LOW-FIELD VERSUS HIGH-FIELD MSK MRI

*MSK MRI for an Emerging World - Wednesday, 9 May 2012*

Robert Downey Boutin, M.D.

*Professor of Clinical Radiology*

*University of California, Davis*

**Objective:** To compare low-field & high-field MRI, focusing on MSK applications.

Clinical MRI scanners are commonly classified into general categories for commercial purposes, such as “low field” [LF] (e.g., ≤ 0.5 T), “mid field” (e.g., between 0.5 and 1.5 T), “high field” [HF] (e.g., 1.5 and 3.0 T), and “ultra high field” (> 3.0 T). Although there are many factors that influence the diagnostic capability and cost of MRI exams (e.g., coil, gradients, software, radiologist), the magnet field strength is a pivotal variable that has been the subject of tremendous controversy.

Tesla (T) is the SI unit of magnetic field strength. In our daily lives, we experience a wide spectrum of magnetic field magnitudes: the brain’s magnetic field is $10^{-12}$ T; the Earth’s magnetic field is on the order of $10^{-5}$ T; a typical refrigerator magnet is $10^{-3}$ T; and medical MRI systems are generally between 0.2 and 7.0 T. Of note, 16 T has been used to levitate a frog!

Debate regarding the “optimal” MRI magnet strength – and the global deployment of LF and HF MRI units -- is influenced by numerous factors, including [I] exam quality & technique, [II] equipment cost & reimbursement, [III] patient comfort & access, [IV] market trends & marketing, and [V] data in the medical literature and clinical case experience.

In addition to examining research from the medical literature, we will review clinical cases in order to provide specific, practical examples of LF and HF MRI in the extremities, including the shoulder (e.g., rotator cuff tears), wrist/hand (e.g., erosions), hip (e.g., AVN, FAI), and knee (e.g., ligament tears, meniscus tears, cartilage derangements, bone marrow edema-like signal), and miscellaneous disorders (e.g., radiographically-occult fracture).

I. Exam Quality & Technique

The SNR is a function of magnet field strength, the volume of tissue being imaged (voxel volume), and the RF coil being used [Shapiro 2010]. Thus, SNR is directly proportional to field strength, and the major advantage for HF MRI relates to SNR.

**High Field.** In theory, doubling the strength of the main magnetic field could result in twice the SNR. In practice, the SNR benefit of increased field strength is partially counteracted by some types of artifacts, increased SAR exposure, and changes in tissue contrast.

- **Artifacts.** As field strength increases, there is potentially increased negative impact from factors such as susceptibility artifact and chemical shift artifact.
Although both of these artifacts can be minimized by increasing (widening) the receiver bandwidth (RBW), this partially offsets the signal gains of increasing magnet strength.

- For example, the RBW is commonly doubled when increasing from 1.5 T to 3 T. Doubling the RBW causes the SNR to decrease by ~30% [Kuhl 2008]. When both B0 and RBW are doubled, there is a net SNR gain of ~ 40%. (SNR is proportional to 1/\sqrt{RBW}. Increasing RBW does confer advantages, such as faster data sampling that can reduce acquisition time.)

- Imaging of orthopaedic hardware may be performed at 3 T [Farrelly 2010], although many msk radiologists prefer a lower field strength, because of susceptibility artifact.
  - Some authors have reported anecdotally/empirically that imaging around metal is actually better at 3 T than at 1.5 T, with little change in FSE image quality when increasing RBW [Amrami 2008].
  - Some authors have cautioned that “the required safety testing should be performed for each piece of hardware at 3 T” [Farrelly 2010].

- At 3 T, there are some problems reported with magnet homogeneity and shimming that are worse than at 1.5 T, with the dielectric effect causing significant shading across large field-of-view images [Amrami 2008]. Engineering complexity often seems to increase with the higher magnet strengths; a HF or ultra-HF magnet, on its own, is not enough to produce high-quality images.

- **SAR.** With HF imaging at 3 T and above, the SAR may be a limiting factor, potentially reducing the number of slices that can be obtained in a single acquisition (particularly when imaging a large volume of tissue, such as the pelvis, compared to standard extremity exams). (When doubling field strength (e.g., from 1.5 T to 3.0 T), the RF power for excitation increases by a factor of four.)

- SAR limitations can be minimized with several technical modifications (e.g., multi-transmit technology, low flip angles).
  - Recent work shows how electromagnetic fields generated by RF coils may be optimized to yield the optimal SNR and the lowest RF power deposition (SAR) [Lattanzi 2011].

