STEPHEN J. POWERS

MRI PHYSICS

TECH TO TECH EXPLANATIONS

WILEY Blackwell

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If you can't explain it to a 6-year-old, you don't understand it yourself.

Albert Einstein

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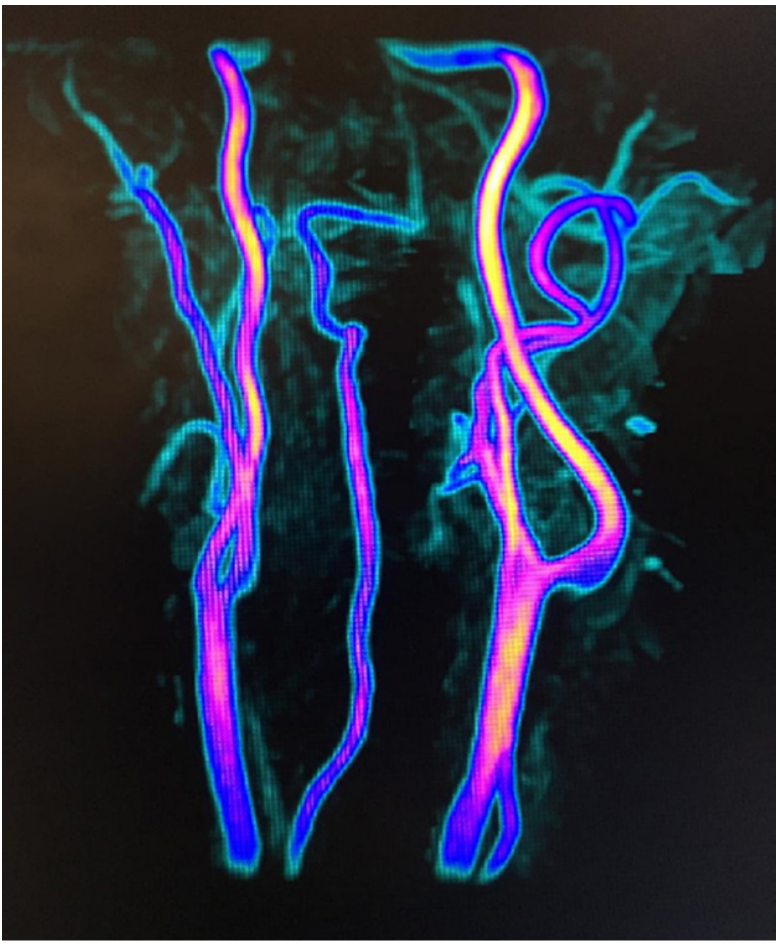

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- Received Associate Degree: Radiologic Technology, Northeastern University, Boston, Massachusetts in 1981. Bachelor of Science: Health and Social Sciences: Roger Williams University, Bristol, Rhode Island, May 1996.
- Served as MR Physics, Cross-Sectional Anatomy and Pathology Instructor: MR Certificate Program, Massasoit Community College, Brockton, Massachusetts 1999–2014.
- Clinical MR Instructor for Massachusetts College of Pharmacy 2010–2014.
- Former MR Applications Specialist: GE Health Care.
- Presently Senior Staff Technologist for Southcoast Hospital Group.
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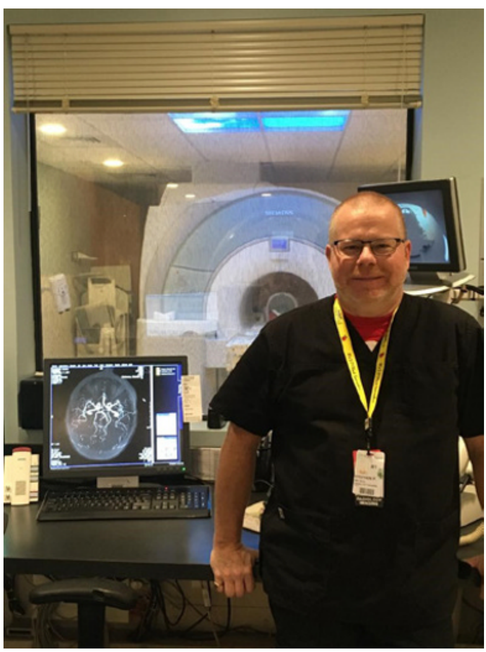

Preface

My hope for this offering is to keep it simple, one tech explaining it to another tech while drawing it on a napkin over a cup of coffee in the cafeteria.

I shall try to not use too many complicated terms, but will however have to use some. I want to keep explanations limited to what is called an "elevator speech." Some trips will go to the third floor; others will go a bit higher.

Either way, I hope to just plain say it.

