醫學影像原理與實務

磁振影像設備與造影原理II

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本週學習目標

1. **認識磁振造影安全議題**
   - 主磁場B_0相關之安全議題
   - 快速切換梯度磁場之安全議題
   - 射頻脈衝之安全議題
2. **了解磁振影像常見假影**
   - 設備硬體相關假影
   - 造影參數相關假影
   - 受試者相關假影

References:

- Fundamentals of Medical Imaging (2nd Ed.) Chapter 4
- MRI The Basics (4th Ed.)
- MRI in Practice, (5th Ed.)

磁振造影安全議題

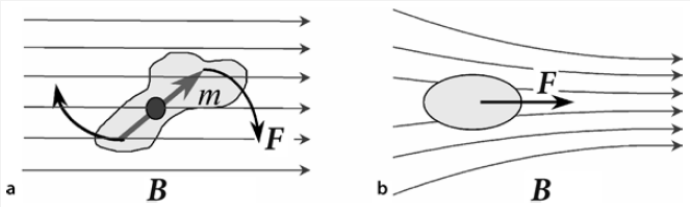
Safety Regulations

- In 2001, a tragedy occurred when a 6-year-old child was killed by a ferromagnetic oxygen tank while in the MRI scanner.
- **White Paper on MRI Safety** by American College of Radiology (ACR) in 2002.
  - https://www.ajronline.org/doi/pdf/10.2214/ajr.178.6.1781335
- International Commission on Non-Ionizing Radiation Protection (ICNIRP)
  - http://www.icnirp.de/index.html
- International Electrotechnical Commission (IEC)
  - http://www.iec.ch/index.htm

Main Magnetic Fields

Projectiles, devices, and implants

- Magneto-mechanical interactions
  - A uniform magnetic field: a magnetic moment experience **a mechanical torque** that align their magnetic moment parallel (or antiparallel) to the B.
  - A non-uniform magnetic field: paramagnetic and ferromagnetic materials become **dangerous projectiles**.



Mumbai MRI death: Nair hospital radiologist arrested in connection to Rajesh Maru's death, released on bail

India PTI **Feb 02, 2018**

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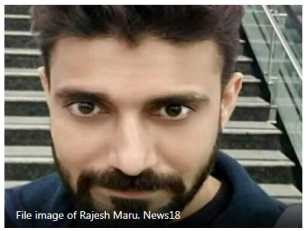
Mumbai: A radiologist of the Nair hospital was arrested in connection with the death of a man in a freak Magnetic Resonance Imaging (MRI) machine accident at the facility on 27 January, police said on Friday.


File image of Rajesh Maru. News18

Agripada police said Dr Siddhant Shah was arrested on Thursday after the family of the 32-year-old victim, Rajesh Maru, told them that the radiologist was also present when the accident occurred.

Shah was charged with dereliction of duty, police said, adding he was released on bail. Shah's was the fourth arrest in the case.

Earlier, police had arrested three hospital staffers — Dr Saurabh Lanjekar, ward boy Vitthal Chavan and attendant Sunita Surve — for negligence causing death.

Maru had accompanied a relative to the hospital for an MRI examination. When he entered the room carrying a liquid oxygen cylinder, the strong magnetic field got activated, pulling him violently towards the machine. The oxygen cylinder burst on impact and he died after inhaling copious quantities of the gas.

Metal objects are not allowed inside rooms having MRI machines.

恐怖意外！核磁共振儀產生巨大磁力吸入氧氣瓶　砸中老翁胸口慘死

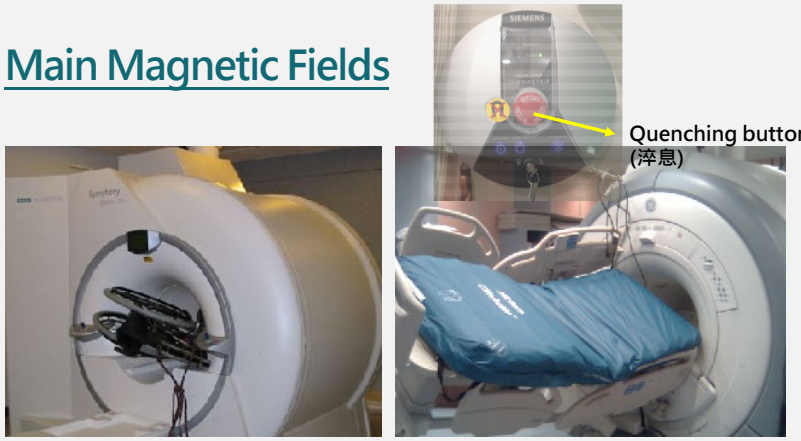
更新時間： 2021/10/17 22:49

南韓傳出一起恐怖的醫療事故，一名老翁在醫院進行核磁共振攝影(MRI)時，疑因攝影室內一個金屬氣瓶沒固定好，被運轉中的核磁共振儀產生的強大磁力吸引，重砸被固定在機器上的老翁胸口，當場慘死。

