Comparing MRI Magnets
The Most Familiar MRI Magnets

“High-Field” MRI

“Classic” Open MRI

Notice the patients are always lying down
The Direction of the Magnetic Field Lines

“High-Field” MRI

“Classic” Open MRI

Parallel to the patient

Perpendicular to the patient
The Magnetic Field Strength of MRI Scanners

Useful Nomenclature

High-Field: 1.5 - 3.0 Tesla
Mid-Field: 0.5 - 1.0 Tesla
Low-Field: 0.2 - 0.35 Tesla**

** A 0.3 Tesla magnet is 6,000 times stronger than the compass-needle-moving magnetic field at the earth’s surface (i.e., 50 microTesla)
• Many physicians incorrectly believe that the MRI universe is simply segmented into “high-field MRI” and “low-field Open MRI.”

• An “Open MRI” is viewed as being just a downgraded high-field MRI that doesn’t do anything clinically different than the high-field MRI.

• The words “Open MRI” have become synonymous with poor image quality.
Change the Playing Field by *Rotating the Open MRI*
A Different MRI Configuration
What’s the *same* about these MRI systems?

The Steps In An MRI Scan

“The whole is greater than the sum of its parts”

~ Aristotle ~
Step #1

The patient is placed in a large magnet
A radio wave is transmitted into the body, and a little bit later another radiofrequency (RF) signal is emitted from the protons in the body that were targeted by the transmission…

… and this is detected by an antenna called the RF receiver coil that is placed around or on the patient.
A precisely timed sequence of RF pulses and rapid synchronous changes to the magnetic field yield *composite detected radio signals that are analyzed by a computer*, which then calculates & displays the digital MRI images.
What’s different about these MRI systems?

- Magnetic field strength
- Operating RF frequency
- Magnetic field direction
- RF receiver coil sensitivity
- NMR $T_1$ relaxation times
- Gradient specifications
- Metallic artifacts
- Acoustic noise
- Patient positioning
- Patient comfort
- Range of MRI applications
“So do you have good images?”
Specialized MRI Applications at 3.0 Tesla

High Resolution

Spectroscopy

Cardiac

Breast

Functional Neuroimaging

Diffusion & Perfusion

Prostate
So is our 0.6 Tesla magnetic field strong enough?

Compare these images from the same patient, same day, same imaging center.

Upright® MRI
0.6 Tesla
5:03 scan time
24 slices
5.0 mm thick
25 cm FOV

3.0 Tesla
3:51 scan time
22 slices
5.0 mm thick
23 cm FOV

Upright® MRI
0.6 Tesla
4:41 scan time
24 slices
5.0 mm thick
25 cm FOV

3.0 Tesla
1:30 scan time
30 slices
4.0 mm thick
23 cm FOV

Why so good? The Upright MRI is twice as strong as most Open MRIs.
The Upright MRI offers an **advantage** for post-operative patients since **artifacts from metal surgical screws diminish** as field strength is reduced.

Compare these images from the **same** patient at **different** MRI field strengths.

The structures in and around anatomy adjacent to the implanted titanium pedicle screws are **less obscured** with the 0.6T Upright MRI.

**Additional Images from the Upright MRI**

These parasagittal slices show pedicle screws used in an L4-S1 fusion do not generate a large metal artifact.
The Upright MRI is *dramatically different from an Open MRI* because **PHYSICS** allows the Upright MRI to use the same type of receiver coil as a high-field MRI to image the spine. An Open MRI is *unable* to do this.

### Which RF Receiver Coil is compatible with which type of MRI?

<table>
<thead>
<tr>
<th>Magnet \ RF Coil</th>
<th>Planar (flat)</th>
<th>Solenoid (“belt”)</th>
</tr>
</thead>
<tbody>
<tr>
<td>High-Field MRI</td>
<td>✓</td>
<td></td>
</tr>
<tr>
<td>Open MRI</td>
<td></td>
<td>✓</td>
</tr>
<tr>
<td><strong>Upright</strong></td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td><strong>Weight-Bearing</strong></td>
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<tr>
<td><strong>(Stand-Up)</strong></td>
<td></td>
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<tr>
<td><strong>MRI</strong></td>
<td></td>
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</tbody>
</table>
Rule of MRI: The axis of symmetry of the RF receiver coil should be perpendicular to the direction of the main magnetic field.

"High-Field" MRI

Planar RF Receiver Coil

Upright MRI

Planar RF Receiver Coil

“Classic” Open MRI

Recumbent Patient

Solenoid RF Receiver

“Belt” Coil

N

S

Images of spinal MRIs are shown for each setup.
Upright Weight-Bearing Multi-Position MRI

We can rotate the bed from recumbent to upright and compare MRI scans in different patient positions.

We can acquire MRI scans in both flexion & extension positions since there is nothing in front of the patient’s face.
**Why an upright, weight-bearing MRI scan?**

An examination of the spine in the seated or upright position is important because the spine changes under the effects of both gravity and position.

The high-field MRIs may not show the abnormalities which account for symptoms experienced while in a seated, standing, extending, flexing or lateral bending position.