Tech to Tech Explanations is not intended as an encyclopedia on MRI but hopefully a quick guide, an answer giver, a reference, or a reminder. Perhaps it will fill in some blank spots you might have, or explain something in a way that others have not.

Should you have a revelation or an "Aah ha" moment, I shall sleep well tonight. My ultimate desire is to make you a better Technologist.

Thank you for your support.

Steve

Disclaimer

I am not, nor shall I be receiving any kind of monetary endorsements, gifts, or favors from any manufacturer or vendor for mentioning their products or using vendor MR specific terminology.

Using some vendor specific terms or techniques will be inevitable in my narratives. I shall not and do not endorse any one company or vendor over another.

I shall try to be as vendor neutral as possible.

Acknowledgements

First, I would like to thank my wonderful wife Suzanne for all the years of patience and support during the many days, nights, weekends, holidays, call, and most recently all those many road trips while I was on the road following my passion.

The next person on my thank you list is a friend, colleague, and mentor: Annette Caballero-Saes. She has taught me a great deal on the MR Applications side of things. Her modus operandi always was “Keep it simple.” That is my hope for this book. With that I say: “Thank you, Annette.”

I never thought myself a teacher until I had the very fortunate opportunity to work with a fine Radiologist and friend Dr Richard Mauceri D.O. I could always ask him questions (and I had lots of them, and he would always patiently answer them. One day after a lengthy barrage of questions, I thanked him and he said to me, “Stevie, it’s nice to know things that others don’t so then you can show them.” That statement was a life changing way of looking at things. I cannot thank you enough Dr Mauceri.

Thank you, Ashley, for your “Word” help! It was huge!

Great cover picture Rachelle! You’re my favorite!

I also need to thank some very good friends, colleagues, and fellow technologists for their help in evaluating many of the chapters in this book: Manny Constantino R.T.(R)(CT)(MR), Diane Ashley R.T.(R) (MR), Susan Pius MA R.T.(R)(CT)(MR), Bernice Resnick R.T.(R)(MR)(M), and Lisa Thornhill DABR, MRSE.

Introduction

Safety

What follows will be a generic safety offering. It is not meant to be all-encompassing or empirical.

- When in doubt, **don't.** You do not want to be "that guy."
- Magnets are always hungry. They do not make mistakes so neither can we. The magnet is always hungry. A healthy dose of paranoia has worked pretty well for me, so far.

There are three different safety considerations in MR:

1. The static magnetic field.
2. The gradient magnetic field.
3. Radiofrequency: Specific absorption rate (SAR).

The Static Magnetic Field

The static magnet field is 20 to 60 thousand or more times stronger at isocenter than the Earth's magnetic field. If something is ferrous and it gets too close, it is going for a ride. You do not want to be in between it and the scanner.

MRI Physics: Tech to Tech Explanations, First Edition. Stephen J. Powers.

Teaching Moment: Magnetism is not governed by the inverse square law like x-rays are. **Magnetism has a cubic exponential relationship of attraction**. Halve the distance and there is 8 times (2^3 or 2 × 2 × 2) the force of attraction. Things get drawn in very quickly. A ferrous object becomes magnetized (not just attracted but a magnet) in the presence of a strong field. Handheld and or wall-mounted ferrous detectors are now pretty much standard, as well as a series of "zone" signs as warnings. A handheld magnet is a very good idea for checking ferrous vs. non-ferrous.

We have all heard the stories and seen the pictures. From the MR point of view, there are two kinds of metals: **Ferrous vs. non-ferrous.**

- ***Aluminum is non-ferrous***, i.e. it is not attracted to a magnet. It has little to no iron content.
- ***Ferrous metals*** include steel and alloys of iron with other metals. Manipulation of the atomic bonds between iron, carbon, and other alloys gives ferrous properties to a metal.
- ***Not all stretchers, IV poles or O_2 bottles are made the same. Do not be that guy. Be paranoid.***

Figure I.1 Beware: Not all stretchers, IV poles, or O_2 bottles are made of non-ferrous materials.

Figure I.1 may not be an overly impressive photo of a hospital bed or respirator, but the scanner was still down for a day and a half.

The "5 Gauss line" (0.5 mT): In Figures I.2 and I.3 these are the red lines on the Gauss diagram and on the floor of the scan room.) This line is considered the "safe zone" outside of which pacemakers, defibrillators, etc. are considered safe. Each scanner has a different "5 Gauss line." Occasionally the lines are physically marked on the floor by colored tape.

