The magic angle effect: a source of artifact, determinant of image contrast, and technique for imaging

Bydder M, Rahal A, Fullerton GD, Bydder GM.
J Magn Reson Imaging 2007;25:290-300. Chappell KE, Robson MD, Stonebridge-Foster A, et al.
AJNR 2004;25:431-440.

報告者：吳旻鎧
報告日期：114.3.5

BACKGROUND AND PURPOSE

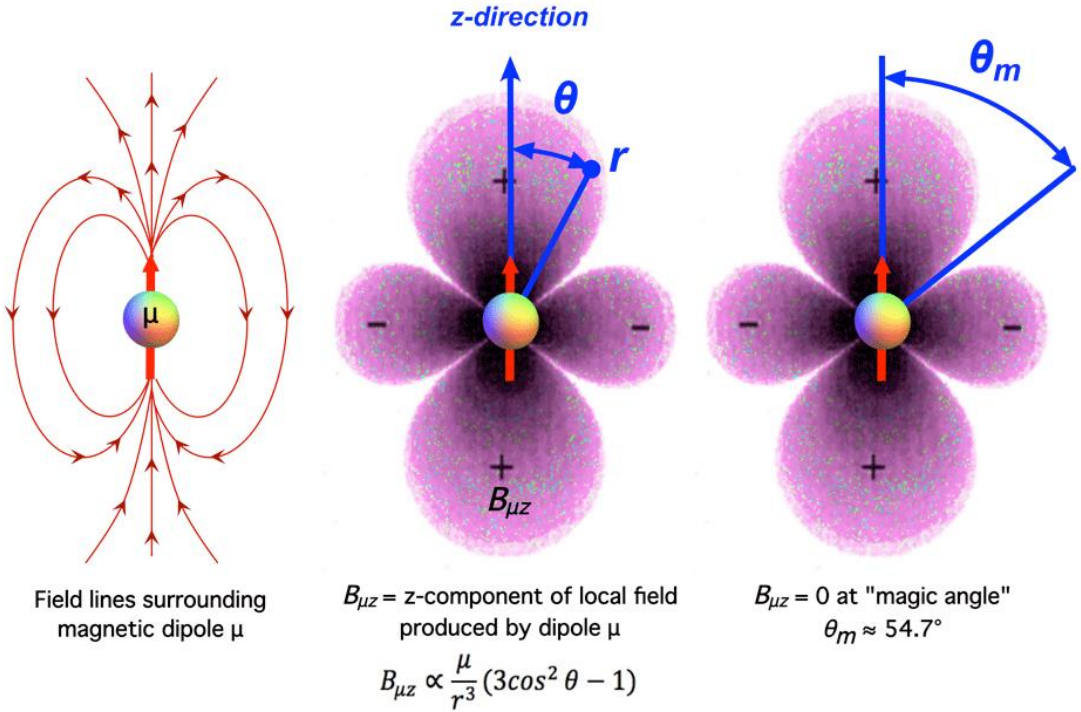
Magic angle effects are well recognized in MR imaging of tendons and ligaments, but have received virtually no attention in MR neurography. We investigated the hypothesis that signal intensity from peripheral nerves is increased when the nerve’s orientation to the constant magnetic induction field (B0) approaches 55° (the magic angle).

Magic Angle Effect(MAE、魔角效應)