警方表示，該攝影室內並無設置監視器，缺乏現場影片佐證，現場工作人員表示，該氧氣鋼瓶被放置在距離核磁共振儀「幾步外」，機器開始運轉產生巨大磁力，鋼瓶就被吸入機器內，不幸砸中老翁胸口致命。

目前警方仍在調查現場供詞的真實性，同時也在了解為何金屬氣瓶會被放置在攝影室內，盼能完整釐清責任。（於慶中／綜合外電報導）

Main Magnetic Fields



http://www.impactednurse.com/?p=2927

How dangerous are magnetic items near an MRI magnet: http://youtu.be/6BBx8BwLhqg

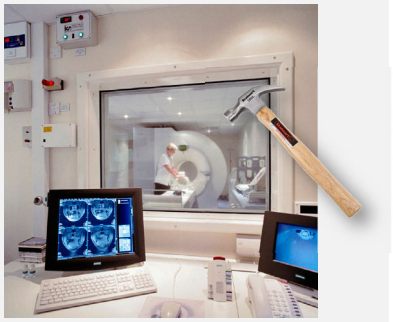
Quench

- Liquid helium is used as the cryogen achieving temperatures as low as 4 K (−269 °C).
- In a scanner with a cryostat volume of 1500 liters, a spontaneous helium boil-off would liberate over 1,000,000 liters of gas.
- All systems should have **helium-venting equipment**, which removes the helium to the outside environment in the event of a quench.
- If this fails, helium will vent into the room and replace the oxygen. ➔ **oxygen monitor!**

https://youtu.be/Q_sZ106ijYg

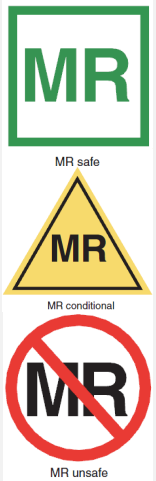
Quench

- If there is a quench pipe failure, an inwardly opening magnet room door may become sealed.
- Possible side effects from a sudden drop in oxygen level, reduced room temperature, and dramatic increase in air pressure:
  - **Asphyxia**
  - **Hypothermia**
  - **Ruptured eardrums**

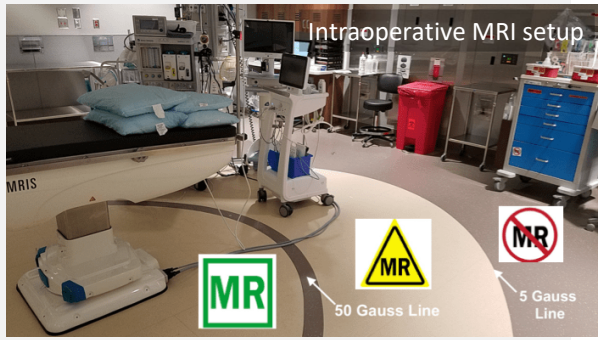


MRI and Implants/Devices

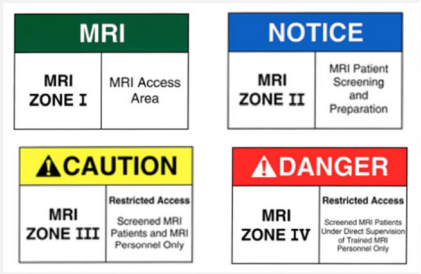
- American Society for Testing and Materials (ASTM) International, 2005
  - **MR safe**: An item that poses no known hazards in all MRI environments.
  - **MR unsafe**: An item that is known to pose hazards in all MRI environments.
  - **MR conditional**: An item that has been demonstrated to pose no known hazards in a specified MRI environment with specified conditions of use.

