Image processing Artifacts: aliasing

- Remedy
 - Increase FOV (may reduce spatial resolution)
 - Use surface coils that only covers the area within FOV.
 - Frequency or phase oversampling ("No Phase Wrap")
 - Use saturation pulses to saturate the signals outside the FOV.

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Image processing Artifacts: chemical shift

- The protons from different molecules precess at slightly different frequencies.
- The protons in H_2O precess slightly faster than those in fat (about 3.4 ppm).
- $\omega_0 = \gamma B_0 = (42.6 \text{ MHz/T})(1.5\text{T}) = 64 \text{ MHz}$
- $64 \text{ MHz} \times 3.4 \text{ ppm} = (64 \times 10^6 \text{ Hz})(3.4 \times 10^{-6}) \approx 220 \text{ Hz}$
- $B_0 \uparrow$, chemical shift \uparrow

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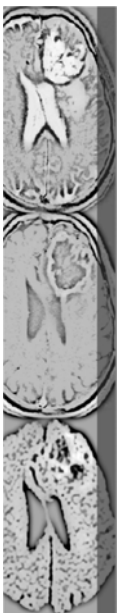


Image processing Artifacts: chemical shift

- $BW = N_x/T_s = 256/(8 \text{ ms}) = 32 \text{ kHz}$
- $BW/\text{pixel} = 1/T_s = 125 \text{ Hz}$
- Pixel difference (H_2O/fat) = $220 \text{ Hz} / 125\text{Hz} = 1.76 \text{ pixels}$
- Fat protons are going to be misregistered from H_2O by about 2 pixels (in a 1.5 T magnet using a standard 32kHz bandwidth).

$$\text{chemical shift (in mm)} = \frac{3.5 \times 10^{-6} \gamma B_0 \times FOV}{BW}$$

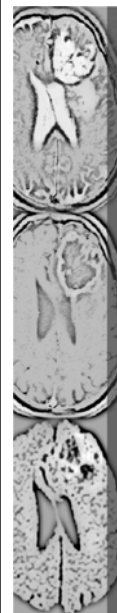
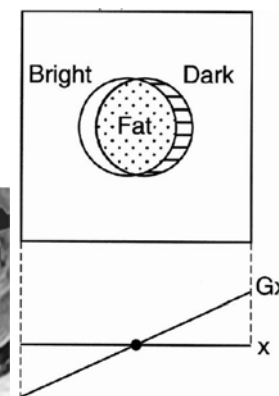


Image processing Artifacts: chemical shift

- Chemical shift artifact only occurs in the frequency-encoding direction.
 - A bright band toward the lower frequencies
 - A dark band toward the higher frequencies



T2 FSE

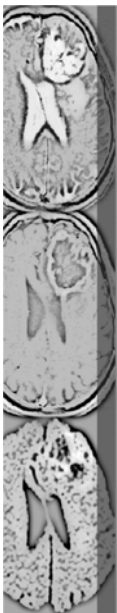
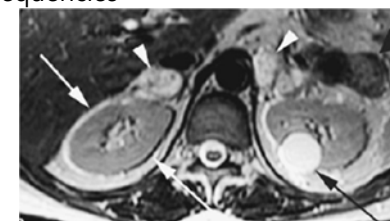
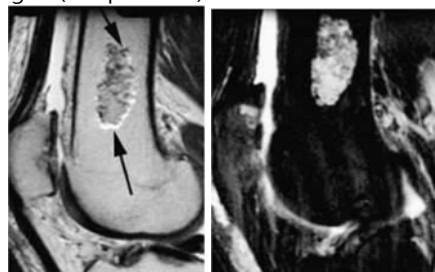
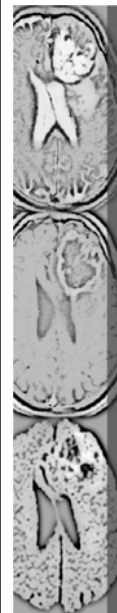


Image processing Artifacts: chemical shift

- Remedy:
 - Fat suppression
 - Increase pixel size by keeping FOV the same and decreasing N_x (spatial resolution \downarrow)
 - Lower the magnet's field strength (not practical)
 - Increase bandwidth (SNR \downarrow)
 - Use a long TE (less signal from fat)