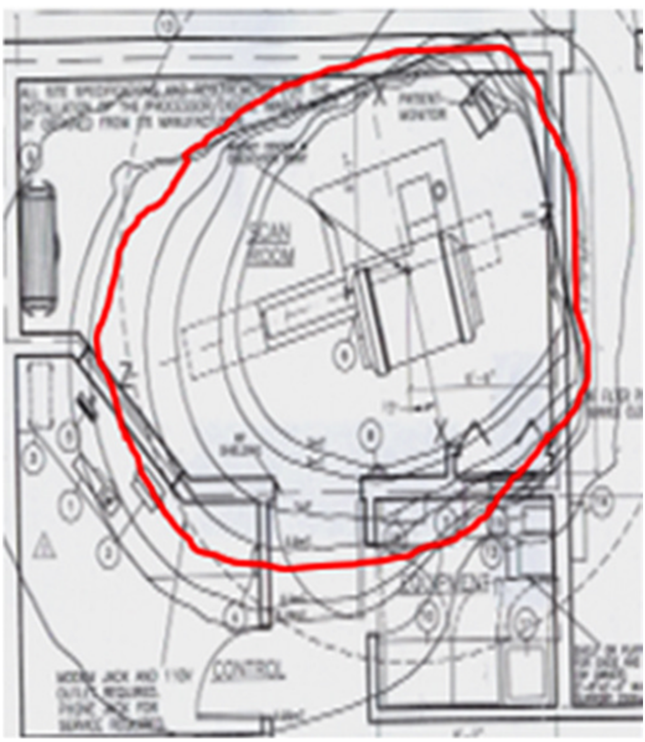

Figure I.2 The 5 Gauss line. Diagram of a scan room.

Figure I.3 The 5 Gauss line. A scan room floor.

Some mechanical medical devices and their batteries do not do well in a strong magnetic field. Parts may become magnetized or battery life may be adversely affected.

The Gradient Magnetic Field

How many patients have asked you what causes the noise? The gradients make noise as they are turned on and off. There are actually three pairs of electromagnets that superimpose themselves onto the main magnet field. They are very rapidly turned on and off, causing the banging noise. Turn it on, bang, turn it off, bang. The stronger the gradient, the louder the noise. A 1.5 T, while noisy, is usually less noisy than a 3 T.

Gradients need to work harder the stronger the static field.

What is a gradient?: A gradient is actually a hill or an incline. Have you ever seen a street or highway sign saying "Steep grade: Truckers use low gear" (Figure I.4)? It is a warning that a big downhill slope is near.

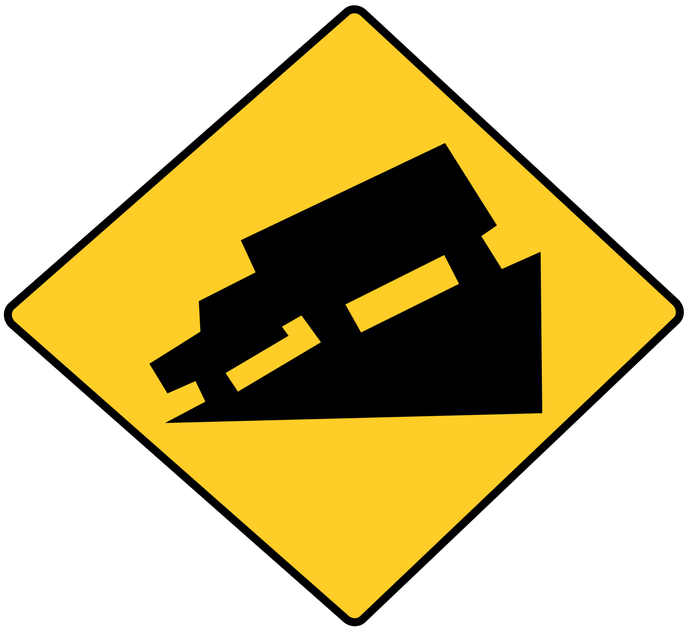

Figure I.4 Street sign warning of a steep gradient.

In MR's case, it is a magnetic hill. One side is made briefly stronger than the other. Briefly is the key word here.

Gradient Magnetic Fields and Peripheral Nerve Stimulation

Gradients are turned on and off rapidly and repeatedly, so essentially what you have are **moving magnetic fields**. The peripheral nerves in our hands and /feet are really tiny wires.

Moving magnetic fields, tiny wires, **Faraday's Law of Induction** – does this sound familiar? The oscillating magnetic fields cause tiny amounts of current to flow in the nerves, like pins and needles when you sleep on your arm.

PNS stops when the stimulus (the gradients) stops.

- You can also induce current in larger wires such as in bone growth stimulators, pacemakers, etc.
- PNS is not harmful. It is commonly caused by sequences with a lot of gradient applications. Some gradient-intense sequences include: DWI, perfusion, functional, and FSEs like those with a long ETL. FSEs are both SAR and gradient intense as well.
- On DWIs, have the phase direction in the correct direction. Many scanners now will give you a pop-up warning.
- Lower the ETL on FSEs. Each echo is caused by a 180° refocusing pulse, which also has a gradient associated with it.
- Thin slices and small FOVs cause steep gradients.

