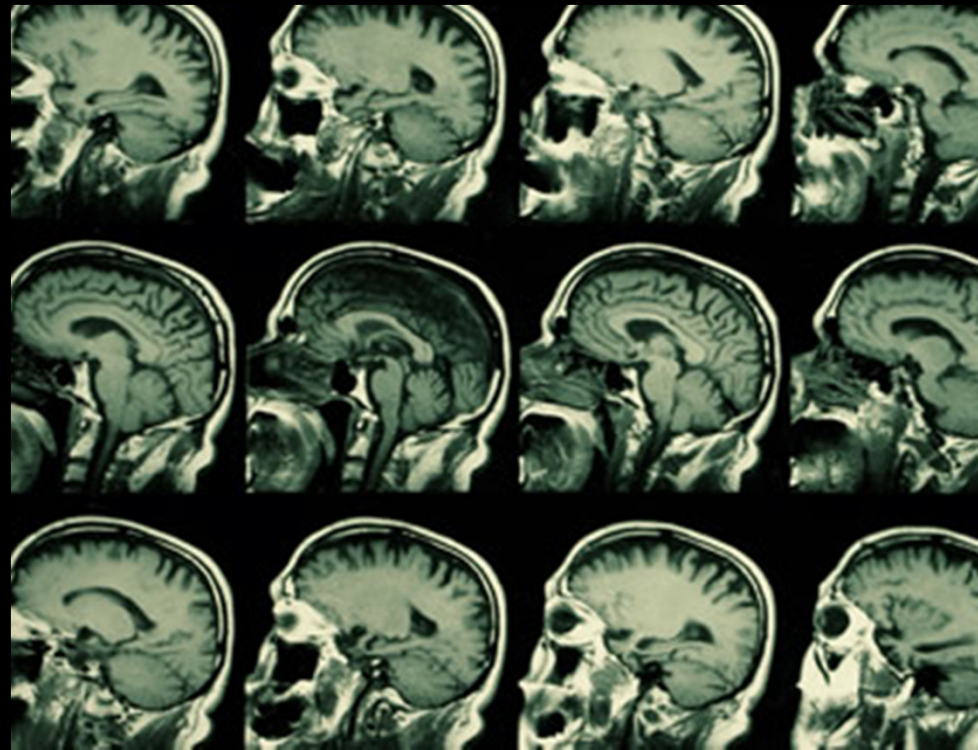


Magnetic Resonance Imaging



Team Members:

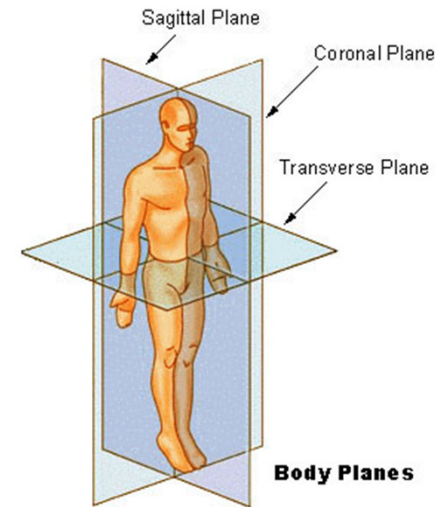
Karen De La Peña

Ronald Montoya-Ugarte

Alina Velasquez

Advantages

- Uses non-ionizing radiation
- Ability to image any plane
- Good contrast
- Able to characterize and discriminate among tissues using their physical and biochemical properties
- Able to diagnose: strokes in the earliest stages; multiple sclerosis; brain and pituitary tumors; brain, spine and joint infections
- Tissues surrounded by bone can be imaged

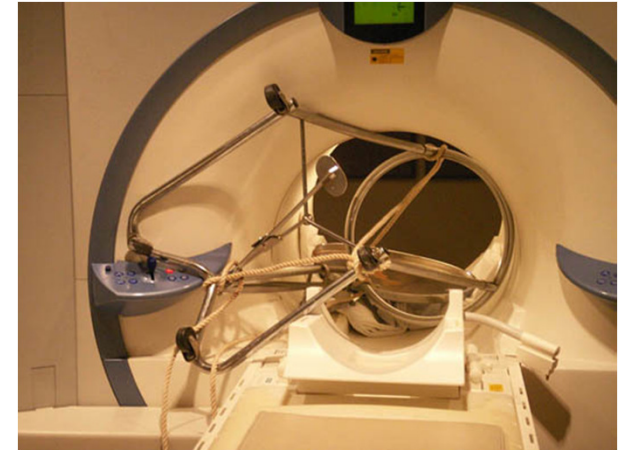


<http://srinivasarao.webs.com/mri.pdf>

http://images.wikia.com/athletics/images/1/13/Body_planes.jpg

Disadvantages

- MRIs are unsuitable for patients who have:
 - Pacemaker
 - Implantable cardioverter-defibrillator (ICD)
 - Nerve stimulators
 - Cochlea implants
 - Drug pumps
 - Brain aneurysm clips
 - Metallic fragments in or near your eyes or blood vessels
 - Prosthetic (artificial) metal heart valves
 - Eye implants
 - An artificial joint that has been fitted within the last six weeks
 - Or patients who are obese
- Immobility for long periods of time is required
- Uncomfortable scanning conditions
- Tissue calcification cannot be detected using MRI
- Expensive

