Title of session: **MR Economics**

Speaker Name: Geoffrey Young gsyoung@partners.org

TALK TITLE: Optimizing Clinical Protocols

TARGET AUDIENCE: MR Radiologists, Clinical MR Physicists, MR Technologists, MR Administrators, MR Researchers, Referring Physicians and other Referring Providers, Healthcare Administrators working for insurance payors and for hospitals or other provider organizations.

OUTCOME/OBJECTIVES

- Review the technical limitations of clinical MRI data acquisition speed
- Review how patient tolerance, finances, and pressure for efficiency limit MRI time
- Note how political and financial changes are increasing pressure for efficiency
- Explain how differential diagnosis and triage guide MRI protocol strategy
- Describe the benefits of a tiered approach: triage, safety, cost-efficiency, quality of care
- Describe critical role of clear communication with expert referring physicians in allowing efficient MRI with high safety, quality and patient/referring physician satisfaction.
- At the end of the talk the listener should be also to describe:
    - The clinical data acquisition constraints, financial and physiological scan time constraints, impact of changing political and health-care finance goals that influence rational clinical protocol development
    - The critical role of interdisciplinary collaboration and communication in formulating and implementing a rational clinical MR protocol approach
    - The basic rationale for and advantages of a tiered approach grounded in differential diagnosis and medical triage that in some circumstances may provide the optimal approach.

PURPOSE

- Clinical MR protocol optimization requires a clear understanding of the physics/engineering, patient physiology, financial constraints, political pressures, clinical goals, and image quality tradeoffs that underlie choice of protocol strategy.
- Understanding these constraints can help to formulate a rational protocol strategy and to dispel some prevalent misconceptions that contribute to suboptimal diagnostic quality, inappropriate utilization, unnecessary cost, decreased patient safety, decrease quality of care and decreased patient and referring provider satisfaction.
- Misconceptions that we commonly encounter in protocol design and implementation include: More is better: “Can we just also scan [your favorite add-on here] while the patient is in MRI?”; “Gd based contrast is always better”; “3T is better”; “Our patients get better scans at [your closest local competitor here] because our radiology department is too greedy to allow long enough scan times”; “Other hospitals can do it all at one time with just as good quality, why can’t you?”.
- Fundamental physical, physiologic, financial and medical facts that underlie and inform a rational diagnostic MRI protocol strategy are introduced and illustrated with examples from BWH neuroimaging, especially epilepsy imaging.
- A multi-tiered approach is proposed and illustrated that at least is certain circumstances in our experience has provided an optimal achievable combination of cost-effectiveness, quality, safety and referring physician and patient satisfaction. I present BWH experience with this approach in epilepsy imaging.

METHODS

- Preparing this talk stimulated me to rigorously examine the underlying technical basis of the rational presented and with the help of Larry Panych PhD our clinical MRI physicist and Vera Kimbrell RT our lead MR technologist/educator, to estimate theoretically achievable maximum clinical data acquisition rates. I present this data briefly in comparison to tactual MRI acquisition times we achieve with our newest instrument.
- The imaging physics tradeoffs underlying protocol optimization decisions are reviewed.
- Financial implications and realities are discussed
- The importance of changing political and financial pressures in the USA are noted and their implication for future protocol strategy is discussed.
- The rationale behind a tiered seizure MRI protocol strategy is presented.
- The critical role of collaboration/teamwork between referring physicians, radiologists, technologists and physicists in optimal protocol design and implementation is discussed and illustrated by our local recent success in gaining acceptance and implementing a rational tiered seizure MRI protocol and failure - to date – in gaining acceptance of or compliance with a rational ER MRI neuroimaging protocol.
- Other examples and tips are presented.

RESULTS/DISCUSSION

(I) Speed Limit: Estimation of Theoretically Achievable MRI Data Acquisition Speed in 2015 & the local speed limit at BWH: There is a maximum data acquisition rate speed-limit for each MRI scanner defined by the maximum bandwidth. In theory this might be as high as 1Mbyte/sec*.* Actual useful pulse sequences have a lower data acquisition rate for a number of reasons including the fact that only a part of each TR can be used to acquire data – in this regard GE is more efficient than spin echo; longer TE and shorter ETL needed to produce acceptable image SNR, CNR etc; spin preparation pulses and gradients such as IR, MT, FS, DW etc; SAR limitations (ie cooling time). At BWH our pulse sequence efficiency on our newest magnet varies from roughly 10% (SE) to roughly 50% (GE) of the theoretical maximum. This is probably as efficient as clinically achievable for the needed image quality and weighting because most of these pulse sequences have been very highly optimized over the years by the manufacturers. While it is possible to achieve some acceleration with higher field strength, parallel imaging, and more advanced sequences, data acquisition speeds on the order of 40k bytes (40k pixels) (range at BWH 15k-60k) per second are the realistic limit for current clinical brain imaging at 3T (your performance may vary…). This is roughly 1.5 (3DSPGR) to 6 (2D sequences) seconds per image.

