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New Strategies for Protocol Optimization for Clinical MRI: Rapid Examinations and Improved Patient Care

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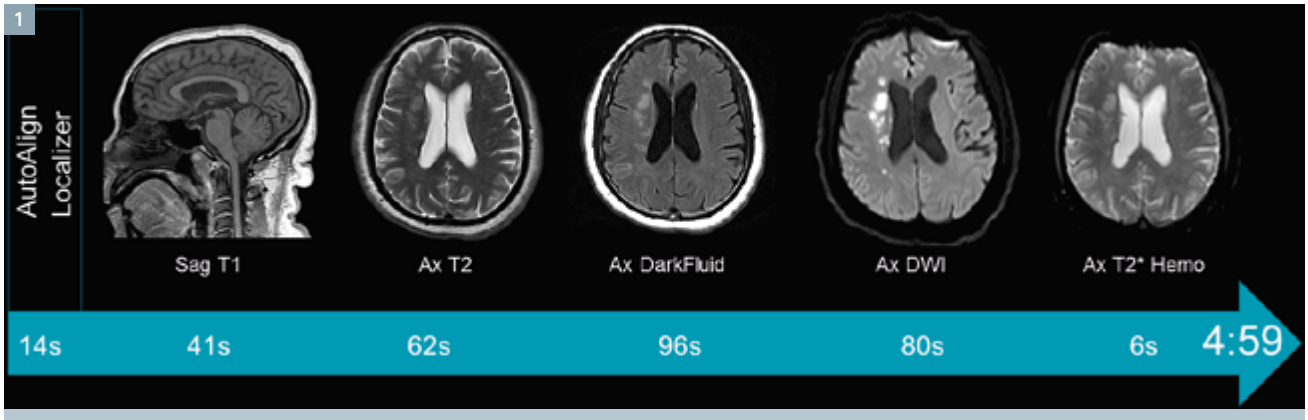
Heightened attention to healthcare costs and value based outcomes in medicine are driving revolutionary changes in the MR industry. The MR community of academics, clinicians and industry experts need to build cooperative programs to dispel the old perceptions of MR as a slow and overly expensive imaging modality. Cooperative changes can be implemented on two fronts through utilization of advanced technology, revised reading procedures, and a culture change around the standard operations of MR. Siemens MR, in cooperation with Massachusetts General Hospital (MGH) in Boston, are building such a program with the first results now being made available with the recent launch of GOBrain, a new application which enables a push-button diagnostic brain examination in 5 minutes. This article will detail the strategic approach behind the implementation of GOBrain and then discuss briefly future potential extensions to GO (Generalized Optimized) strategies to develop fast and clinically validated examinations in MR.

GOBrain is a clinically validated diagnostic brain exam which takes 5 minutes[1]. It consists of five diagnostically-important MR brain protocols [1, 2] acquired with optimized pulse sequences. Integrated with individual anatomical landmark-based AutoAlign technology providing automatic slice positioning, this push-button exam requires minimal interaction from the technologist. The included sequences are a sagittal T1-weighted, axial T2-weighted, axial T2-weighted DarkFluid, axial diffusion-weighted and an axial T2*-weighted contrast. Within the allotted five minutes for the complete exam, contrasts with stronger diagnostic utility were prioritized and afforded longer acquisition times, with the decided order of prioritization set as the DarkFluid, T2 -weighted, diffusion, T1-weighted and the T2*-weighted contrasts. The axial views cover the same field-of-view (FOV) and are acquired with identical slice thickness in order to read out multiple contrasts with synchronized display protocols (Fig. 1).

MR technologies which enabled the realization of GOBrain include parallel imaging [3] with high channel density coils [4, 5] and 3 Tesla imaging. The original expectation was that rapid exams could only be facilitated by higher field strength and high channel systems. However, during the course of the development effort, it became clear that the methodical approach towards a GO protocol optimization could also impact 1.5 Tesla systems and lower channel count head coils with some modest increase in total

[1] Achieved on a MAGNETOM Skyra with the Head 32 coil. Total examination time can take up to 6 minutes depending on system field strength and coil density.



1 A schematic illustration of GOBrain with the corresponding image labels and scan times. Images acquired on a MAGNETOM Skyra 3T with the Head 32 coil.

scan time (see Appendix for the protocols across 1.5T and 3T systems). A key driving principle behind GOBrain was to preserve the image impressions in terms of contrast and resolution for radiological reading of routine MR exams and, at the same time, finding signal-to-noise ratio (SNR) limits acceptable for diagnostic imaging. A salient correlation can be made to the recent drive towards dose reduction in computed tomography (CT). With innovative developments in CT on the technology side, (e.g. dual energy), low-dose CT protocols were also developed for targeted applications where the diagnostic quality of the images is tuned to the application. Borrowing a similar approach and strategy in MR leads to a reframing of the protocol development goal towards a scan session which is as fast as reasonably achievable while maintaining at least the same diagnostic value.