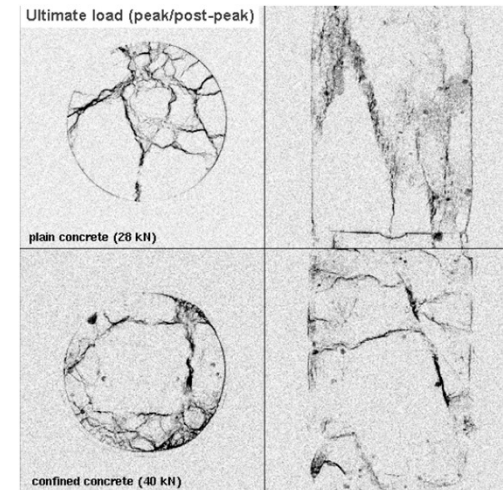


<http://www.knowsley.nhs.uk/health-a-to-z/m/mri-scan/>

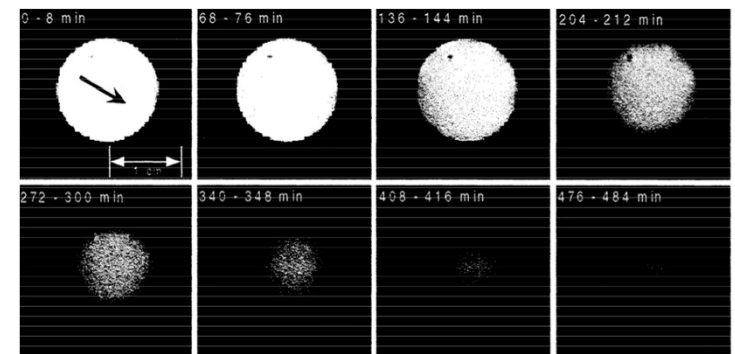
<http://www.radiologyschools.com/Radiology-Courses/cardiacmr/Indications/Advantages.html>

Non-Medical Application

- **Cement and Concrete:**
 - Study the hardening of concrete samples
 - Able to measure fractures
- **Plastics and polymers:**
 - Used to study how plastics are put together, and to relate their chemistry with their known physical properties
- **Wood pulp and Paper**
 - Visualization of a spatial moisture distribution
- **Oil Analysis**
 - Used to measure rock porosity, estimate permeability from pore size distribution and identify pore fluids (water, oil and gas) in a borehole



Images of slices through concrete samples after the ultimate load has been reached



Series of 2D MRI images during a drying experiment

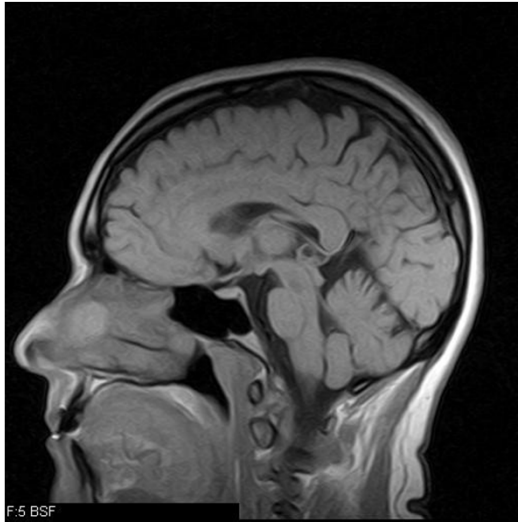
<http://www-civ.eng.cam.ac.uk/cjb/papers/cp73.pdf>

http://en.wikipedia.org/wiki/Nuclear_magnetic_resonance

<http://smartech.gatech.edu/jspui/bitstream/1853/2922/1/tps-862.pdf>

<http://www.emrf.org/EMRF%20FAQs/FAQs%20non-medical%20applications.htm>

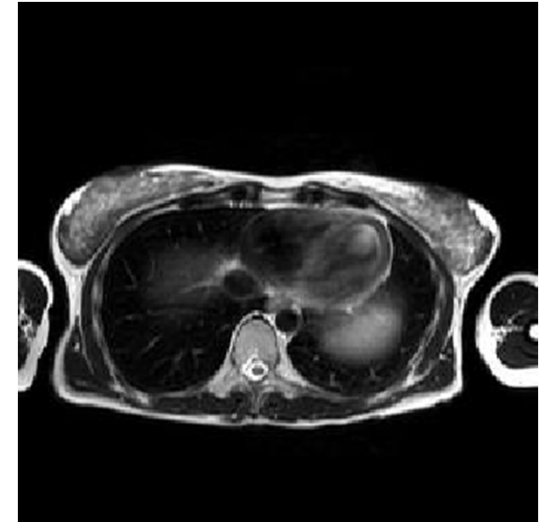
Medical Application



Head MRI



Abdomen and
Pelvic MRI



Thoracic MRI

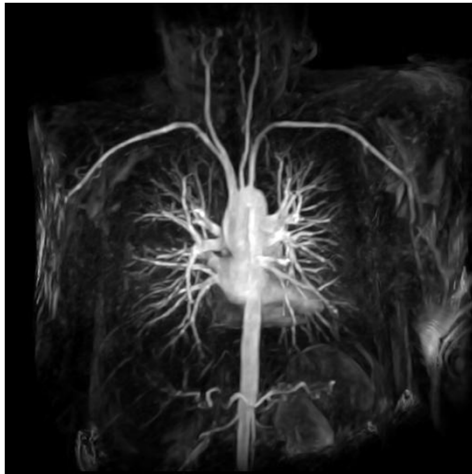
<http://www.webmd.com/a-to-z-guides/magnetic-resonance-imaging-mri>

<http://stevebmd.files.wordpress.com/2011/02/mri1.jpg>

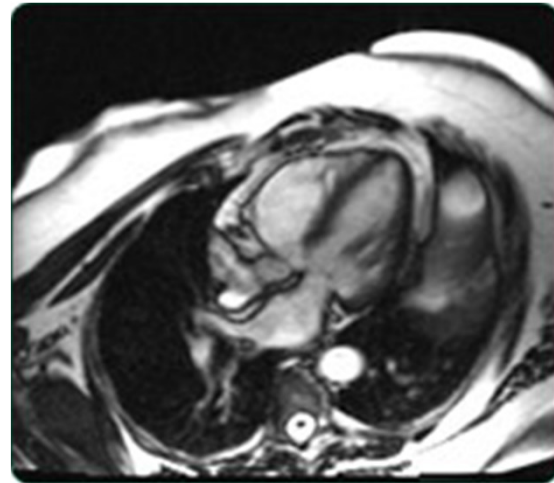
<http://www.mr-tip.com/serv1.php?type=img&img=MRI%20Thorax%20Basal%20Plane>