(II) Time Limits – Local exam slot determined by patient tolerance and finances: The patient's ability to hold still is limited (usually about 30-60 minutes maximum). The amount that the patient's insurance is willing to pay is limited. Since the minimum overhead costs of owning and operating the MRI scanner and protocoling, supervising and interpreting the images are fixed, this means that the total amount of MRI time that can be used to make the diagnosis is limited. In practice, this is similar to the patient's ability to hold still. At BWH we use 40 minutes for most exams. It takes some time to get the patient in and out of the room and scanner and

to set up the injector or hand inject contrast. As a rule of thumb 5 minutes at either end is realistic. Thus a 30 minute slot will allowing 20 minutes of gradient time and a 60 minute slot 50 minutes of gradient time. At BWH we use a 40 minute time slot allowing 30 minutes (1800 seconds) of gradient time at BWH.

(III) Data Limits: Pixels, Voxels, Images: 30 minutes (1800 secs) of gradient time allows roughly 1800sec x 40k pixels/sec = 72M pixels (roughly 720 320x320 images). We can get a few more pixels if we accept lower SNR and/or CNR and greater image distortion, but for all practical purposes these 72M pixels are all we have to make the diagnosis, so we have to choose how to use the data to best effect. We can use it to fill larger or smaller pixels which are cubic (isotropic 3D) or elongated (anisotropic 2D), and arranged in thinner or thicker slices, covering more or less anatomy, with different contrast weightings, higher or lower contrast to noise ratio, and higher or lower signal to noise ratio.

(IV) All Pixels Are Not Equal: Better Diagnostic Data Quality Takes More Time: Any improvement in image quality takes time – more contrast takes more time, more spatial resolution (smaller voxels) takes more time, more coverage (more voxels) takes more time. The relatively large pixels adequate for detecting acute urgent findings of trauma, hemorrhage, infarction, infection and tumor are not adequate for detecting subtle cortical malformations, hippocampal sclerosis, inner ear derangement, inner ear or pituitary or cranial nerve tumors etc.

(V) You can have it all, but not at the same time: We are not near the point where optimum resolution of the whole brain can be achieved to diagnose subtle brain conditions (epilepsy, pit tumors, IAC tumors, CN abnormalities) routinely, much less in spine etc. Thus, optimal and efficient MRI requires that the radiologist understand the clinical differential diagnosis and/or other goals of imaging, work with physicists and technologists to develop specialized protocols that rationally address these clinical goals and help referring physicians and patient approach the exam with realistic expectations.

(VI) Teamwork: Implementation Requires Clear Communication: Implementation of optimized protocols also requires close communication between an expert referring physicians who can narrow the pre-test differential diagnosis and a neuroradiologist who can prescribe and protocol targeted to that differential diagnosis. The less expert and/or thorough the referring physician or the less clear the communication, the broader the indication will be and the more the protocol will resemble an inefficient low sensitivity screening protocol. Optimal imaging also requires having a way to appropriately triage patients to the right scanner hardware as well as using the right protocol

(VII) Effects of Health-Care Re-imbursement Models: Market-driven Models of Patient Care as Customer Service vs Government/Society Mandate for Cost-Efficient, Safe, High Quality Care: Currently we are in transition between to models of health care. The “consumer-centered” or “patient-centered” convenience-driven

model of care that has emerged from several decades of fee-for-service and medicolegal liability driven expansion of imaging use continues to drive much of practice. Rationally, this suggests that emphasis on efficiency and value will have to increasingly replace the emphasis on convenience over the next 5 years, but it pays to remember that reason has been a poor predictor of prior health care reform in the past...

(VIII) Optimization is a Compromise: Achieving the Balance: Radiologists have to take time to partner educate and collaborate with referring physicians to select a shared approach that employs an efficient tiered multi-protocol approach providing accurate diagnosis of the most urgent and common conditions in an initial comprehensive scan, and reserves more specialized an time intensive high resolution and/or high contrast imaging for a second or third scan used in a much smaller number of patients.