A key step in the development of GOBrain was to establish the diagnostic equivalence of a rapid MR approach versus conventional examinations. The validation approach required two board-certified radiologists to perform double blind reads of clinical neuro exams and to score the images with regard to contrast, SNR and artifacts in 6 patient exams. To control for motion behavior in patients, the five-minute exam was placed randomly either prior to the conventional exam or after in order to average out any effects related to the order of acquisition. Additionally, both the rapid and conventional exams were read with clinical findings reported. The principle findings of the study (submitted to a peer reviewed journal for publication) [2] were that the rapid exam was

1) less prone to motion artifacts
2) of sufficient quality to make the diagnosis and
3) made no difference in the final radiological diagnosis.

These findings led to the primary conclusion that this fast examination may replace the conventional protocol, especially in motion-prone inpatient settings.

Adoption of rapid MRI protocols into the clinical service can trigger a culture change in the clinical team. Adaptations may be required to operations in terms of both workflow and training. GOBrain is a push button exam with automatic slice and orientation positioning and each sequence will run automatically one after the other. The scanner noise changes in pitch and volume during the continuously driven exam. However, if the technologists allow the scanner to run through the multiple contrasts without interaction, then the entire exam becomes a single protocol from the patient perspective. The acquisition is built with fast, individual sequences, which minimize the risk of motion artifacts. Also, if one contrast is corrupted by motion artifacts then only that single contrast needs to be reacquired. In a patient-centered approach, a rapid MR can substantially improve the patient experience at the scanner.

In the realm of personalized medicine, advanced imaging techniques will be required to address additional structural and functional markers of the disease process. The scan time requirements for acquiring enhanced imaging biomarkers need to be balanced with the increasing pressure on reducing scheduling time slots towards 30 minutes and below. A rapid MR approach for a core brain protocol opens possibilities to incorporate imaging into time-restricted scan slots. With the recent availability of Simultaneous Multi-Slice (SMS) technology [6 – 9] which can greatly accelerate diffusion and BOLD imaging, this further reduces the time required for important functional information. Other examples of GOBrain potential add-on exams are susceptibility-weighted imaging (SWI), post-contrast MPRAGE, perfusion-weighted imaging and high-resolution 3D DarkFluid. GOBrain can then be viewed as a scout exam and also function as a backup scan in cases where the high-resolution 3D protocols are corrupted by motion.

Extension of the GO protocol projects are now under consideration for other high volume MR indications. The vision is to build a comprehensive suite of fast, optimized diagnostic protocols which are clinically validated. The general structured approach for developing a GO protocol is as follows:

1) Establish the time budget for a given core exam. The scan time goal should be considered a restraint on the protocol development process and should not be revised until completion of the protocol development exercise.
2) Define the set of required contrasts for routine diagnosis and rank them in order of clinical priority based on literature evidence. Each contrast should be given an individual time budget based on their relative diagnostic importance.
3) Research the available methods for the acceleration of each sequence. Prototype and iterate on individual protocol candidates for each contrast from the protocol simulator.
4) Once candidate protocols are identified, conduct healthy volunteer scans to assess image quality in terms of tissue contrast and signal to noise levels. Several iterations may be required to finalize the protocol.
5) Once finalized, perform head-to-head comparisons to conventional examinations in the target patient population to compare the rapid MR protocol to the conventional exam with blind reads by at least two board certified radiologists. The reports should contain a qualitative assessment of the image quality, such as contrast and presence of artifacts and diagnostic findings appropriate for the indication. Concordance between both protocols across readers then validates the clinical utility of the rapid protocol.

MAGNETOM Skyra, 3T, Head/Neck 64													Total exam time: 4:36
Plane	**TR (ms)**	**TE (ms)**	**FOV (mm)**	**Phase FOV (%)**	**Slices**	**Slice (mm)**	**Gap (%)**	**Matrix**	**Phase Direc-tions**	**iPAT factor**	**b-values**	**Direc-tions (no)**	**TA (mins)**
AutoAlign Head Scout													
3D	3.15	1.37	260	100	128	1.6	20	160	A-P	3	NA	NA	0:14
T1 GRE FLASH													
Sag	240	2.46	220	100	35	4.0	20	256	A-P	3	NA	NA	0:34
T2 TSE													
Axial	6200	78	220	87.5	25	5.0	20	256	R-L	3	NA	NA	1:02
T2 TSE DarkFluid													
Axial	8000	114	220	87.5	25	5.0	20	256	R-L	3	NA	NA	1:20
ep2d Diffusion													
Axial	4000	65	240	100	31	5.0	12	160	A-P	3	0,800	12	1:20
ep2d T2*-weighted													
Axial	6120	30	220	100	25	5.0	20	128	A-P	1	NA	NA	0:06