<http://www.adventisthealthnw.com/treatment/mri>

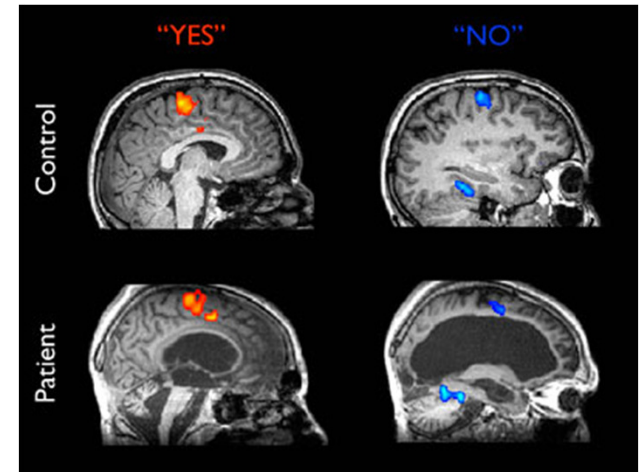
Medical Application



Blood vessels
Magnetic
Resonance
Angiography
(MRA)



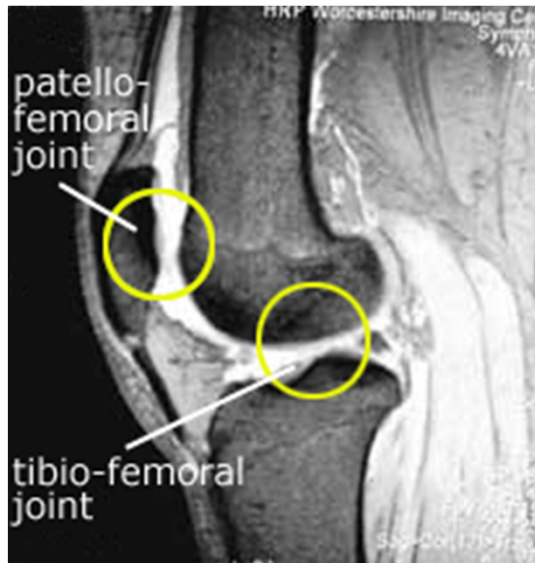
Cardiac MRI



Functional MRI

http://www3.americanradiology.com/pls/web1/wwimggal.vmg?img_in=12401
http://www.mrc-centre.cam.ac.uk/reg_com/cbsu_brain_scan.html
<http://www.dedicatedimaging.com/services/diagnostic-imaging/index.php>
<http://www.nhs.uk/Conditions/MRI-scan/Pages/What-is-it-used-for.aspx>

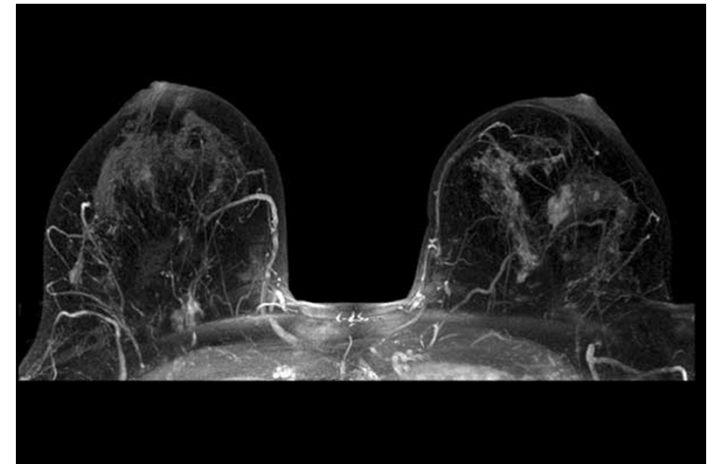
Medical Application



Bones and Joints



Spine MRI



Breast MRI

<http://www.mricenter.com/images/breast2.jpg>
http://www.e-radiography.net/radrep/Spine/Spine_metastases_MRI/tastases_MRI.htm
<http://www.kneeguru.co.uk/KNEEnotes/node/755>

HISTORY OF MRI

1930's

Isidor Rabi: Pioneer in Biological Magnetism

- 1944 Nobel Prize Winner in Physics
- Uses RF signals coupled with magnetic field
- Invented atomic and molecular beam MR method of observing atomic spectra (range in light) in gases



<http://www.3rd1000.com/nuclear/cruc18.htm>

http://www.nobelprize.org/nobel_prizes/physics/laureates/1944/rabi-bio.html

1940s NMR Spectroscopy



Felix Bloch

- Creates Bloch equations to describe motion due to magnetic moment in atomic nuclei
- Co-recipient of Nobel Prize in Physics in 1952 for his analysis of ethanol using NMR (liquids)

Edward Purcell

- Discovered NMR in solids
- Analyzed alkanes, particularly crystals, and wins Nobel Prize in Physics in 1952.
- Improved method of obtaining NMR



<http://books.nap.edu/html/biomems/epurcell.html>

<http://www.osti.gov/accomplishments/bloch.html>

Early 1970's



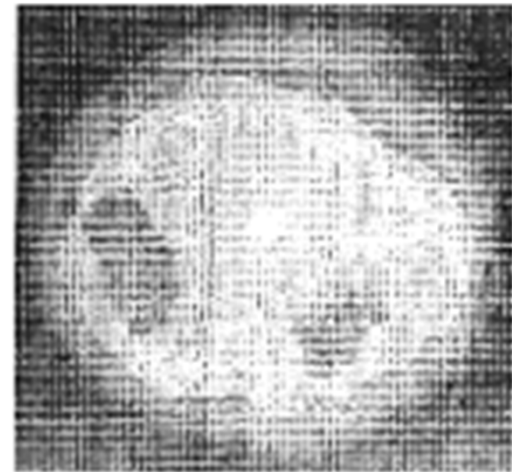
Raymond Damadian

- Not a physicist; a physician!
- Determines T1 of cancer tissue is higher than T1 of healthy tissue
- Damadian, leading to investment in technology

1973

Paul Lauterbur

- New imaging technique that he termed Zeugmatography
 - Utilized gradients in the magnetic field to determine the origin of the radio waves emitted
- 2D images were produced by back projection



<http://irmresonance.over-blog.com/article-4580047.html>

http://www.isbe.man.ac.uk/personal/dellard/dje/history_mri/history%20of%20mri2.htm

1975

Richard Ernst

- Introduced 2D NMR using phase and frequency encoding, and the Fourier Transform



