1.5 T VERSUS 3 T
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Background

Units for magnetic field
- The magnetic field of MRI units is generally expressed in units of Tesla (T)
- One (1) Tesla is equal to 10,000 gauss
- The earth’s magnetic field is approximately 0.5 gauss.
  So 1.5 T is equal to 15,000 gauss (approximately 30,000 times the magnetic field of the earth).

Three “fields” are used in MRI
Magnetic Resonance Imaging (MRI) utilizes:
1. a magnetic field AND
2. gradient magnetic fields AND
3. a pulsed radiofrequency (RF) field.

1. A very powerful externally applied magnetic field is used to magnetize the hydrogen protons in tissues (primarily water and fat). The individual magnetic field of a hydrogen proton is very small. However, the human body is approximately 80% water and hydrogen is nearly 100% abundant in human tissues. When tissue is placed in the strong externally applied magnetic field, the magnetic field of the individual hydrogen protons align and add to a larger summed or net magnetic field of the tissues. It is this summed (or net) magnetization that produces the detectable signal from the tissues. The stronger the external magnetic field, the greater the number of hydrogen protons that will “participate” in contributing to the tissue net magnetization. This results in greater potential signal from the tissue.

2. The time varying gradient magnetic fields alter the static magnetic field at a local level by either adding to or subtracting from the total field. It is this local alteration of the static field which allows for spatial encoding of the signal. This is how multiple imaging planes and image slices can be collected without physically moving the patient. The strength and speed of the time varying gradient fields are similar in 1.5 T and 3 T MR scanners.

3. MRI also uses a pulsed radiofrequency (RF) field to change the orientation of the tissue’s bulk (or net) magnetic field resulting in the induction of a current (or signal) in an antenna (receiver coil).

To produce the images, that tissue magnetization must be made to rotate through an antenna (receiver coil) so the signal can be sampled. In order to do this, RF (radiofrequency) is pulsed at prescribed time intervals and at specific frequencies. The frequency required to elicit a response from the tissue’s magnetization is dependent on the field strength of the externally applied magnetic field.

a. For example, at 1.5 Tesla, the RF frequencies would be in the range of 64 MHz.
b. At 3.0 T, the frequency required would be in the range of 128 MHz.

For a given field strength system, the coils and associated RF electronics (transmit and receive) are designed and deployed based on the specific field strength of the MR magnet and the associated RF frequency.

Why can’t the MRI settings of a 3 T MRI machine be changed to 1.5 T?
The magnetic strength (as measured in Tesla) of the MRI machine is determined by the amount of electric current applied to the coils when the system is designed and installed.

Given that the RF coils and associated electronics are designed to work within a specific frequency range based on the field strength of the MR magnet, coils designed and built for a 3 T system cannot be used on a 1.5 T system.

One cannot practically change the amount of current in the coils of a superconducting magnet, which determines the field strength. Additionally, one cannot alter the coils and associated electronics of the RF sub-system of an MRI system. Therefore, a 3 T system cannot be changed to a 1.5 T system.

Why can’t the patients with Medtronic MRI systems get an MRI in a 3 Tesla machine?
- Medtronic MRI systems were tested to be imaged at 1.5 Tesla and the associated RF frequencies
- The RF frequency of a 1.5 T signal is 64 MHz and the frequency of a 3 T signal is 128 MHz

The systems have not been tested for 3 T at this time.

Since the potential for lead heating is a function of RF frequency (as well as other factors), and, since the RF frequency varies with the magnetic field strength of an MRI system, lead heating performance in a 3 T MRI machine may be different than in a 1.5 T MRI machine.
Benefits of 3 T MRI Machines

What is the benefit of a 3 T MRI machine compared to a 1.5 T MR machine?

The inherent signal from the tissues will be greater on a 3 T system due to the stronger static field.

- A stronger signal can be used to produce high resolution images, which is the primary reason 3 T is preferred for brain imaging.
- Alternatively, the increased signal due to the higher field strength can provide shorter scan times with an image resolution similar to 1.5 T.

Are there diagnostic benefits of the higher resolution images that a 3 T MRI machine can generate? Is there data on better patient outcomes as a result of the higher resolution images?

Increasing spatial resolution has obvious clinical advantages. A radiologist friend of mine once made the statement: “Seeing it better is seeing it better.” However, to my knowledge, there are currently no studies which definitively show improved patient outcomes based on 3 T vs. 1.5 T.

Can a 3 T MRI machine scan faster than a 1.5 T MRI machine, thus improving the efficiency of an MRI center?

Rapid data acquisition and shorter scan times are really two different things. Reducing overall scan times to increase throughput is generally not the way most 3 T systems are utilized. The scan time is one (often small) part of the overall time required for a patient’s MRI scan. And, therefore, shorter scan times do not translate into significant increases in throughput.

For which types of scans does 3 T provide a significant diagnostic advantage over 1.5 T?