- **Tissue Contrast.** Pulse sequence parameters commonly are modified at higher field strengths because of changes in tissue contrast.
  - With HF imaging, the TR needs to be increased due to the increase in T1 relaxation time of musculoskeletal tissue (e.g., approximately 15-22% greater at 3 T than 1.5 T). (Image acquisition time is proportional to TR.)

- **Speed.** Thus far, the medical benefit of rapid acquisitions that is afforded by HF MRI has been less important for standard msk applications than for neuro and body imaging (e.g., fMRI, MR angiography, breath hold applications).

- **Advanced Techniques.** The most recent HF platforms facilitate work with isotropic imaging (e.g., 3D-FSE CUBE) and novel contrast mechanisms (e.g., T1rho and T2 mapping for cartilage). In light of the excellent accuracy of optimized 1.5 T images for diagnosing most clinically relevant musculoskeletal disorders, there is relatively little room for additional improvement at 3 T (given current medical and surgical treatment options in general practice). However, 3 T does allow for decreased scan time (improving patient throughput) or increased spatial resolution (improving evaluation of small parts), as well as multitudinous research opportunities.
  - More extensive clinical studies are needed to determine whether 3D FSE acquisitions can be used as a single sequence in evaluation of the knee menisci. Recent work at 3-T MRI found that conventional 2D FSE performed better than 3D FSE (SPACE) in the evaluation of menisci, while 2D and 3D techniques were similar in the evaluation of ligaments [Subhas 2011].
  - T1rho and T2 mapping are feasible methods for quantitatively and noninvasively monitoring the maturation of repaired tissue following microfracture surgery over time [Theologies 2011].
  - At 7 T, DT imaging of patellar cartilage in vivo has been performed with good test-retest reproducibility, and may be accurate in discriminating healthy subjects from subjects with OA. ADC and FA are two promising biomarkers for early OA [Raya 2011].
Low Field. LF scanners, on the other hand, have the intrinsic disadvantage of lower SNR that may be partially compensated for altering parameters (e.g., increasing FOV, increasing slice thickness, decreasing matrix, lowering BW, and increasing NEX), often at the expense of spatial resolution and/or increasing acquisition time.

- Longer acquisition times may translate into an increased likelihood of patient motion artifact.
- Other relative disadvantages of LF MRI can include limitations on spectral fat suppression. (At HF, frequency-selective chemical fat suppression is much more robust (especially when imaging near isocenter), due to the wider separation of fat and water peaks (220 Hz at 1.5 T and 440 Hz at 3 T). At LF, however, STIR imaging is a robust method of producing fat-suppressed, fluid-sensitive images.

II. Equipment Cost & Reimbursement

MRI equipment is relatively expensive to buy and maintain.

Costs. Although prices vary substantially, new 1.5-T and 3-T scanners can cost more than $1.5 and 2 million, respectively. By comparison, the cost of LF scanners is vastly less expensive, traditionally costing 2-3x less.

- So, although the “patient throughput” (exam duration) may be much lower for LF units (often by ~35%), the “break-even point” (number of exams per day that must be performed before turning a profit) is also significantly lower.

- In the USA, the routine (non-contrast) exam time slots at outpatient facilities are often scheduled at 45 minutes for LF exams and 30 minutes for HF exams. However, there is substantial variability. For example, some facilities schedule both LF and HF exams for 45 minutes, while other sites have decreased time slots for routine HF exams to only 20 minutes.
  - Future innovations could prominently impact patient throughput. For example, news headlines in Diagnostic Imaging recently announced “New MRI Algorithm Cuts Scan Time by Two-Thirds”, so that a 45-minute scan might be done in 15 minutes [Bilgic 2011].

- Other factors (e.g., siting, shielding, maintenance, staffing) also can be significant variables affecting the financial viability of a scanner.
  - In some countries, LF permanent magnets may be preferred, owing to an unreliable power supply or the expense/availability of cryogens.

Reimbursement. Although reimbursement rates vary substantially, the cost of the MRI exam in most countries is not influenced by field strength or image quality. However, in the USA, there is a trend towards requiring MRI unit accreditation (e.g., by the American College of Radiology), in order to ensure a basic level of quality control. Some private payors (e.g., health insurance corporations) have suggested guidelines restricting payment for LF MRI exams, unless a compelling medical need is documented (e.g., claustrophobia).