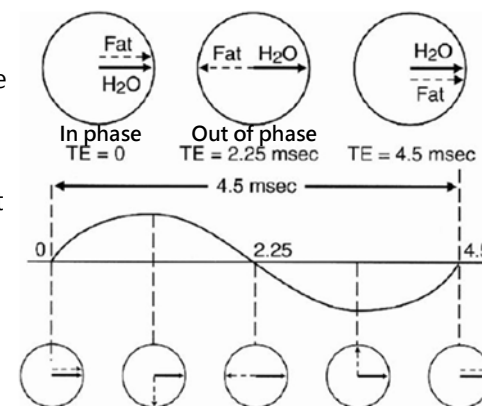


T2 with/without fat saturation



Chemical shift of the second kind

- 220 Hz at 1.5T:
- Fat and water are in phase every 4.5 msec.
- Only exist in GRE (without 180° rephasing pulse).
- Not only in the frequency-encoding direction



Chemical shift of the second kind

- Boundary effect (when out of phase)

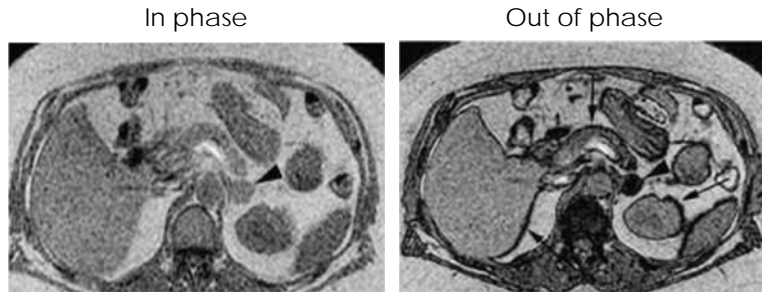


Image processing Artifacts: Truncation

- Truncation artifacts (Gibbs Phenomenon)
- Occurs at high contrast interfaces
 - Skull/brain, spinal cord/CSF, meniscus/fluid in the knee
- Due to insufficient samples for the large signal changes
 - Mostly seen in the phase direction (because fewer samples are usually taken)
- Causes alternating bright and dark bands
 - Pseudo syrinx of the spinal cord
 - Pseudo tear of the knee meniscus

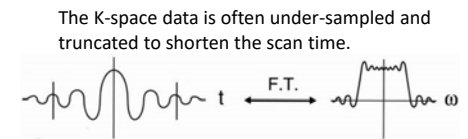


Image processing Artifacts: Truncation

- Remedy:
 - Decrease pixel size (increase phase encoding steps, reduce FOV)
 - Increase sampling time, increase sampling bandwidth

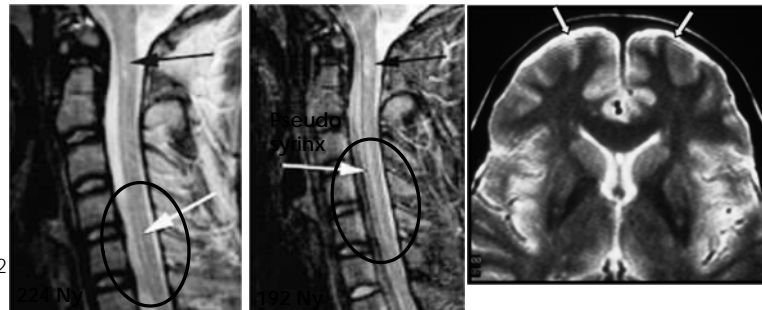
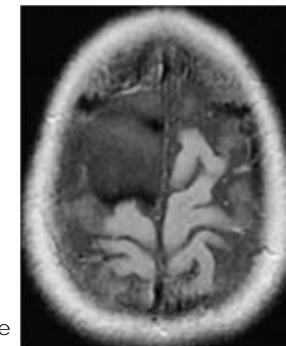
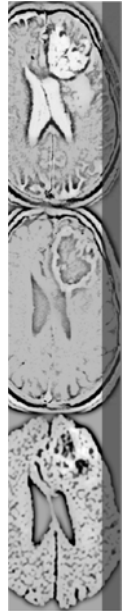


Image processing Artifacts: Partial volume

- Remedy: decrease the slice thickness

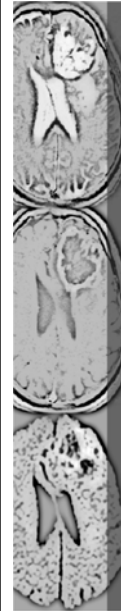


Axial FLAIR image



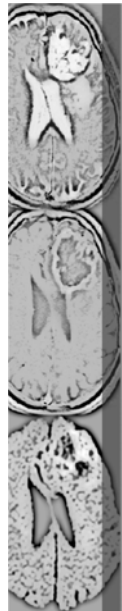
Subject-related Artifacts

- Motion artifacts
- Magnetic susceptibility artifacts
 - Diamagnetic, paramagnetic, ferromagnetic
 - Metal