(IX) Illustration: BWH Seizure Protocol Experience: In the long run the tiered 3 protocol stepwise approach saves time and cost since the majority (>90%) of Sz 1 protocol patient never need to go to Sz 2 or Sz3 and thus avoiding the longer initial study saves time on 90+% of patients.

CONCLUSION

- **G*oal* is optimal diagnosis and therapeutic planning**
- ***Efficiency (cost-efficiency)*** means achieving the goal of optimal therapeutic planning with the least use of money
    - ***Magnet time costs money whether or not it is scanning***
    - Radiologist time costs money
    - Tech time costs money
- ***Delayed or incorrect diagnosis is very expensive***
    - Repeat exams
    - Unnecessary additional visits, testing and/or therapy
    - Malpractice settlements
    - Under fee for service these costs have largely been borne by the patients and insurers, but under the new health-care financing models based on risk-based provider contracts these costs will be borne by providers including radiology practices
- ***Providing optimal care required careful choices in protocol strategy, sequence development and implementation developed by a collaborative team of radiologists, technologists, physicists, and referring clinicians who share a clear understanding of the underlying physical, physiological, financial and clinical context of MRI.***
- ***Tiered protocol strategies*** may be more optimal than shotgun approaches.

REFERENCES

MRI Data Acquisition Speed

1. Young GS, Panych L, Kimbrell V. Unpublished estimates of MRI data acquisition speed 2015

2. Young GS, Panych L, Kimbrell V. Unpublished scan times derived from brain imaging with a 16 channel head coil on state of the art 3T MRI scanner (Siemens Skyra(R)). BWH 2015.

USA Health Care Finance Reforms

1. *Health care in America - Shock treatment: A wasteful and inefficient industry is in the throes of great disruption.* The Economist Mar 7th 2015.
2. https://en.wikipedia.org/wiki/Clinton_health_care_plan_of_1993 Accessed 20150320
3. H.R.3600 Health Security Act (Introduced in House - IH) Bill Text 103rd Congress (1993-1994) http://thomas.loc.gov/cgi-bin/query/z?c103:H.R.3600.IH: Accessed 20150320
4. PUBLIC LAW 93-222-DEC. 29, 1973 http://www.gpo.gov/fdsys/pkg/STATUTE-87/pdf/STATUTE-87-Pg914.pdf Accessed 20150320
5. https://en.wikipedia.org/wiki/Managed_care Accessed 20150320
6. https://en.wikipedia.org/wiki/Health_Maintenance_Organization_Act_of_1973 Accessed 20150320
7. https://en.wikipedia.org/wiki/Patient_Protection_and_Affordable_Care_Act Accessed 20150320
8. Public Law 111 - 148 - Patient Protection and Affordable Care Act http://www.gpo.gov/fdsys/granule/PLAW-111publ148/PLAW-111publ148/content-detail.html Accessed 20150320

Epilepsy Epidemiology, Differential Diagnosis and Therapy

1. Annegers JF. The epidemiology of epilepsy. In: Wyllie E, ed. The treatment of epilepsy: principles and practice 3rd ed. Philadelphia: Lippincott Williams & Wilkins, 2001:165-72.
2. Browne TR, et al. N Engl J Med. 2001;344:1145-1151
3. Cascino GD. Video-EEG monitoring in adults. Epilepsia. 2002;43 Suppl 3:80-93
4. Englot DJ et al. Seizure outcomes after resective surgery for extra-temporal lobe epilepsy in pediatric patients. J Neurosurg Pediatr. 2013 Aug;12(2):126-33.
5. Fricker 1998; Kwan and Brodie 2001
6. Harvey AS et al, Epilepsia 2008; 49(1):146-155
7. Hemb M et al. An 18-year follow-up of seizure outcome after surgery for temporal lobe epilepsy and hippocampal sclerosis. J Neurol Neurosurg Psychiatry. 2013 Jul;84(7):800-5.
8. Lerner JT et at. "UCLA experience…" Epilepsia, 2009.50(6):1310-1355
9. Lowenstein DH. Seizures and epilepsy. In Kasper DL et al, eds. Harrison's Principles of Internal Med. 16th ed. NY: McGraw-Hill; 2005:2357-72
10. Ramey WL et al Current management and surgical outcomes of medically intractable epilepsy. Clin Neurol Neurosurg. 2013 Dec;115(12):2411-8.
11. Smith MC, et al. Dis Mon. 1996;42:729-827
12. Wagner et al. Epilepsy Behav 2009;16(1):161-165