MAGNETOM Skyra, 3T, Head 32													Total exam time: 4:59
Plane	**TR (ms)**	**TE (ms)**	**FOV (mm)**	**Phase FOV (%)**	**Slices**	**Slice (mm)**	**Gap (%)**	**Matrix**	**Phase Direc-tions**	**iPAT factor**	**b-values**	**Direc-tions (no)**	**TA (mins)**
AutoAlign Head Scout													
3D	3.15	1.37	260	100	128	1.6	20	160	A-P	3	NA	NA	0:14
T1 GRE FLASH													
Sag	240	2.46	220	100	35	4.0	20	256	A-P	2	NA	NA	0:41
T2 TSE													
Axial	6200	78	220	87.5	25	5.0	20	256	R-L	3	NA	NA	1:02
T2 TSE DarkFluid													
Axial	8000	119	220	87.5	25	5.0	20	256	R-L	2	NA	NA	1:36
ep2d Diffusion													
Axial	4000	65	240	100	31	5.0	12	160	A-P	3	0,800	12	1:20
ep2d T2*-weighted													
Axial	6120	30	220	100	25	5.0	20	128	A-P	1	NA	NA	0:06

Appendix

The GOBrain exam consists of a localizer scout with AutoAlign functionalities and five fundamental unenhanced MRI sequences (sagittal T1-weighted, axial T2-weighted, axial DarkFluid/FLAIR, axial DWI and axial T2*-weighted MRI sequences). Depending on the field strength (1.5T and 3T) and the number of elements in the coil used for imaging, total exam time lasts between 4:36 minutes on a 3T system with the Head/Neck 64 coil to 5:56 minutes for imaging on a 1.5T system with the Head/Neck 20 coil. Protocol parameters including scan times are detailed above for each system.

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MAGNETOM Skyra, 3T, Head/Neck 20													Total exam time: 5:11
Plane	**TR (ms)**	**TE (ms)**	**FOV (mm)**	**Phase FOV (%)**	**Slices**	**Slice (mm)**	**Gap (%)**	**Matrix**	**Phase Direc-tions**	**iPAT factor**	**b-values**	**Direc-tions (no)**	**TA (mins)**
AutoAlign Head Scout													
3D	3.15	1.37	260	100	128	1.6	20	160	A-P	3	NA	NA	0:14
T1 GRE FLASH													
Sag	240	2.46	220	100	35	4.0	20	256	A-P	2	NA	NA	0:41
T2 TSE													
Axial	6200	78	220	87.5	25	5.0	20	256	R-L	3	NA	NA	1:02
T2 TSE DarkFluid													
Axial	8000	119	220	87.5	25	5.0	20	256	R-L	2	NA	NA	1:52
ep2d Diffusion													
Axial	4200	72	240	100	31	5.0	12	160	A-P	2	0,800	12	1:16
ep2d T2*-weighted													
Axial	6120	30	220	100	25	5.0	20	128	A-P	1	NA	NA	0:06

MAGNETOM Aera, 1.5T, Head/Neck 20 (XJ and XQ gradients)													Total exam time: 5:56
Plane	**TR (ms)**	**TE (ms)**	**FOV (mm)**	**Phase FOV (%)**	**Slices**	**Slice (mm)**	**Gap (%)**	**Matrix**	**Phase Direc-tions**	**iPAT factor**	**b-values**	**Direc-tions (no)**	**TA (mins)**
AutoAlign Head Scout													
3D	4.52	2.38	260	100	128	1.6	20	160	A-P	3	NA	NA	0:19
T1 SE													
Sag	595	11	230	100	27	5.0	20	256	A-P	2	NA	NA	1:11
T2 TSE													
Axial	4700	101	220	87.5	25	5.0	20	256	R-L	2	NA	NA	0:56
T2 TSE DarkFluid													
Axial	5700	80	220	87.5	25	5.0	20	256	R-L	1	NA	NA	2:03
ep2d Diffusion													
Axial	4500	89	240	100	31	5.0	12	128	A-P	2	0,800	12	1:21
ep2d T2*-weighted													
Axial	6120	75	220	100	25	5.0	20	128	A-P	1	NA	NA	0:06

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