受$B_{\mu z}$影響會使T2弛緩產生變化，當$B_{\mu z}$為0時(大約 54.7°、125.3°等等位置)使T2值增加

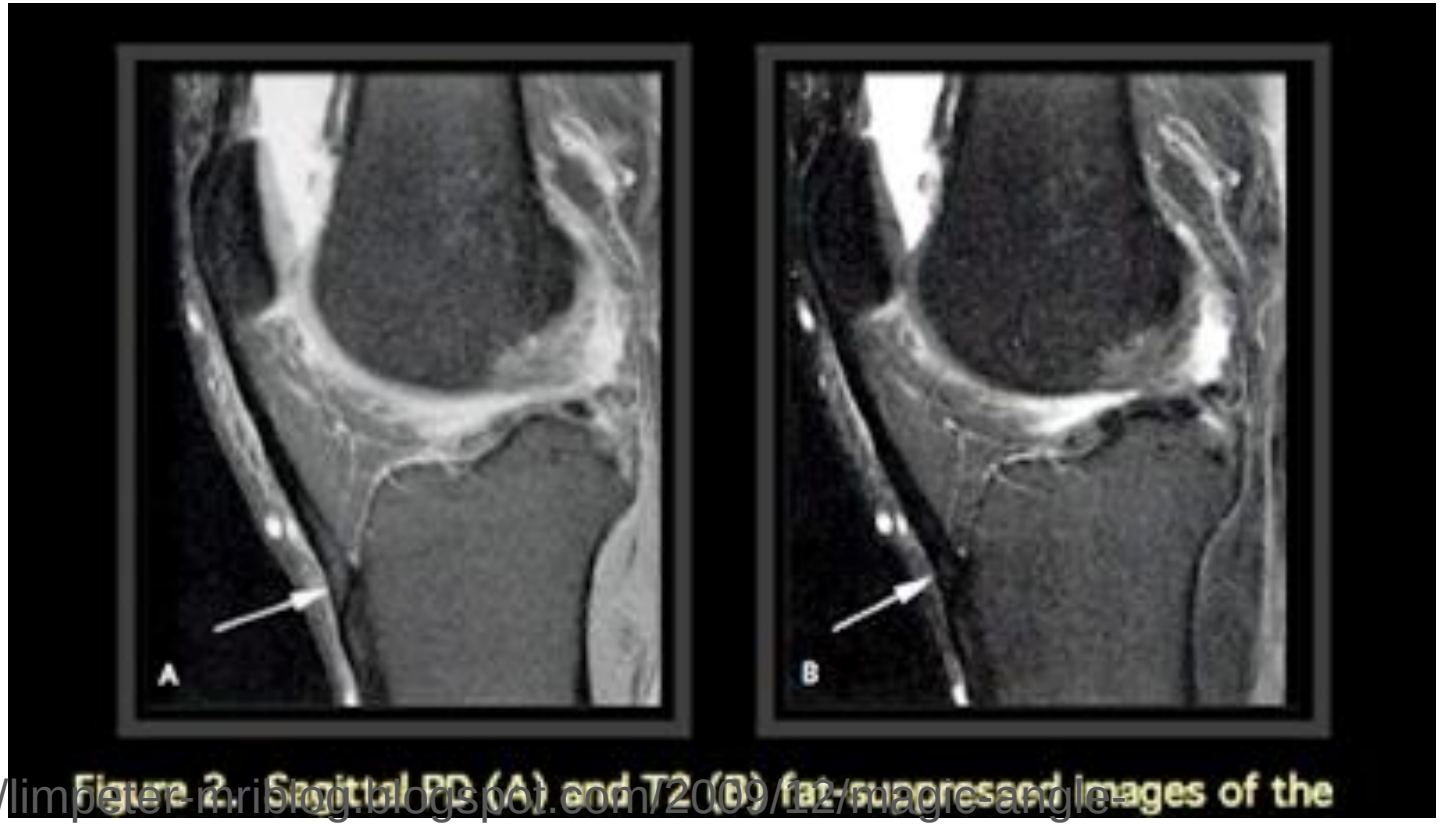
故在TE短波序(T1W、PDW)容易觀察到MAE的現象產生。

TE長波序(T2W)因給予足夠長的T2 Decay，則不會出現MAE。



資料來源：
https://mriquestions.com/magic-angle.html

Magic **A**ngle **E**ffect(**MAE**、魔角效應)

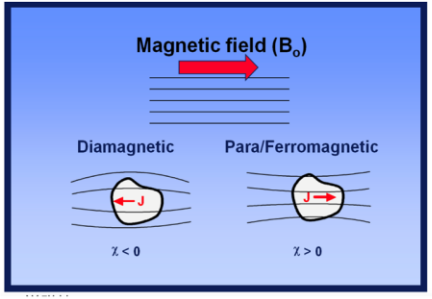


資料來源：https://limpeter-mrisog.blogspot.com/2009/12/magic-angle-phenomenon.html

Susceptibility Artifact

Susceptibility 磁化率

- 所有物質放在磁場中時，均有一定的磁化程度，而這些磁化程度大小不同；
  一個物質的感磁性（magnetic）以希臘字母 χ 表示。



- 當物質與磁場相互作用時，會產生內部磁化強度或極化(J)，從而對抗或增強外部磁場。
  J 是一種量子現象，主要由電子與外部磁場的相互作用所引起。
- 如果**極化與施加的場相反**，則物體內的有效場會減小，線會分散，這種效應稱為**抗磁性**。
- 如果**極化方向與外場相同**，則磁力線集中在物體內，導致**順磁性**、**超順磁性**或**鐵磁性**，取決於增強程度。

$\chi = J / Bo$ (磁化率是兩個磁場的比值)

$$\text{Susceptibility Artifact Size} \propto \frac{(\Delta\,\text{Susceptibility}) \cdot B_0 \cdot TE}{\text{Bandwidth}}$$