Subject-related Artifacts: Motion

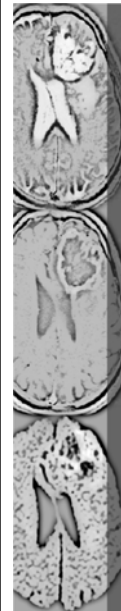
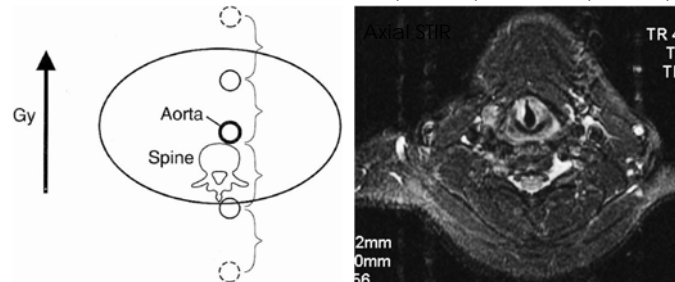
- Random movements, periodic motion (pulsating flow in vessels)
- We only get motion artifacts in the phase-encoding direction (the sampling time for frequency-encoding is short).



Periodic Motion

- Ghost artifacts of the vessels are equally separated along phase-encoding direction.

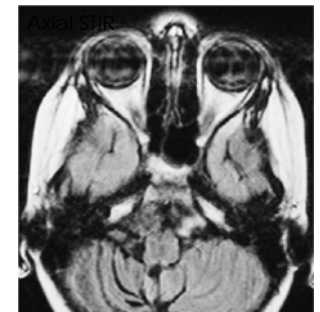
$$\bullet \text{ separation (SEP in pixels)} = \frac{TR \times Ny \times NEX}{T(\text{motion})} = \frac{\text{acquisition time}}{T(\text{motion})}$$



Motion artifacts

- Remedy for Periodic motion
 - Spatial presaturation pulses to saturate inflowing protons
 - Increase separation between ghosts
 - Swap phase and frequency (only change the direction of artifacts)
 - Use cardiac/respiration gating
 - Use flow compensation
- Remedy for random motion
 - Patient instruction: **don't move!**
 - Fast scanning techniques
 - Sedation

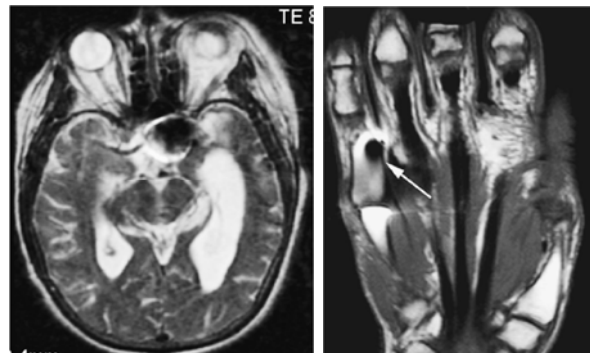
Random eye movements



Magnetic susceptibility artifacts

aneurysm clip

Metallic foreign body



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Magnetic susceptibility artifacts

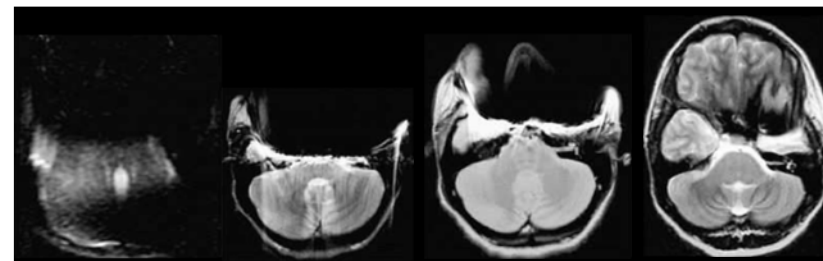
- A patient with dental braces

EPI B0

CSE T2

CSE PD

FSE T2



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- 請完整練習此部分國考題，很多臨床假影影像實例！
- 請閱讀ACR MRI phantom補充教材

THE END

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