1977



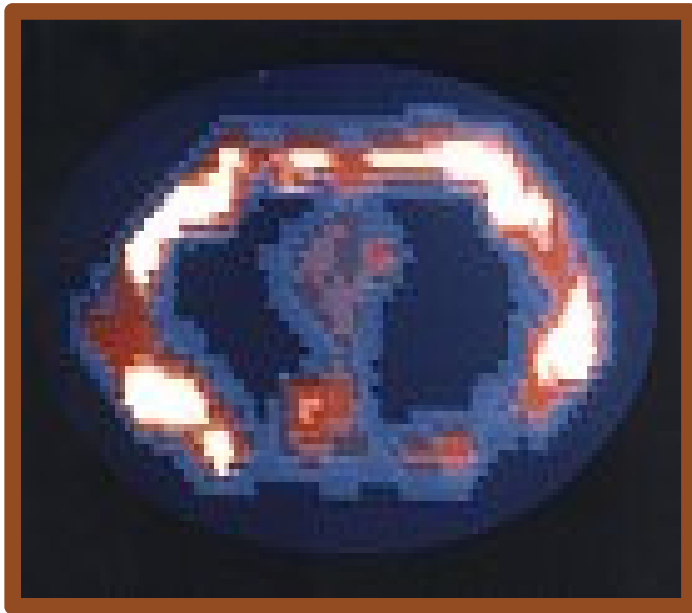
- After 7 years Damadian completed the first Magnetic Resonance scanner (Indomitabile)
- July 3, 1977 first MR scan of the human body - Scan time 4hrs and 45 min

Dr. Damadian with his post-doctoral research fellows, L. Minkoff and M. Goldsmith, And the *Indomitabile*

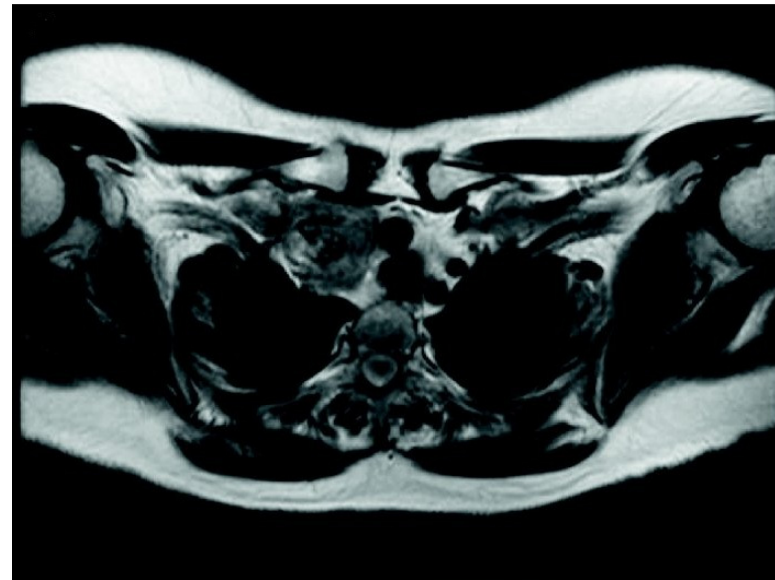
<http://web.mit.edu/invent/iow/damadian.html>
<http://www.teslasociety.com/mri.htm>
<http://www.fonar.com/timelineofmri.htm>

First MRI scan vs. Today's Conventional MRI

Cross-section of the human chest at the level of the 8th thoracic vertebra



Damadian's first MRI Scan
Scan time: 4hrs and 45 mins



Modern MRI Scan
Scan Time: After 30 mins

<http://www.fonar.com/timelineofmri.htm>

http://www.archbronconeumol.org/bronco_eng/ctl_servlet?_f=40&ident=90027791

1980s

1980

- FONAR introduces first commercial MRI

1982

- FONAR introduces Oblique Imaging: Produce multiple images at “any angle”

1986

- MRI becomes faster
- Takes >5 seconds to obtain an image
- Increased magnet strength, improved computerization of images



MRI's in the 1980's were already being used in hospitals

<http://fonar.com/history.htm>
<http://ard.highwire.org/content/58/3/156.full>

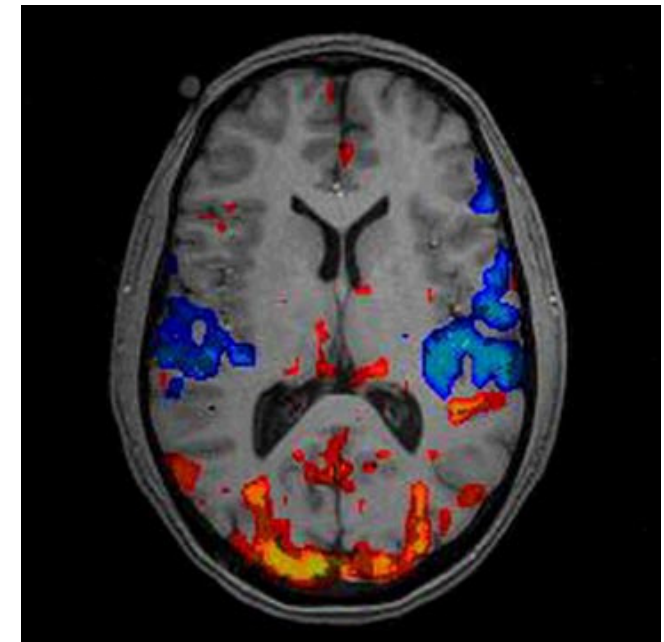
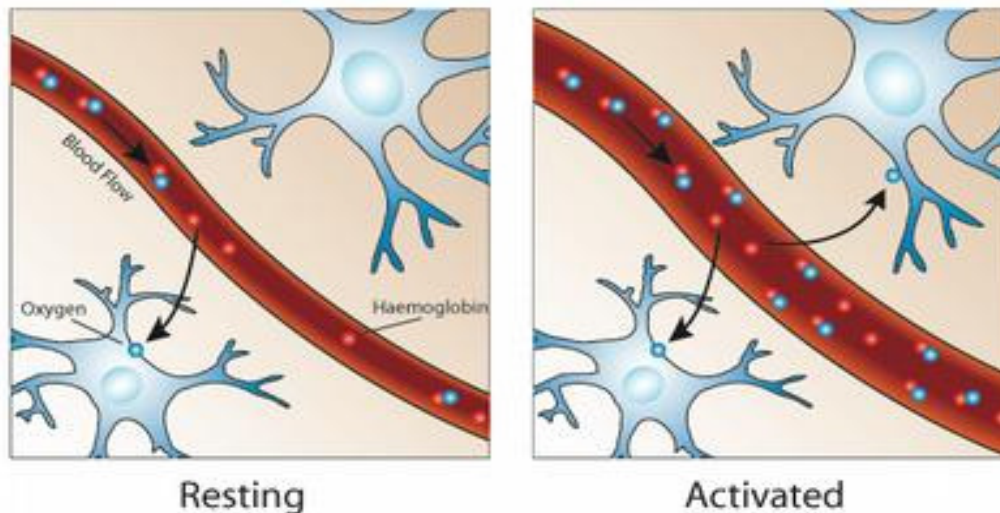
1990s