Radiofrequency and Specific Absorption Rate (SAR)

The RF energy used in MRI, circled in the electromagnetic spectrum in Figure I.5, is close to the microwave range. There will be some heating of the patient.

Some pulse sequences are more RF intense than others. Compare GRE's to Spin Echo: A GRA has only one RF pulse and it is usually less then 90°, while a Spin Echo has a 90° and a 180° RF Pulse. There is less heating during a GRE sequence. Now consider a Fast Spin Echo sequence with several 180° RF pulses. As an FYI, a Saturation band or Sat Pulse is an RF pulse.

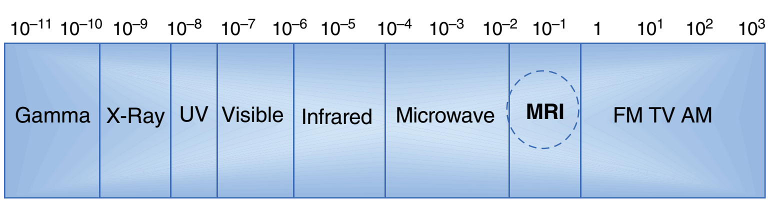

Figure I.5 The electromagnetic spectrum. Radiofrequencies used by MRI are circled.

Other considerations include:

- What body part are you scanning? Ankle or lumbar?
- What kind of coil are you using? Receive only or transmit/receive?
- Is the bore fan on? Are there lots of blankets on the patient?
- What about the patient's ability to regulate body temperature? Are they febrile? On a water mattress?

All MR rooms have what is called RF shielding or a "Faraday cage." The Faraday cage is made of copper sheets that completely cover all surfaces in the room. Like lead shielding in X-ray, its job is to keep the MR RF in, and another people's RF out.

There is a chance of RF leaks, which will of course cause artifacts in the images. Is security nearby on a walkie-talkie? Is the door not closed fully? What about the integrity of the door seal? Are those little fingers missing or bent backwards? Is there a new or different piece of equipment in the room?

Teaching Moment: Did a light bulb recently get replaced? If so, just hope it is not an LED. LEDs have a small transformer in them to convert A/C to D/C. The transformer can cause RF or data spikes (Figure I.6).

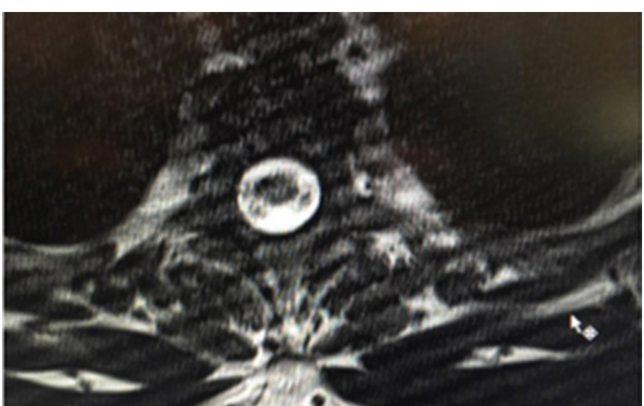

Figure I.6 Artifact caused by LED light bulb.

Your Point of View While You Are Scanning

This section is to orient you, or give you a point of view to visualize the MR physics of transverse (X/Y) and longitudinal (B_0) planes.

What a piece of paper fails to get across is that imaging modalities are 3D, whereas a piece of paper is of course 2D. So, for this book, always assume that the patient is head first and supine in the scanner.

Your point of view (POV) is not always sitting at the console looking at the sole of the patient's feet; rather you are looking down from the ceiling with the top of the magnet cut off (as if the patient is in a bath tub, the magnet being the tub).

Occasionally you will need to imagine yourself at the end of the bore looking at the patient's feet to picture the coil and transverse plane.

Try to train your brain to think in 3D. You have two eyes, so see in 3D; try to think in it as well. The Cartesian coordinate system is the three cardinal directions in MR, much as North, South, East, and West are the four cardinal directions on Earth.

- The longitudinal plane (0° and 180°) is running head to foot.
- The transverse or X/Y (90°, 270°) is right/left and actually anterior/posterior (A/P) also (Figure I.7).

Why are these "degrees" important?: They denote positions of the NMV before, during, or after the sequence as a result of the applied RF.

Note that the head coil and actually all coils are in the X/Y, also known as the transverse or 90°, 270°.

Protons pointing at the coil at the TE will be bright.