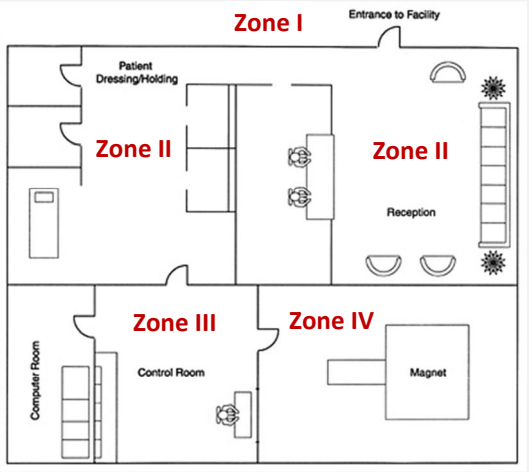


50 and 5 Gauss Line



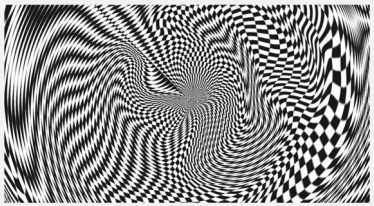
ACR Safety Zones

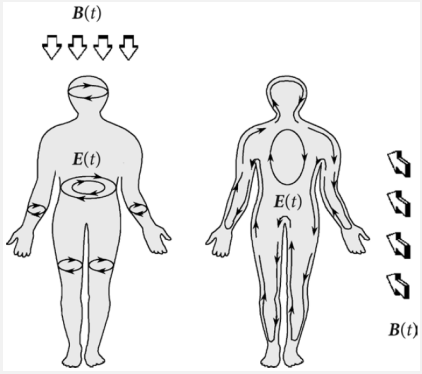




Gradients: Time-Varying Magnetic Fields

- TVMF effects include
  - peripheral nerve stimulation
  - magneto-phosphenes
  - acoustic noise





Acoustic Noise

- As current is passed through the gradient coils during image acquisition, a significant amount of acoustic noise is created.
- ACR recommends:
  - all patients, volunteers, family members, and healthcare workers (essentially anyone who intends to enter the scan room during image acquisition or during scanning) should be offered and encouraged to use hearing protection prior to MR imaging.

Ear plugs

MR-compatible head phones

- MRI generates 110~120 dB of noise.
- Simple foam earplugs can attenuate the acoustic noise by 10 dB to 20 dB.

Radiofrequency Electromagnetic Fields

- Specific absorption rate (SAR, in W/kg)

$$SAR \propto (\sigma \cdot A^2 \cdot B_0^2 \cdot \alpha^2 \cdot \frac{tp}{TR})/2\rho$$

  - σ: electrical conductivity of tissue (metal objects are highly conductive)
  - A: body cross-sectional area (body size)
  - B_0: Strength of magnetic field
  - α: flip angle of RF pulse
  - tp/TR: The ratio of the pulse duration tp and the TR of the sequence, the duty cycle
  - ρ: body mass.
- Patient's weight must be correctly input to ensure the SAR does not exceed the permitted levels.

Radiofrequency Electromagnetic Fields

- Exposure of humans for 20-30 min to RF fields producing a whole-body SAR of up to 4 W/kg results in a body temperature increase between 0.1 and 0.6°C.

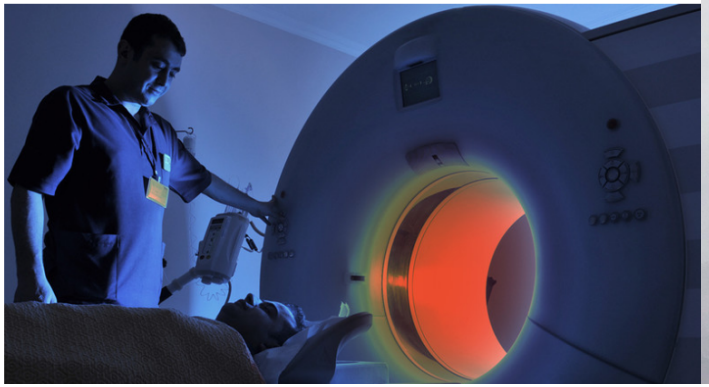
Operating mode	Rise of body core temperature (°C)	Spatially localized temperature limits		
		Head (°C) (or 3.2W/kg)	Trunk (°C) (or 8W/kg)	Extremities (°C) (or 12W/kg)
Normal	0.5 (or 2W/kg)	38	39	40
Controlled	1 (or 4W/kg)	38	39	40
Experimental	> 1 (or >4W/kg)	> 38	> 39	> 40