1990

- Full body MRI's enter hospitals

1993

- Functional MRI is developed
 - Uses blood oxygenation level dependent (BOLD) contrast



BOLD Contrast: During activated periods, the blood flow increases and more oxygenated hemoglobin are found at this location

<http://www.bis.gov.uk/assets/biscore/corporate/migratedd/publications/f/file28050.pdf>

<http://library.thinkquest.org/TQ0312532/thinkquestH1/history.html>

<http://www.fmrib.ox.ac.uk/education/fmri/introduction-to-fmri/what-does-fmri-measure>

http://scientopia.org/img-archive/scicurious/img_836.jpg

1996

- FONAR introduced the Stand-Up MRI



Stand-Up MRI, or multi-positional MRI, allows patients to be scanned at various positions which may be more comfortable for them.

<http://fonar.com/history.htm>

Latest Trends in MRIs

- Open MRI Improvements
 - Increased magnet strength
 - Larger scanning space (70 cm diameter)
 - Designed to accommodate claustrophobic and obese patients
 - Some have television screens placed on top to allow patient to view it



Latest Trends in MRIs

- Portable MRI: Fact or Fiction?
 - Received FDA clearance in 1998
 - Used for orthopedic scanning (foot, ankle, wrist, etc.):
 - Scanning time for wrist or hand: 12 minutes
 - Weighs~100 lbs and is easily transported
 - Special shielding not needed for the room
 - Scans can be completed during same day-office visit



<http://www.healthcare.uci.edu/news/releases/MagneVu.htm>
<http://www.mr-tip.com/serv1.php?type=db1&gid=1345>

Magnevu 1000 Portable MRI Specs

<u>Device</u> Information and Specification	
CLINICAL APPLICATION	Dedicated <u>extremity</u>
CONFIGURATION	Portable <u>open MRI</u>
PULSE <u>SEQUENCES</u>	<u>T1</u> and <u>T2 weighted</u> SE, <u>STIR</u>
IMAGING MODES	3-dimensional multi-echo data acquisition
<u>SLICE THICKNESS</u>	3D: 0.6–1 mm
<u>SPATIAL RESOLUTION</u>	0.5–1 mm
<u>MAGNET</u> TYPE	Permanent
<u>MAGNET</u> WEIGHT	about 50 kg
POWER REQUIREMENTS	110 V
<u>FIELD STRENGTH</u>	0.2 T

<http://www.mr-tip.com/serv1.php?type=db1&gid=1345>

Pacemakers and MRI: Can they coexist?

- MRI friendly pacemakers FDA approved in 2011
- Currently costs around \$6500
- Pacemaker must be programmed at the time of scan and then reprogrammed
- Changes in lead composition that make it MRI-friendly



http://www.pennlive.com/bodyandmind/index.ssf/2011/04/mri-friendly_pacemakers_debut.html
<http://limpeter-mriblog.blogspot.com/2010/04/cardiac-pacemaker-designed-for-mri.html>

Newest from MRI

- Transition from 1.5 T to 3 T; slowly producing more 7T magnets
- Multi-channel receiving capability allows for “Parallel Imaging”, creating multiple images simultaneously

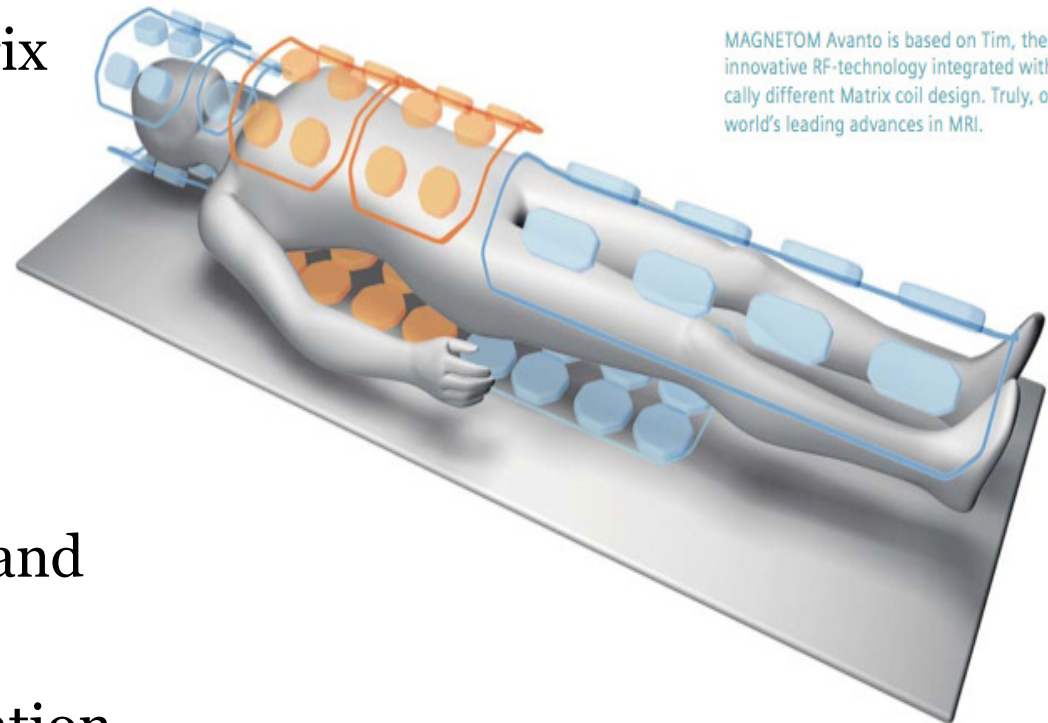


<http://www.aapm.org/meetings/amos2/pdf/26-5961-46702-744.pdf>

<http://science.dodlive.mil/2011/10/21/afghanistan-theater-receives-state-of-the-art-mri-systems/>

TIM MRI (Total Imaging Matrix)

- Flexibility:
Seamlessly integrated matrix coil allow patient to be personally imaged.
- Accuracy:
High Signal Noise Ratio provide by local coils
- Speed:
Head to toe, front to back, and side to side for unlimited Parallel Imaging. Even for double oblique slice orientation
- Body Matrix coils only 950 g (2 lbs)



MAGNETOM Avanto is based on Tim, the most innovative RF-technology integrated with a radically different Matrix coil design. Truly, one of the world's leading advances in MRI.