A patient’s hips and knees are often flexed and the knees supported by a pillow to take the strain off the back in order to help the patient lie down in a traditional high-field MRI. This is an unnatural position and not at all optimized to visualize the cause of spinal pathology for which symptoms are often experienced when sitting or standing.

Finally, many patients with spinal issues are not able to lie down without experiencing pain.
The weight of the body is acting through the axis of the spine, compressing the intervertebral discs and therefore showing the spine under normal upright weight-bearing conditions.

SLIDE COURTESY OF FW SMITH, MD UNIVERSITY OF ABERDEEN, UK
“The dominant motions at both the lower cervical and entire lumbar spine, where most clinical pathology occurs, are flexion-extension”

~ AMA Guides to the Evaluation of Permanent Impairment ~
Typical Conversations with Physicians

Q: “Do you know anyone with back pain?”
A: “Yes.”
Q: “What do they usually do to relieve the pain?”
A: “They lie down.”
Q: “So why scan them that way?”

We frequently hear the same story from numerous physicians:

“I send my patient out for an MRI scan. Then when the report comes back I tell them that there’s nothing wrong. And the patient tells me ‘yeah, but it doesn’t hurt when I’m lying down!’”

Q: Have you ever had a patient with a positive EMG and a negative MRI?
Summary: MRI Magnet Comparison

✓ The Upright MRI is *twice as strong* as most Open MRIs.

✓ The Upright MRI has a competitive advantage for post-operative patients since *artifacts from metal surgical screws diminish* as the MRI’s field strength is reduced.

✓ The Upright MRI is *dramatically different from an Open MRI* because physics allows the Upright MRI to use the same RF receiver coil as a high-field MRI to image the spine. The Open MRI is unable to do this.

✓ The position-dependent pathology we detect will be *invisible* or *underestimated* at higher field strengths. Sometimes *patient positioning TRUMPS a small increase in resolution* or a small decrease in scan time.
Position-dependent Pathology: A Helpful Analogy

What’s the best way to diagnose whether or not you have a flat tire?

The weight-bearing position!

Position-dependent tire compression

Proper positioning plays a critical role in detecting clinically significant pathology
Clinical Case Studies

You need the **Upright MRI** to see the pathology highlighted in red.

Each box compares the **same** patient in **different** positions on the **same** day in the **same** MRI scanner.
Twenty-five (25) chronic low back pain patients with prior “negative” recumbent-only MRIs …

What percentage **showed** abnormalities in one or more of the upright positions, and still **nothing** in their recumbent position?
Twenty-five (25) chronic low back pain patients with prior “negative” recumbent-only MRIs …

What’s the clinical relevance?

What percentage showed abnormalities in one or more of the upright positions, and still nothing in their recumbent position?

Each of these patients had surgery and six months later they remain symptom-free.
What’s the Clinical Relevance?

Peer-reviewed Scientific Publications: Effects on Patient Treatment

52% of a group of 25 chronic low back pain patients with prior “negative” recumbent-only MRIs demonstrated abnormalities in one or more seated postures “that were not evident in the recumbent position, and each of these patients has undergone appropriate surgery and six months post-surgery they remain symptom-free.”

“Upright MRI in the Seated Position Increases Insight into Degenerative Disc Disease” FW Smith MD et al., Dept. of Radiology, Univ. of Aberdeen, UK, *Clinical MRI* (2006) 15:3

Neurosurgeons examining 20 patients with symptoms consistent with cervical radiculopathy or myelopathy concluded that “when only static supine MRI is performed ... the true abnormality may be overlooked and inappropriate surgical plans instituted because of a lack of illustration of the changes that occur with movement.”

What’s the Clinical Relevance?

Peer-reviewed Scientific Publications: Effects on Patient Treatment

In a study of 553 patients with symptomatic back pain, in those with normal or less than a 3 mm bulge in the neutral position, [19%/15%] demonstrated an increase in herniation to greater than 3 mm in [extension/flexion]

“Missed Lumbar Disc Herniations Diagnosed With Kinetic Magnetic Resonance Imaging”

“In [510] patients with back pain, missed spondylolisthesis in neutral MRIs but found in flexion MRIs is 18.1% for all the levels if the spondylolisthesis is considered as more than 3 mm translation.”

“Missed Spondylolisthesis in Static MRIs But Found in Dynamic MRIs in Patients with Low Back Pain” S.W. Hong, M.D. et al., UCLA The Spine Journal (2007) 7:5S

“... there is no doubt that clinically relevant spinal canal stenosis can be uncovered by imaging the erect position. In cases where conventional MRI shows no evidence of cauda equina or lumbar nerve root compression in the setting of convincing clinical symptoms that warrant surgical intervention, re-imaging in the upright position, with the addition of flexion and extension, is recommended.”

What’s the Clinical Relevance?

**Peer-reviewed Scientific Publications: Effects on Patient Treatment**

A multi-center study of 1200 patients with neck pain showed recumbent MRI underestimates the incidence of herniated cerebellar tonsils. The incidence of tonsillar herniation in non-traumatic neck pain patients was about the same, 5.3-5.7%, for both recumbent and upright positions, while in whiplash patients, 23.3% examined upright showed herniation of the cerebellar tonsils, whereas only 9.3% examined recumbent showed this abnormality.