Hospitals warn patients: Your Lululemon yoga pants could burn you during MRIs

Published: May 12, 2018 9:24 a.m. ET

17 Aa

One 11-year-old girl took an MRI wearing an athleisure top and ended up with second-degree burns



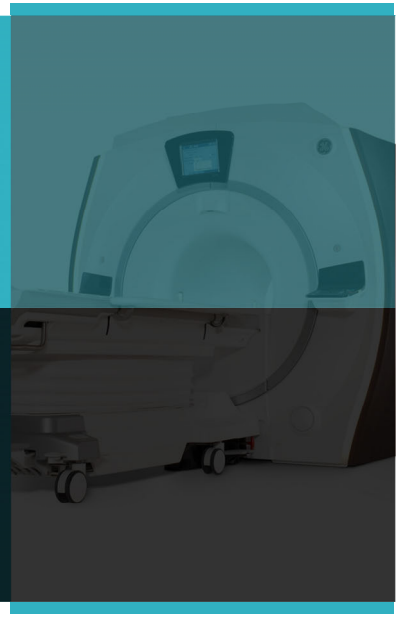
Many clothing companies, like, lululemon athletica, are now using metallic fibers in exercise, spandex, and stretch clothing. These fibers can burn you if worn in the MRI scanner. If you have on clothing, even undergarments, that could potentially have these fibers, please notify the technologist. We will provide you with clothing to wear.

We care about your safety!

Safety Tips

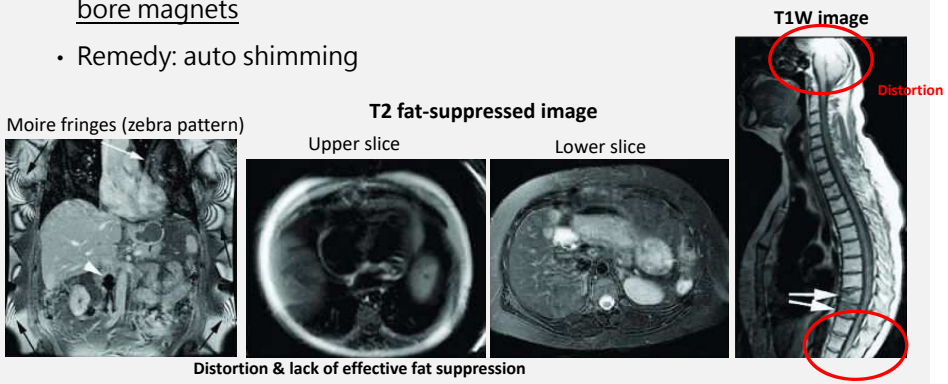
- Carefully screen the patient and anyone accompanying them into the scan room.
  - Surgical histories and procedures
  - Metal injuries
  - Pacemakers
  - Contraindicated implants
- Remove all belongings, and wear an examination gown
- Tattoos can heat up during image acquisition. A cool wet cloth placed over the tattoo acts as a good heat dissipater.
- Let patients use the earplugs correctly!

磁振影像常見假影



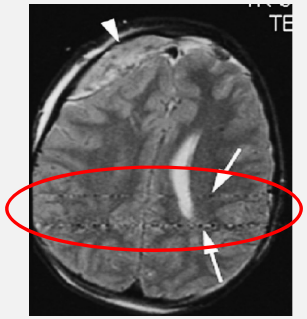
Main Magnetic Field Artifacts

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



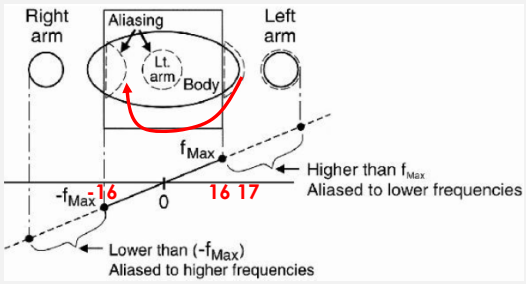
RF-related artifacts: Zipper artifacts

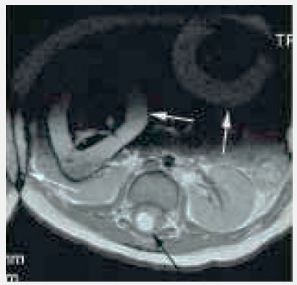
- Unwanted external RF noise (TV, radio station, electronic monitoring equipment)
- Occurs at the specific frequency
- Remedy: improve RF building, shut the door of MR room