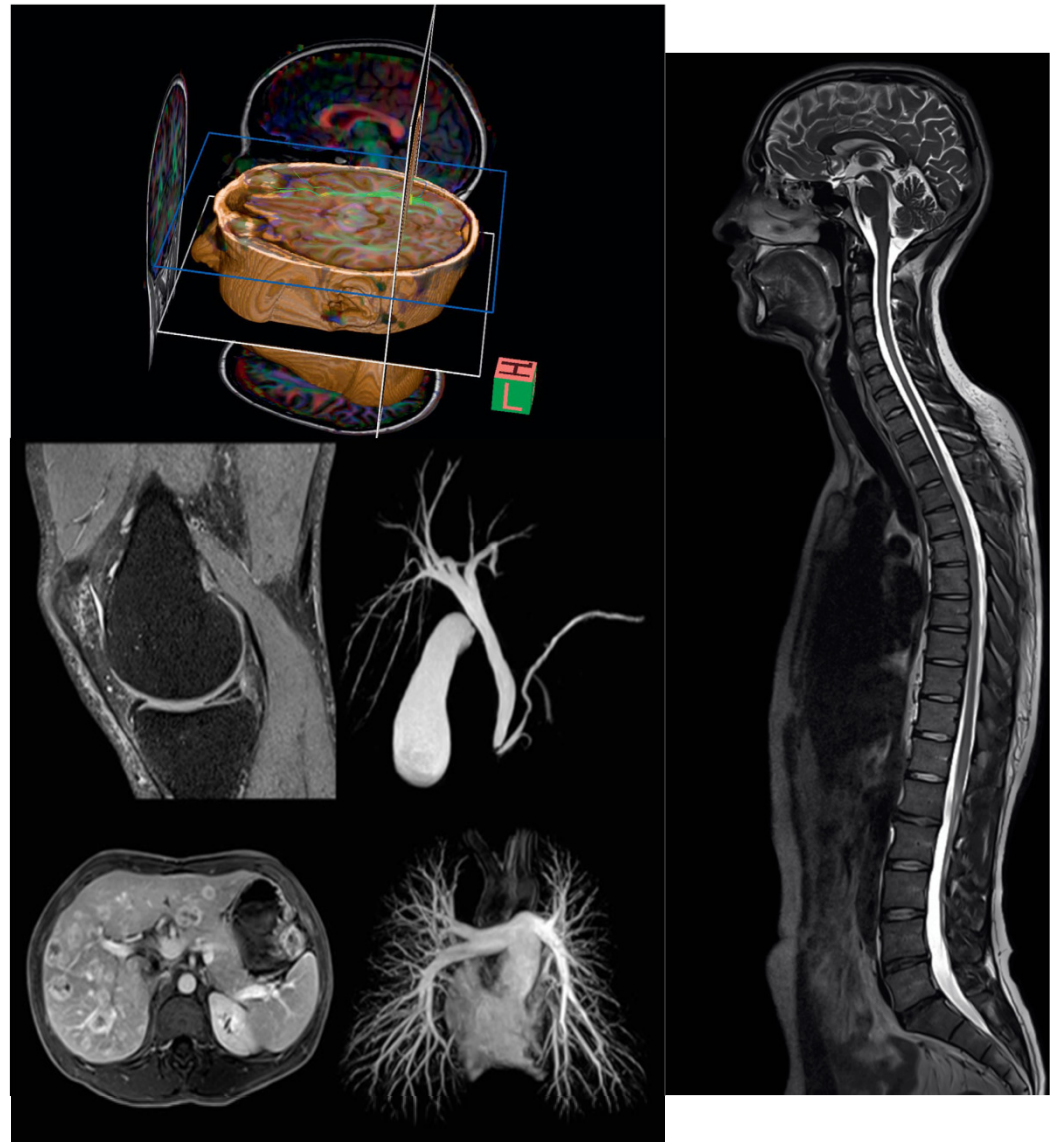
TIM MRI

- Able to scan without the necessity of patient to go through the magnet of the machine
- Reduces the claustrophobic element
- Less noise than usual MRI machines
- True whole-body coverage
- Faster and clearer pictures of examined tissue. (Acquisition speed breaks new records)



TIM MRI

- Up to 102 seamlessly integrated matrix coil elements
 - Matrix coils unleash enormous SNR
- Up to 32 independent RF Channels
 - Total imaging matrix: combination of matrix coils and RF Channels
- Extreme precision for exams
 - From 5 mm to 196 cm Field of View (FoV)
 - No need to reposition coil or patients



<http://www.mrc.wayne.edu/equipment.html>

http://www.european-hospital.com/en/article/6780-Siemens_introduces_Tim_and_Dot.html

http://www.medical.siemens.com/siemens/en_US/gg_mr_FBAs/files/MRI_Hot_Topics/MAC_Print_Tim_Appl_Suite.pdf

MRI Machine Cost

- Average cost of MRI machine:
 - \$2 million (price of machine plus installments)
- Price to run MRI machine:
- \$800,000 per year
- Main factors that contribute to the costs of running an MRI:
 - Capital costs (one-time equipment, building costs)
 - Maintenance and service costs (equipment maintenance, software upgrades etc.)
 - Staffing costs (salaries)
 - Consumable costs (electricity, films, etc.)
 - Overhead costs (building maintenance, cleaning etc.)