This is likely to change over time as technology advances. At this point, there are a few exams where 3 T improves overall exam quality.

1. **Prostate MRI**: Because of the small size of the prostate gland, MRI of the prostate at 1.5 T requires the use of a coil designed to be inserted into the rectum. This is obviously unpleasant for the patient (as well as the MR staff). The increased signal of a 3 T system makes it possible to image the prostate with an external surface coil as opposed to the endorectal coil.

2. **Spectroscopy**: This is a type of exam which does not produce images per se but rather evaluates the amount of certain chemicals (metabolites) in tissues. The most common application is in the brain (although techniques have been developed for breast and prostate). Because the signal from the specific chemicals being studied is generally very small (compared to water-based hydrogen), the increased static field strength of a 3 T MR system greatly improves the quality of these studies. Spectroscopy is most often utilized in the brain to help characterize lesions and to assess response to therapy.

3. **fMRI**: Functional MRI (fMRI) is a technique utilized to evaluate areas of the brain responsible for various functions (speech, hearing, sight, motor, etc.). When the patient performs certain tasks (movement of fingers for example), a certain area of the brain which controls that function will experience a very slight and brief increase in blood flow. This results in a very slight change in the local magnetic field resulting in change in the MR signal. The amount of change is only 1 - 2% at 1.5 T but upwards of 4% at 3 T, making such an exam performed at 3 T more sensitive than those performed at 1.5 T. These types of exams are often performed as part of pre-operative planning, follow-up and for various reasons in a research setting.

4. **Arterial Spin Labeling (ASL)**: ASL is a technique to assess blood perfusion primarily to the brain. It utilizes RF pulses to “tag” blood protons flowing into the brain. Standard techniques for perfusion studies require the use of a gadolinium-based contrast agent. ASL has been demonstrated at 1.5 T but is much more effective at higher fields (such as 3 T).

There are certainly people who believe 3 T offers many clear benefits over 1.5 T but I am currently not aware of applications or techniques that are non-diagnostic when performed at 1.5 T as opposed to 3 T, other than those above.

What about vasculature?

The increased image clarity revealed by 3 T is particularly beneficial for pathological conditions involving the brain, spine, and musculoskeletal system. The benefits of the 3 T scanner are not confined to Magnetic Resonance Imaging. The increased spatial resolution of the 3 T scanner allows for high-quality vascular imaging. Thus, 3 Tesla MR Angiogram studies may often supplant the need for invasive interventional catheter studies.

Which medical conditions are better diagnosed with 3 T scanners?

Due to the increased sensitivity to slight variances in the local magnetic field in tissues (see fMRI section above), certain imaging sequences (when acquired on a 3 T system) have been shown to be more sensitive to small hemorrhagic lesions in the brain.
Are there any guidelines from ACR on the use of 1.5 T versus 3 T machines?
No.

What proportion of total MRI scans do these scans represent?
For the four studies listed above, I estimate those represent 1% or less of the clinical MR studies performed today.

However, for exams of the brain and spine which can benefit from the increased signal available at a higher field strength, the percentage is much greater (in the United States, approximately 30% of MRI scans are of the brain and upper spine).

It should be pointed out that, while MRI studies performed at 3 T can be more sensitive to pathologies in multiple clinical situations, this does not mean that 1.5 T studies are non-diagnostic.

Prevalence of 3 T MRI Machines

Are most new MRI machine purchases of the 3 T type?
24% of new scanner sales in Europe were 3 T in 2011 (2012 Frost & Sullivan Outlook).

What percentage of existing MRI machines are 1.5 T? 3 T?
- In Europe in 2011, 72% were 1.5 T, 11% were 3 T (Millennium Research Group)
- In the United States in 2011, 10% of MRI machines were 3 T, 76% of MRI machines were 1.5 T (Millennium Research Group)

What other field strength systems are commonly used? I've heard of a research center with a 7 T MRI machine. Will that be common soon?
It is likely that at some point 7 T MRI systems will get FDA approval. However, using 7 T systems for routine clinical imaging is not likely to be realized for many years. Their current advantage being studied is in the area of functional MR studies (spectroscopy and fMRI). The issue of field strengths greater than 3 T should not be of concern. Numerous fundamental technological challenges will have to be addressed, particularly as they pertain to the RF power and frequencies required to image at 7 T and higher.

I've heard that more and more MRI centers are moving to 3 T MRI machines. Will my patient be able to find an MRI center that has a 1.5 T machine?
Many clinicians have the perception that “most” centers have 3 T machines. This is currently not the case and will vary significantly by country and center.

Although many new MRI machines are 3 T, the vast majority of existing MRI machines in the United States and Western Europe are 1.5 T. And, most centers with more than one MRI machine have at least one 1.5 T machine.

Medtronic can help to find the MRI centers with 1.5 T machines that are conducting scans on device patients.