Aliasing Artifacts

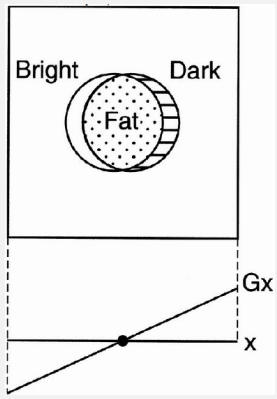
- Any frequency higher than the maximum frequency allowed by the gradient cannot be detected correctly.
- f(perceived)= f(true)-2f(max)





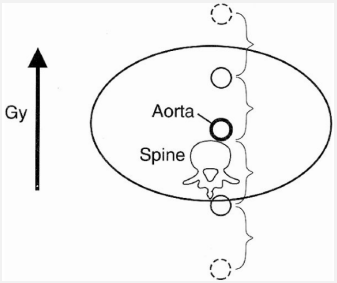
Chemical Shift Artifacts

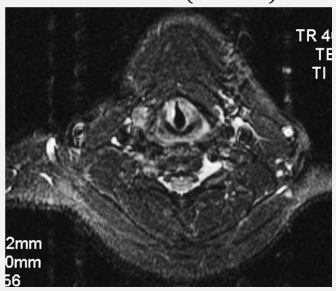
- Chemical shift artifact only occurs in the frequency-encoding direction.
  - A bright band toward the lower frequencies
  - A dark band toward the higher frequencies



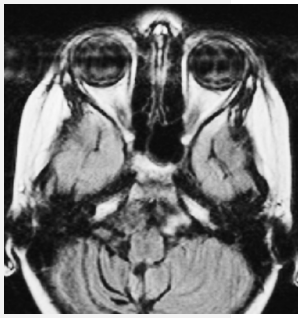
Motion Artifacts

- Ghost artifacts of the vessels are equally separated along phase-encoding direction.
- $\boldsymbol{separation\ (SEP\ in\ pixels)} = \frac{\boldsymbol{acquisition\ time}}{\boldsymbol{T(motion)}}$



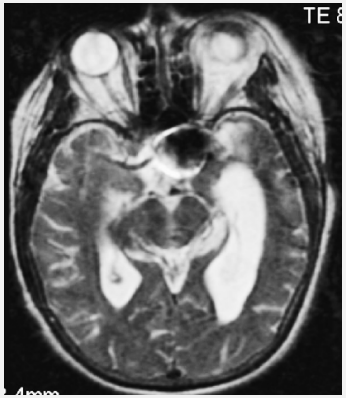


Random eye movements



Magnetic Susceptibility Artifacts

Aneurysm clip

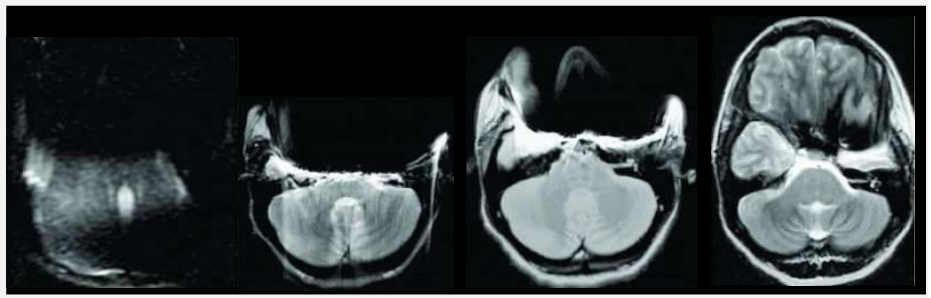


Metallic foreign body

Magnetic Susceptibility Artifacts

- A patient with dental braces

EPI B0 | CSE T2 | CSE PD | FSE T2



重點回顧

- 主磁場、空間編碼使用之梯度磁場、射頻脈衝，皆有其不同面向之安全議題。
- 過往MRI相關之嚴重生命危害案例，多因忽視主磁場的強力磁性吸引力而造成。
- 其次則與射頻脈衝的加熱效應有關，應特別避免穿著有金屬纖維成分之貼身衣物，以防範燙傷發生。
- 造影過程中，梯度磁場的快速變動，往往造成嚴重噪音，務必穿戴耳塞避免聽力受損。
- 磁振假影造成之原因較為複雜，影像表現也不盡相同，需先能辨識產生原因，方能有效找到解決方法。

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