- Changes. In the USA, the “Deficit Reduction Act of 2005” significantly reduced reimbursement rates paid by federal government insurance programs (for the equipment component of the MRI fee), and further decreases in scan reimbursement have been threatened, which may impact the ability of some enterprises to pay for new HF equipment with currently existing business plans.

- Variability. Even within the USA, the reimbursement can vary dramatically by geography and provider. For example, hospitals may charge far more than $1000 per exam, compared to outpatient facilities that may charge/clean an average of only ~$400-500 per exam. The level of reimbursement obviously affects the “break even point”, as well as which of three general categories of business strategies are pursued: “high quality”, “low cost”, and/or “service differentiation” [Rothenberg 2006].
III. **Patient Comfort & Access**

**Comfort.** LF units have been marketed as offering greater comfort and access, thus making them well suited for patients who are very large, severely anxious, claustrophobic, or in need of easy physical access during an exam. MRI units with open architecture also have an added benefit -- msk body parts can be easily positioned in the magnet isocenter.

- **“Open” Design.** Although LF units once had exclusive claim to “open” scanner designs, manufacturers have made a concerted effort to make scanners more “patient friendly”, including HF scanner bores that are relatively short (e.g., 1.25 m) and relatively wide (e.g., 0.7 m). (This shortened magnet design limits the FOV down the bore direction.)

- **Data on Claustrophobia.** MRI exams are not completed in about 2 million patients annually because of claustrophobia. Compared to the conventional closed-bore design, non-randomized studies generally have shown that open LF scanners and HF short-bore can reduce claustrophobic events.
  - A successful LF open MRI exam can be accomplished in over 90% of patients who have failed to complete a scan because of claustrophobia in a conventional closed-bore HF unit [Spouse 2000].
  - In a comparison of short-bore versus closed-bore scanners in 55,734 consecutive patients, the short-bore scanner reduced claustrophobic events by a factor of 3 [Dewey 2007].
  - Bangard and co-workers, for example, evaluated 36 claustrophobic patients; the scan termination rate was reduced to 8%, compared to 58% during previous conventional closed-bore imaging attempts in the same patients.

- **Room for Improvement.** Claustrophobia may occur with open and short-bore architecture.
  - In a recent study of 174 patients at high-risk for claustrophobia, MRI was precluded in more than 25% of examinations, despite using scanner designs expected to lower the rate of claustrophobic events [Enders 2011]. (There was no significant difference between the claustrophobic events in the short-bore group [39%] and the open scanner group [26%].)

- **Potential Solutions.** For anxious and claustrophobic patients, there are a number of strategies to help improve the likelihood of exam completion, regardless of scanner architecture (e.g., medication, relaxation strategies, virtual reality distraction). However, there is a potential need for [a] further scientific investigation of “best practices” and [b] further modifications towards a more patient-centered scanner environment.

**Access.** Immediate availability of MRI services is taken for granted by those of us in the USA who live in urban areas with health insurance.

- **Is MRI Availability Limited by High Cost?** Even in economically developed countries that enjoy “universal” health care, prompt access to MRI services may be limited, particularly in rural areas where the lower density/volume of patients may not make it economically feasible to support more expensive HF systems. In other words, with higher cost of HF equipment, fewer scanners might be purchased and there is potentially more constrained access to care.
  - In the Canadian province of Nova Scotia, for example, waiting times have been reported to consistently range between 20-60 working days (1-3 months) for a neuro MRI exam and 200 working days (11 months) for an orthopaedic MRI exam (2004 data).
IV. The MRI Market, Trends, & Marketing

The MRI Manufacturers. The manufacturing sector for imaging equipment is relatively consolidated. Only four corporations in the MRI systems market account for ~70-80% of global revenue in this industry sector. The greatest market shares are held by Siemens (24-32%) and GE, followed by Philips and Toshiba. Other companies have a smaller market presence, including Hitachi, Esoate, and Time Medical Systems.

The Market for Scanners. The market for both LF and HF MRI units of all field strengths is strongly influenced by factors that are not directly related to: [a] the analysis of MRI physics by PhDs, or [b] the accurate interpretation of images by MDs, or [c] the recommended utilization guidelines by MPHs. Rather, it is the MBAs and other business leaders/experts that may ultimately impact decisions on what types of MRI units will be manufactured by multinational corporations, researched by ISMRM members, and purchased for clinical use.