“A Case-Controlled Study of Cerebellar Tonsillar Ectopia (Chiari) and Head/Neck Trauma (Whiplash)” M Freeman et al., Oregon University School of Medicine, Univ. of Aarhus, Univ. of Aberdeen, Spinal Injury Foundation, Columbia Univ., Univ. of Nebraska, Wisconsin Chiari Center *Brain Injury* 24:7-8 (2010)

Ten subjects who had undergone radiographic imaging for idiopathic scoliosis were also evaluated using a rapid upright MRI with SMMR ... “Scoliosis may now be accurately and reliably quantified using MRI technology, thereby decreasing radiation exposure and its inherent risks.”

“Evaluation of Scoliosis with Standing Rapid MRI with SMMR: An Alternative to Plain Radiography” Q. Hammouri, J. Grauer et al. Yale University School of Medicine, *IMAST (2009) Vienna* [International Meeting on Advanced Spine Techniques]
Orthopedic surgeons concluded that “**patellofemoral joint contact areas should be measured under loaded conditions** ... when trying to understand potential mechanisms of patellofemoral pain” to account for cartilage deformation and changes in patellar alignment.

*“Patellofemoral Joint Contact Area Increases with Knee Flexion and Weight-bearing”* TF Beiser PhD, G Gold, MD et al., Stanford University, *Journal of Orthopaedic Research* (2005) 23

Radiologists reported that “weight-bearing imaging of the forefoot ... **demonstrated position-related changes of the neurovascular bundles relative to the metatarsal heads** ...”

*“MR Imaging of the Forefoot under Weight-Bearing Conditions: Position-Related Changes of the Neurovascular Bundles and the Metatarsal Heads in Asymptomatic Volunteers”* D Weishaupt MD et al., Univ of Zurich, Switzerland *Journal of MRI* (2002) 16

A radiologist concludes that “the main drawback of MRI is supine imaging that can limit the dynamic component of the examination ... **upright scanners may ultimately lead to MRI being the one imaging test for PFD.”*

*“Pelvic Floor Dysfunction”* H Pannu MD, Dept. of Radiology Johns Hopkins University *WomansImagingOnline* (2007)
Misunderstanding Field Strength

“I must have the best images”
Possibly requires:
• Particular anatomical region
• Specific type of image contrast
• Demanding spatial resolution
• Extreme image clarity
• Artifact-free images
• Specialized imaging applications
• Different patient positions

Q: Why?
A: “I don’t want to miss anything”
“So Don’t”

- The *Upright Weight-Bearing MRI* actually does something clinically valuable that a high-field MRI *cannot* do.

- Sometimes, patient positioning *trumps* a small increase in resolution or a small decrease in scan time.

- Patient positioning plays a critical role in detecting clinically significant pathology.
Frequently Asked Questions from Patients

<table>
<thead>
<tr>
<th></th>
<th>“Can I be scanned so there is nothing in front of my face?”</th>
<th>“Can I be scanned sitting up so I’ll be more comfortable?”</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Upright MRI</strong></td>
<td>YES</td>
<td>YES</td>
</tr>
<tr>
<td><strong>Open MRI</strong></td>
<td>NO</td>
<td>NO</td>
</tr>
</tbody>
</table>

You’ll be *more comfortable and less anxious* in the **Upright MRI** compared to an Open MRI.

*We are dramatically different than the Open MRI ... we’re Upright!*
FAQ: What about patient motion?

Removable Seat

The bed’s upright position is a tilt backwards at -8°

Flexible placement of trans-polar stabilization bars
Reduce amount of time our T2W scans are exposed to motion by shortening TR in each of a series of **multiple sub-scans**

**Our software allows the technologist to increase the number of slices *without* increasing the repetition time TR.**

<table>
<thead>
<tr>
<th></th>
<th>Number of Slices</th>
<th>Total Scan Time</th>
<th>Sub-scan Scan Time</th>
<th>Number of Sub-scans</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>9</td>
<td>1:54</td>
<td>0:38</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>21</td>
<td>5:16</td>
<td>1:19</td>
<td>4</td>
</tr>
</tbody>
</table>

Illustration of the *nine* slices in a typical cervical spine scan
MRI Application: Hard-to-Scan Patients

Patients that are unable to lie down

Large Patient Scanning

425 lbs.

Kyphosis

Cases Courtesy of FW Smith, MD
Department of Radiology
University of Aberdeen, UK
A child sitting on his mother’s lap watching the television during his spine MRI scan.
Summarizing the Unique Benefits of the Upright MRI

There is considerable evidence that the Upright Weight-Bearing MRI provides medical benefits that are not duplicated by any other MRI.

- Patient positioning plays a critical role in detecting clinically significant pathology.
- Recumbent-only imaging can underestimate the maximum degree of pathology.
- Peer-reviewed publications demonstrate the impact on treatment.

The Upright Weight-Bearing MRI actually does something clinically valuable that a high-field MRI cannot do!

Yes, we offer exceptional patient comfort, but this MRI is not just for claustrophobic patients.