減少Susceptibility Artifact的方法
- 增加頻帶寬度（Increase bandwidth）：減少頻率變化對影像扭曲的影響。
- 使用 TSE（Turbo Spin Echo）序列：比 GRE 影像對磁敏感性影響較小。
- 增加影像解析度（Smaller voxel size）：減少單個體素內的磁場不均勻性。
- 改變影像方向（Change phase encoding direction）：減少重要區域的訊號錯位。
- 使用磁敏感校正技術（e.g., SEMAC, MAVRIC for metal artifacts）：特別用於降低金屬植入物的偽影。

- **抗磁性物質**（Diamagnetic substances）：具有**負**磁化率（$\chi < 0$）

1. 此類物質置於外加磁場B_0中時，會感應出一個微弱的磁場（M），**方向與B_0相反**。
2. 幾乎所有生物組織都具有弱抗磁性。

- **順磁性物質**（paramagnetic substances）：具有正磁化率（$\chi > 0$）

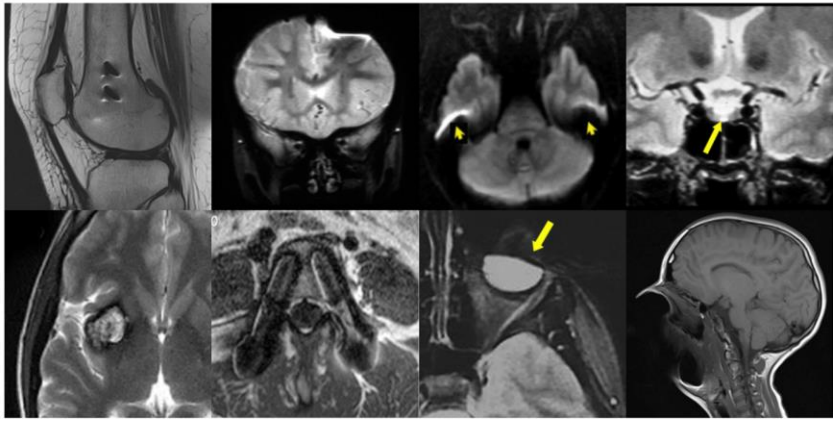
1. 當外加磁場B_0存在時，他們會被磁化；而當外加磁場關閉時，他們的磁性會消失。
2. 釓（gadolinium,Gd）對比劑
3. 去氧血紅素
4. 空氣、白金、錫、鋁、

- **超級順磁性物質**（superparamagnetic substances）：具有正磁化率（$\chi > 0$）

1. 氧化鐵（SPIO）之類的造影劑
2. 金、銅、銀、碳、鉛

- **鐵磁性物質**（ferromagnetic substances）：具有正磁化率（$\chi >> 0$）

1. **鐵磁性**物質會受到磁場強力的吸引，甚至在磁場移除之後，具有永久的磁性。
2. 鐵（Fe）、鈷（Co）、鎳（Ni）



資料來源：
https://mriquestions.com/susceptibility-artifact.html

MRI Image Stitching and Artifacts

What is MRI Image Stitching?

- Combines multiple MRI images into a single large image.
- Used for imaging large anatomical regions or high-resolution scans.
- Prone to artifacts at image boundaries.