Trends & Forecasts. Industry analysts identify trends and make forecasts that influence the types of units that are marketed, distributed, used, and refurbished. (Marketing and sales data is largely influenced by new unit sales efforts; in contrast, data on re-sale of used MRI equipment are more scant.) The global MRI market is expected to grow from $4.0 billion in 2011 to $4.8 billion in 2016 (at an estimated compound annual growth rate [CAGR] of 3.6% from 2011 to 2016). Another, more optimistic, report predicts the global MRI equipment market will total $8.2 billion by 2017.

- **Positive** macroeconomic trends that benefit the MRI market include: an aging worldwide population; an increasing prevalence of major diseases (e.g., heart disease, cancer, diabetes, OA); and expanding access to healthcare services (e.g., particularly in emerging markets, in rural areas, and for younger populations).
- **Negative** global trends include stricter medical insurance reimbursement policies and widespread economic turbulence throughout the world.

- In the USA, however, the recent “Great Recession” has resulted in downward pressure on new MRI equipment purchases. (Decreasing MRI exam volume may have occurred in some areas as patients elected to decline or defer treatments, due to loss of health insurance benefits or high out-of-pocket costs for expensive procedures.)

Developed vs Emerging Markets – Geographic Analysis. The leading markets for MRI systems are the developed countries in North America, followed by Europe and Asia. In recent years, market growth occurred particularly in Europe and Asia.

- The North American market is expected to increase at a 4.4% CAGR (worth $2.3 billion in 2010 and expected to reach $2.9 billion in 2015). In the USA, recent reimbursement changes and the economic downturn have called the expanding use of MRI scanning into question.

- In economically developed countries, sales are largely replacement purchases or “upgrades” at existing facilities. The deployment/distribution of MRI systems is relatively saturated. The market emphasizes features such as technical innovations and potentially improved efficiency.

- In emerging economies of the Asia-Pacific and Latin America regions, the MRI market has not yet been “saturated”. Growing GDP and increased utilization of imaging are major drivers in the increasing demand for de novo MRI systems. For example, the Asia-Pacific market was reported to have a CAGR of 11.6% from 2005-2010. Healthcare spending in emerging economies is expected to double over the next seven years.
High Field vs Low Field – Analysis by Field Strength.

“Whatsoever we expect with confidence often becomes a self-fulfilling prophecy.”

High Field. HF MRI systems command the largest share within the MRI market, and HF sales are expected to be the key revenue generator in the future. In particular, 3-T systems currently represent the fastest growing segment of new sales, as facilities in developed regions upgrade old equipment. (Industry cynics suggest that manufacturers push HF scanners because they facilitate higher profit margins.)

- “Within the next 10 years in MRI, the move towards a large installed base of 3T scanners is the most predictable development” [Blamire 2008].

Low Field. LF scanners generally have a minority share of the market. In Japan, for example, LF units account for approximately one-fourth of all installed scanners [Hayashi 2004]. In the USA during 2006, new scanner sales were much less likely to be LF units (160 [16%]), compared to HF units (750 [72%] scanners were 1.5 T; 120 [12%] scanners were 3 T).

- Although LF units are numerous and widely distributed, some experts predict the decline of this market, with a negative CAGR of 2.6% in the coming five years. These analysts believe that the LF scanner sales will be replaced largely by HF MRI scanners that [a] now have more open architecture and [b] can generate higher resolution or faster images.

- “Sales of open-sided (LF) units are a pale ghost of the halcyon days in the mid-1990s when these designs represented as much as 50% of the annual market. At the RSNA, it was hard to find any references to Profile (0.2T) or Ovation (0.35T) from GE…; Concerto (0.2T) or Magnetom C! (0.35T) from Siemens…; or Panorama 0.23T from Philips [Bell 2007].”

- Other reports prognosticate continued growth for LF sales is possible (e.g., by Esaote, Time). The market for used scanners is expected to be substantial in tough economic times, especially in regions where entrepreneurial private practices are strong or there is not a high population density.

New vs Used Equipment. The business in refurbished medical imaging equipment has been growing in some sectors, likely due to increasing demand in emerging economies, as well as facilities in developed economies that view the purchased of used equipment as the best economic decision in uncertain economic times.

- In Europe, the refurbished imaging equipment market has been projected to grow with a CABR of 7.1% from 2009 to 2016.

- Refurbishment is done both by OEMs (e.g., Philips, Siemens, GE) and “third-party” refurbishers. There is generally more demand for cosmetic refurbishment than for electromechanical refurbishment because of the cost involved.