MRI Scan Cost

- Ranges between: \$400 to \$3,500 (depends on procedure)
 - Example: National Average Price
 - Shoulder (Upper Extremity): \$1,550
 - Brain: \$2,550
- MRI costs are broken down into 2 areas:
 - Technical Fees
 - Professional Fees

[http://newchoicehealth.com/Directory/Procedure/45/MRI%20Shoulder,%20Arm,%20Wrist,%20Hand%20\(Upper%20Extremity](http://newchoicehealth.com/Directory/Procedure/45/MRI%20Shoulder,%20Arm,%20Wrist,%20Hand%20(Upper%20Extremity)

<http://www.comparemricost.com/>

MRI Scans Performed in 2010-2011

East North Central	IL, IN, MI, OH, and WI
East South Central	AL, KY, MS, and TN
Middle Atlantic	NJ, NY, and PA
Mountain	AZ, CO, ID, MT, NM, NV, UT, and WY
New England	CT, MA, ME, NH, RI, and VT
Pacific	AK, CA, HI, OR, and WA
South Atlantic	DC, DE, FL, GA, MD, NC, SC, VA, and WV
West North Central	IA, KS, MN, MO, ND, NE, and SD
West South Central	AR, LA, OK, and TX

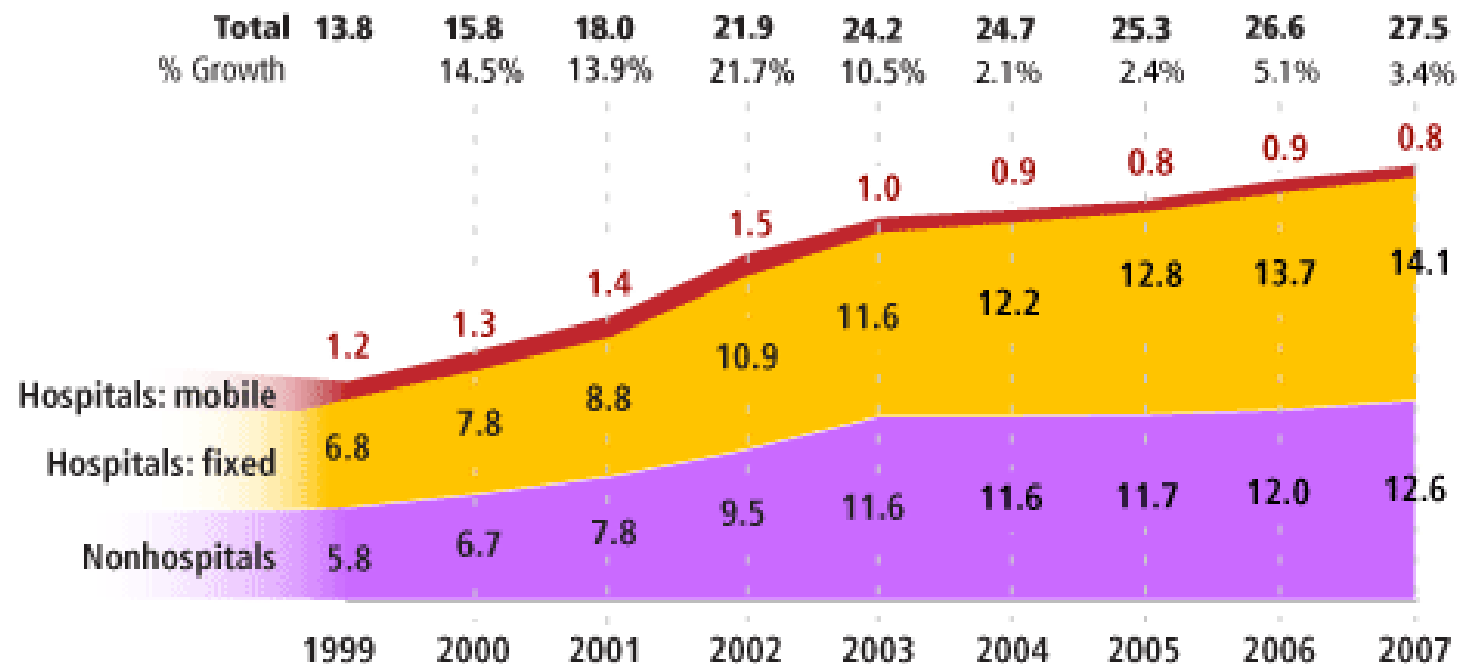
- AHRA Regions

- MRI Exams per 1,000 People

REGION	2010	2011	GROWTH
East North Central	77.21	77.47	0.33%
East South Central	82.93	83.21	0.34%
Middle Atlantic	93.73	93.95	0.23%
Mountain	86.73	87.29	0.64%
New England	79.24	79.39	0.19%
Pacific	89.99	90.32	0.37%
South Atlantic	94.19	94.67	0.51%
West North Central	78.21	78.43	0.28%
West South Central	80.53	80.93	0.49%
Total	86.32	86.67	0.41%