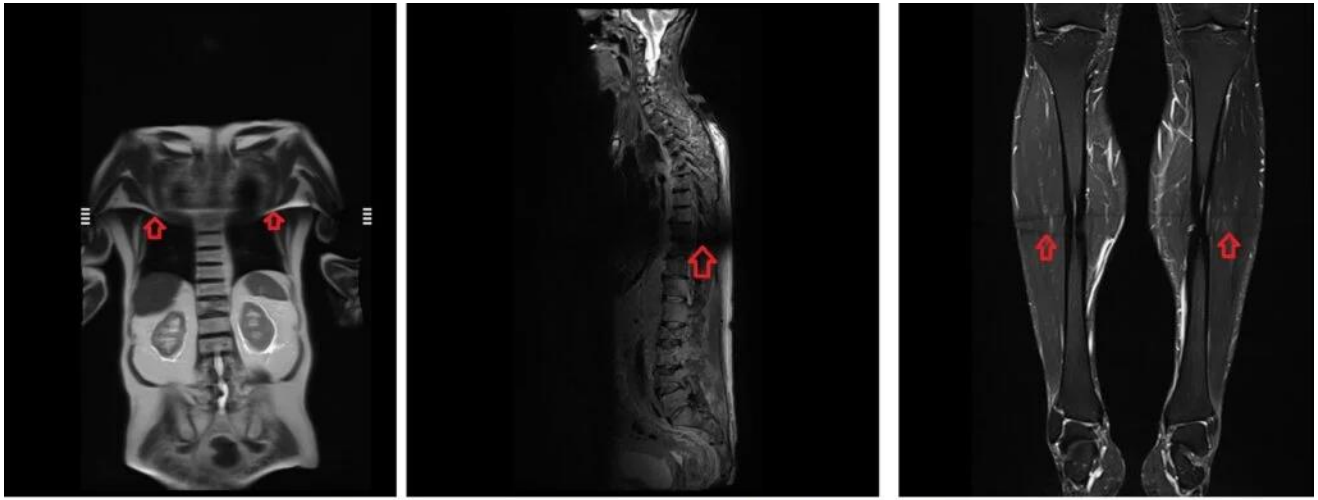
Common Artifacts

- **Motion Artifacts:** Patient movement causes misalignment and visible seams.
- **Inhomogeneity Artifacts:** Magnetic field variations create intensity differences at stitching boundaries.
- **Intensity Variations:** Differences in SNR, contrast, or brightness lead to visible artifacts.
- **Geometric Distortions:** Magnetic field inhomogeneities affect image alignment.

Minimizing Artifacts

- ✓ **Increase FOV Overlap** – Improves image alignment and blending.
- ✓ **Manual Editing** – Adjust boundaries or mask artifacts.
- ✓ **Geometric Distortion Correction** – Use correction algorithms or field mapping.
- ✓ **Intensity Normalization** – Standardize brightness, contrast, and SNR.

MRI Image Stitching and Artifacts



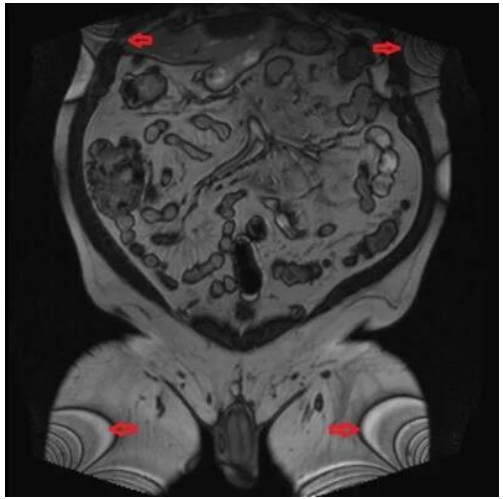
Composing / image stitching artifact

Moiré fringes Artifacts (摩爾紋/水波/Zebra stripes)

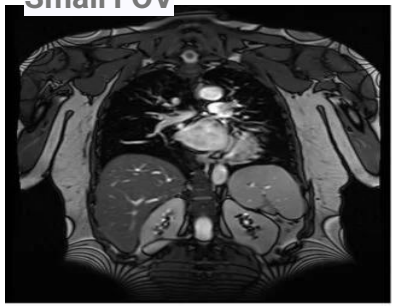
Gradient echo (GRE) sequences

Inhomogeneity of the main magnetic field
The wrap-around or aliasing:
areas outside the coil that contribute to the image formation

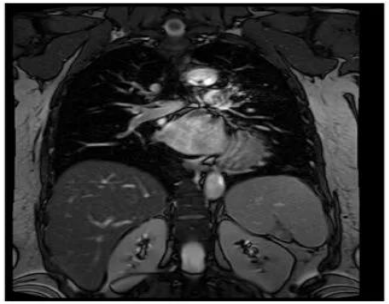
Surface coil sensitivity



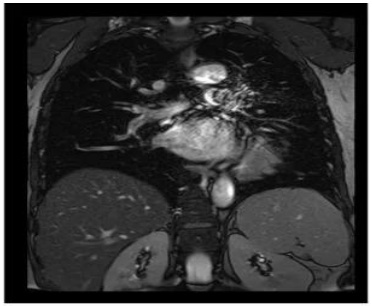
Small FOV



FOV 500mm

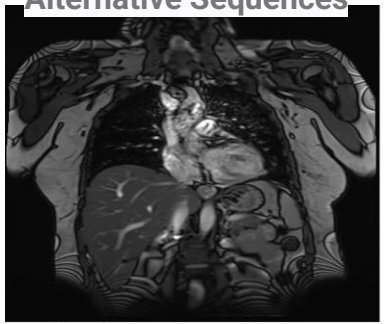


FOV 400mm



FOV 300mm

Alternative Sequences



Gradient echo sequence

Turbo spin echo sequence

Shimming

?

References

https://mriquestions.com/index.html