- The average selling price (ASP) of OEM-refurbished equipment is quoted at 30-40% less than that of comparable new equipment. The ASP of third-party refurbished equipment can be ≥ 20% less than an OEM’s price. Depending on the market, the ASP of used equipment may depreciate by ~8% annually.

V. Medical Literature & Clinical Cases

There is a relative paucity of medical literature that significantly differentiates LF versus HF accuracy and outcomes (e.g., comparative effectiveness or cost-effectiveness) in adequately sized, properly controlled, randomized prospective trials that are without bias.

Image Quality = Patient Outcome? Proponents of HF and LF scanning generally agree that HF MRI provides better quality images than LF MRI [Sanal 2009].
For proponents of LF MRI, however, the real question is whether images that are more visually pleasing result in significantly greater diagnostic accuracy for most patients [Ghazinoor 2007]. They maintain that, in a world with limited healthcare resources, it is reasonable to ask: *How much diagnostic accuracy, exam speed, and improved patient outcome are affected by the increased cost of a HF scanner?*

**American College of Radiology Position.** The ACR “Practice Guidelines” state:

- Various investigators have reached contradictory conclusions regarding the diagnostic performance of LF-strength MRI scanners [Kransdorf 2010].
- LF scanners generally are more susceptible to degraded image quality than their HF counterparts [Rubin 2011].
- For some indications, imaging on a LF system may be particularly disadvantageous compared to a HF system. For example, for some indications like high-resolution imaging of articular cartilage, images obtained with a LF system will be lower quality compared to those acquired on a HF system. Detection of other conditions, such as meniscal and anterior cruciate ligament tears, is less dependent on magnet strength and design [De Smet 2010].

**Medical Coverage Policies.** Although government policies obviously influence the “marketplace” for LF and HF MRI, private health insurance corporations also exert huge influence in the USA (e.g., Anthem, Blue Cross, Cigna). (For Americans under the age of 65, private health insurance is obtained through the workplace for 58%, while 18% have no health insurance coverage [National Center for Health Statistics 2011].) After analyzing the available scientific literature, these corporations establish policies specifying which medical services they will be paid for, but may reach very different conclusions.

- For example, one major payor states that “LF MRI ≤ 0.2T magnet strength is considered investigational and not medically necessary for all orthopedic applications.” Another policy “covers open-design MRI as medically necessary when conventional design is contraindicated (and) does not cover LF MRI for ANY other indication.” Another insurance company's policy does not restrict use of LF scanners at all: “Open MRI units of any configuration…are considered to be an acceptable standard alternative to standard “closed” MRI units.”

**CONCLUSION**

The intrinsically superior SNR of HF units can be used to decrease the scan time and/or increase the spatial resolution of images. The traditional trade-off between patient-comfort designs and enhanced diagnostic information appears increasingly passé, because of the “open-ness” of new wide/short-bore HF MRI units and the decreasing sales of new LF scanners.
REFERENCES

I. Exam Quality & Technique

- Farrelly C, Davarpanah A, Brennan S, Sampson M, Eustace SJ. Imaging of soft tissues adjacent to orthopedic hardware: comparison of 3-T and 1.5-T MRI. AJR 2010;194:W60-4

II. Equipment Cost & Reimbursement


III. Patient Comfort & Access

- Spouse E, Gedroyc WM. MRI of the claustrophobic patient: interventionally configured magnets. BJR 2000;73:146-151

IV. The MRI Market, Trends, & Marketing

- Global Industry Analysts Inc report of November 2011; Accessed 12/7/2011
- CompaniesAndMarkets.com report of Nov 2011; Accessed 12/7/2011
- Blamire AM. The technology of MRI — the next 10 years? BJR 2008;81, 601-17
Strach K, et al. Low-field magnetic resonance imaging: increased safety for pacemaker patients? Europace 2010;12,952–60

V. Medical Literature & Cases

Appendix A: Low & Mid Field MRI Products – (KLASresearch.com) (2011-2012)
- Siemens MAGNETOM Concerto 0.2T Open MR
- Hitachi AIRIS Elite .3T Open MR
- Siemens MAGNETOM C! 0.35T MR
- Toshiba OPART 0.35T Open MR
- GE Signa Ovation 0.35T MR
- FONAR Upright .6T Open MR
- GE Signa OpenSpeed 0.7T Open MR
- GE ONI MSK Extreme 1.0T
- Philips Panorama 1.0T Open MR
- Hitachi Oasis 1.2T Bore-Less High-Field MRI