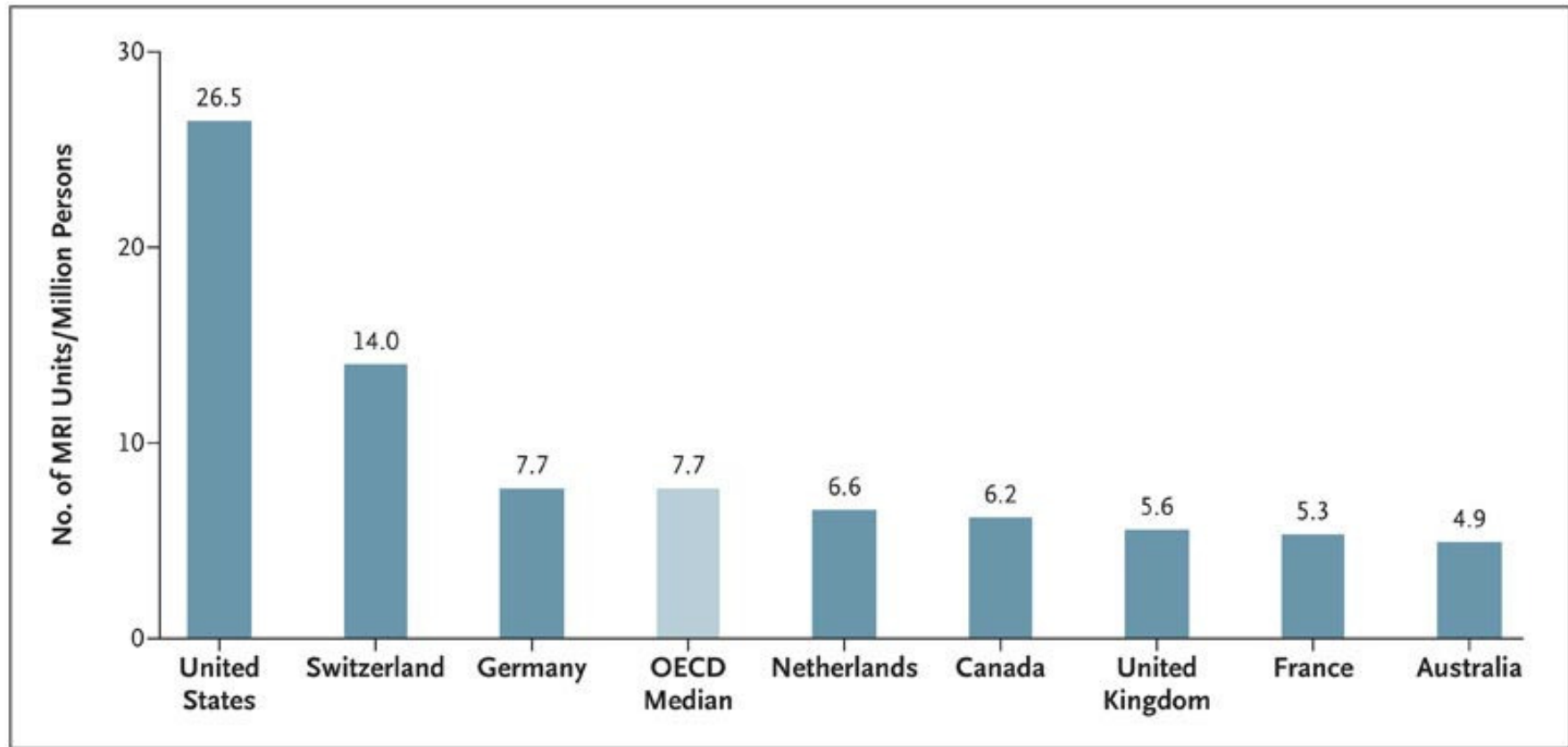
MRI Scans on an Annual Basis

Total MRI procedure volume in millions, 2000-2007, hospital and nonhospital sites



Timeline from 1999 to 2007 with the total MRI procedure volume in millions. Hospitals with fixed MRI machines and non-hospitals are incrementing every year.

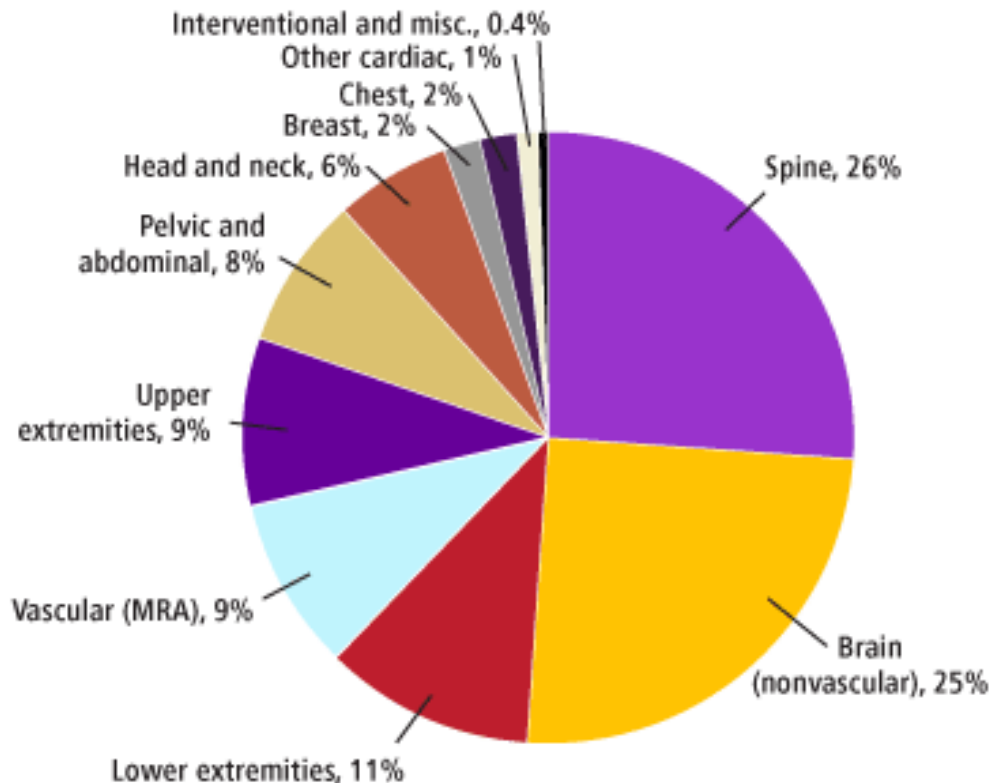
<http://www.numberof.net/number%20of%20mri%20scans%20per%20year/>
<http://www.auntminnie.com/index.aspx?sec=sup&sub=bai&pag=dis&ItemId=81355>



The United States is the top country, with 91.2 MRI scans per million population, which equals about 28,000,000 magnetic resonance imaging scans each year. (OECD Health Data 2009)

<http://www.numberof.net/number%20of%20mri%20scans%20per%20year/>
<http://www.auntminnie.com/index.aspx?sec=sup&sub=bai&pag=dis&ItemId=81355>

MRI procedure mix, 2007, all sites



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Studies show that in 2007, the most popular MRI scan procedure are from the spine and the brain. MRI is less used in breast and chest.

<http://www.numberof.net/number%20of%20mri%20scans%20per%20year/>
<http://www.auntminnie.com/index.aspx?sec=sup&sub=bai&pag=dis&itemId=81355>

QUESTIONS???

