The comprehensive contrast-enhanced neuro exam

R. Marc Lebel[1,2], Yi Guo[3], Yinghua Zhu[3], Sajan Goud Lingala[3], Richard Frayne[2], Linda B Andersen[2], Jacob Easaw[4], and Krishna S Nayak[3]
[1]*GE Healthcare, Calgary, Alberta, Canada,* [2]*Radiology, University of Calgary, Calgary, Alberta, Canada,* [3]*Electrical Engineering, University of Southern California, Los Angeles, California, United States,* [4]*Oncology, University of Calgary, Calgary, Alberta, Canada*

Introduction: Contrast-enhanced (CE) MR exams are routinely employed to visualize pathology, tissue abnormalities and/or vascular structures. A basic CE brain exam will often acquire T_1-w anatomical images before and after contrast injection; advanced studies may acquire dynamic images during injection of the agent for angiography and/or pharmacokinetic modeling. Despite high clinical significance, current exams are typically inefficient and provide limited information: pre- and post-contrast T_1-w acquisitions are performed independently and require 3–6 min each; the dynamic series (if acquired) has an application specific compromise between spatial/temporal resolution and spatial coverage and provides a single piece of information.

We demonstrate that sparse sampling and constrained reconstruction can be used to greatly improve CE brain exams. **From a single acquisition, we are able to reconstruct many clinically relevant image sets, including pre- and post-contrast anatomical images and dynamic images suitable for time-resolved angiography and for quantitative modeling**, **Fig 1**. This approach requires fewer acquisitions and less scan time than a basic CE brain exam yet provides all salient information, with high resolution and full brain coverage.

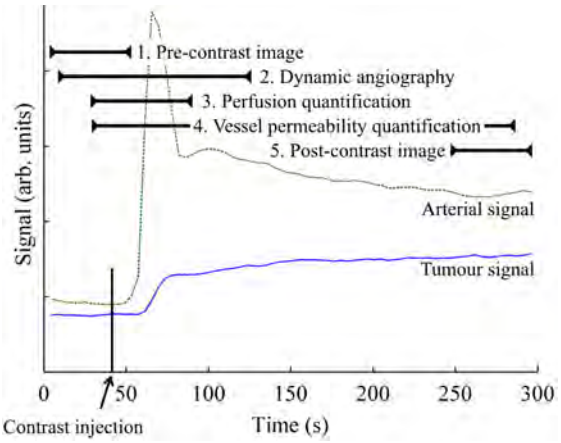

Figure 1: Signal evolution in two tissues during a contrast-enhanced exam. Multiple image series are reconstructed from different portions of a single highly accelerated acquisition, effectively providing a comprehensive exam.

Methods: Data were acquired on eight consenting subjects on a 3T MR750 (GE Healthcare). The acquisition matrix was 256x240x120 over a 240 mm cubic FOV. The TR was 4.9 ms; the flip angle was 15°. Total scan time was 7 min. The vendor supplied 3D spoiled gradient echo pulse sequence was modified to sample along radial spokes in the ky-kz plane [1]. This sampling scheme is effective for compressed sensing while allowing retrospective selection of the temporal resolution. In addition to T_1 mapping, three constrained reconstructions were performed to obtain static pre- and post-contrast images and dynamic images. A sparseSENSE image model was employed [2]:

$$\underset{m}{\operatorname{argmin}} \; ||\mathrm{F_U S}m - k||_2 + \lambda_1||\mathrm{V_t}m||_1 + \lambda_2||\Psi m||_1 + \lambda_3 \,\mathrm{TV}(m)$$

The desired image (m) is related to the acquired data (k) via coil sensitivity (S) and undersampled Fourier transform (F_U). Three sparsity transforms were enforced for the dynamic images: a temporal high pass filter (V_t), a 4D complex dual-tree wavelet (Ψ), and spatial total variation (TV). Regularization factors ($\lambda_{1,2,3}$) were set empirically; static T_1-w pre- and post-contrast images were reconstructed without temporal constraints.

Results: All image sets listed in **Fig. 1** were successfully reconstructed from individual acquisitions. Total reconstruction time was ~12 hours per subject on a 12-core workstation; static T1-w images were available within 5 minutes. Example images from one glioblastoma patient are shown in **Fig. 2**. Anatomic pre- and post-contrast images clearly depict tumour enhancement (see arrows) and were of comparable quality to dedicated clinical T_1-w sequences (not shown). Dynamic images provided time resolved angiograms with sufficient temporal resolution (2.5 s) to qualitatively distinguish arterial and venous phases in all subjects. Pharmacokinetic modeling of the images generated whole brain permeability and blood flow maps.

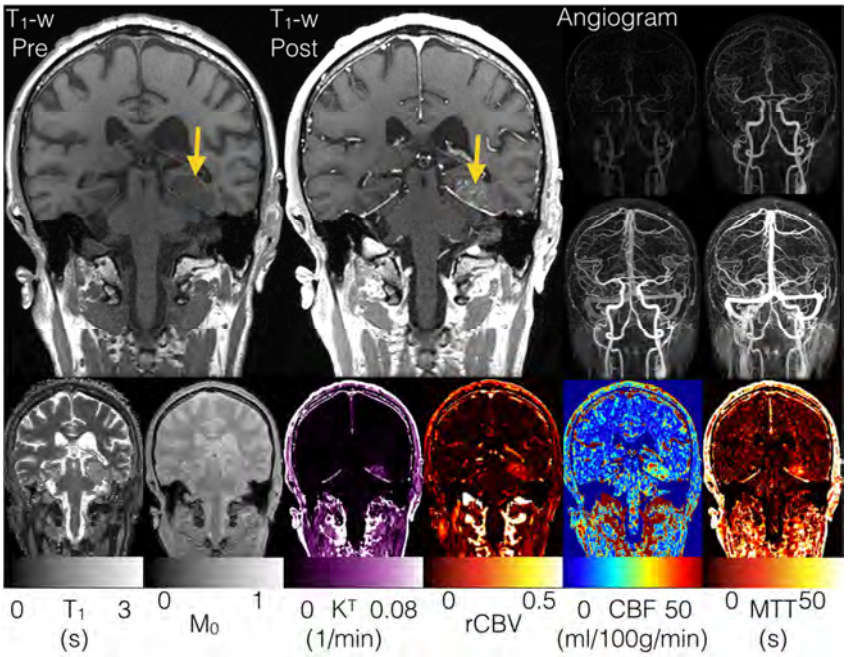

Figure 2: Qualitative and quantitative output images from our comprehensive contrast enhanced exam. T_1 maps were acquired separately, but all other series were generated from one seven-minute scan. Whole brain coverage is available with a temporal resolution of 2.5 seconds.

Discussion/Conclusion: This approach provides much more information than is currently possible in standard contrast enhanced exams, requires fewer acquisitions, and uses less total scan time. While not employed here, this sequence and sampling scheme is amenable to integrated motion correction and T_1 mapping—making it even more robust. This comprehensive single-scan approach may improve every clinical CE brain exam.

References: [1] Zhu Y, *et al*. ISMRM 2014; [2] Lebel RM, *et al.* MRM. 2013.