Appendix B: High Field MRI Products – 1.5 & 3-T (KLASresearch.com) (2011-2012)
- **1.5-T**
  - GE: Optima MR450w 1.5T; Signa HDxt 1.5T MR; Signa EXCITE HD 1.5T MR; Discovery MR450 1.5T
  - Hitachi Echelon 1.5T MR
  - Philips: Achieva 1.5T MR; Intera 1.5T MR
  - Siemens: MAGNETOM Aera 1.5T MR; MAGNETOM Symphony 1.5T MR; MAGNETOM Espree 1.5T MR; MAGNETOM Avanto 1.5T MR
  - Toshiba: Vantage 1.5T MR; Vantage Titan 1.5T MR
- **3.0-T**
  - GE: Signa HDxt 3.0T MR; Discovery MR750 3.0T; Signa HD 3.0T MR; Signa EXCITE HD 3.0T MR
  - Philips: Achieva 3.0T MR; Achieva XR 3.0T MR; Intera 3T MR; Ingenia 3.0T MR
  - Siemens: MAGNETOM Verio 3.0T MR; MAGNETOM Trio 3T MR; MAGNETOM Skyra 3T MR
  - Toshiba: Titan 3T MR
TABLE. Sample Generic Costs and Assumptions for Low-Field, 1.5-T, and 3-T MRI scanners.

<table>
<thead>
<tr>
<th>MRI Field Strength</th>
<th>MRI Unit ASP: New ($)</th>
<th>MRI Unit ASP: Refurbished*, OEM ($)</th>
<th>MRI Unit ASP: Refurbished*, Non-OEM ($)</th>
<th>Service Contract: OEM ($/Year)</th>
<th>Break Even Point:** (Outpatients/Day)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low Field (0.3 T)</td>
<td>-</td>
<td>200,000 - 400,000</td>
<td>150,000 - 325,000</td>
<td>60,000</td>
<td>4-6</td>
</tr>
<tr>
<td>1.5 T</td>
<td>1,000,000 – 1,500,000***</td>
<td>800,000 - 900,000</td>
<td>500,000 - 600,000</td>
<td>100,000</td>
<td>6-8</td>
</tr>
<tr>
<td>3 T</td>
<td>1,700,000 – 2,200,000</td>
<td>1,300,000</td>
<td>800,000 - 900,000</td>
<td>150,000</td>
<td>10-12</td>
</tr>
</tbody>
</table>

+ These are only possible, approximate costs and assumptions, based on informal non-scientific survey of professionals working in the U.S. imaging industry (personal communications in December 2011). Actual costs are expected to vary widely, including due to factors such as manufacturer, hardware/software packages, currency conversion, geography, siting, and market timing. Comments/opinions by these professionals regarding factors influencing their decisions in the current market included:

- Medicare rates may be approximately 20% higher than private medical insurance (HMO) reimbursement
- Siting costs for 3-T units may be 50% greater than for 1.5-T units
- Maintenance/service contract costs for 3-T units may be 50% greater than for 1.5-T units
- 2% tax on expensive medical equipment starting in 2012 (Obama Healthcare Plan)

* Assumes refurbished unit (e.g., 5 years old) with standard coils and 1-year warranty.

** Medicare outpatient rate is assumed at ~$470/exam. Inpatient rates are much higher.

*** In developing countries, major vendors price new 1.5-T units much lower (e.g., $700,000-900,000) [Rethinking Operations for a Two-Speed World. February 2011; http://knowledge.wharton.upenn.edu]

SOME ABBREVIATIONS & DEFINITIONS

- ASP = Average Selling (“Street”) Price.
- CAGR = Compound Annual Growth Rate.
- Cost Effectiveness may be measured as a cost utility and calculated as an incremental cost effectiveness ratio, equivalent to the ratio of the full cost of an imaging study /studies / program (using a particular modality and infrastructure) less the direct (downstream) savings in health costs (relative to a comparator method, not necessarily imaging ) per additional DALY avoided or QALY gained.
- Health Gain is generally measured in terms of disability adjusted life years (DALY) avoided or quality adjusted life years (QALY) gained.
- HF = High Field.
- LF = Low Field.
- OEM = Original Equipment Manufacturer.
- SAR = Specific Absorption Rate. The amount of energy deposited by the RF transmitter in a given tissue mass, expressed in watts per kg.
- T = Tesla. One tesla is equal to one weber per square meter (i.e., 10,000 gauss).