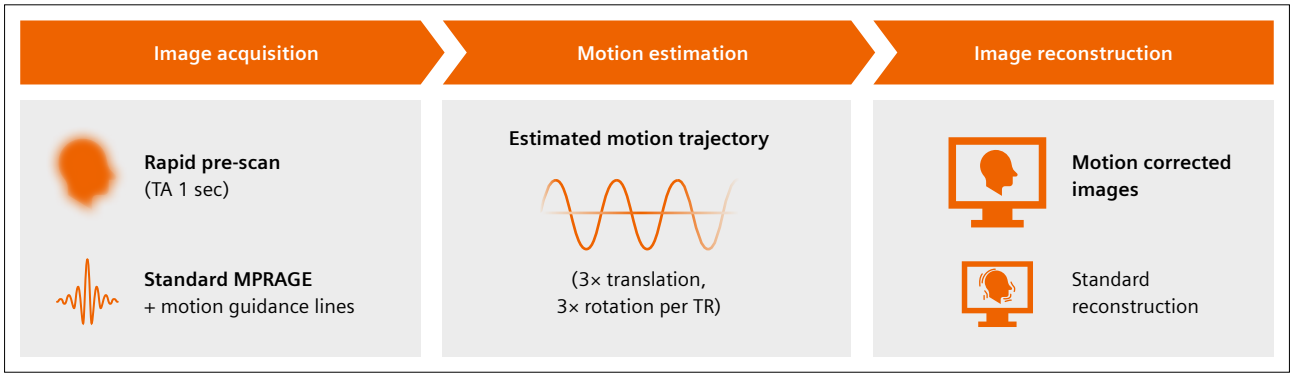
Scout-Accelerated Motion Estimation and Reduction (SAMER) for Pediatric Brain MRI

Azadeh Tabari[1,2]; Daniel Polak[3]; Komal Manzoor[1]; Min Lang[1,2]; Daniel Nicolas Splitthoff[3]; Bryan Clifford[4]; Wei-Ching Lo[4]; Stephen Cauley[4]; John Conklin[1,2]; Michael S. Gee[1,2]; Susie Y. Huang[1,2,5]

[1]Department of Radiology, A. A. Martinos Center for Biomedical Imaging, Massachusetts General Hospital, Charlestown, MA, USA
[2]Harvard Medical School, Boston, MA, USA
[3]Siemens Healthineers, Erlangen, Germany
[4]Siemens Medical Solutions, Boston, MA, USA
[5]Harvard-MIT Health Sciences and Technology, Massachusetts Institute of Technology, Cambridge, MA, USA

One of the biggest challenges in pediatric magnetic resonance imaging (MRI) is managing motion artifacts. Sedation or anesthesia is frequently used in pediatric[1] MRI, to minimize the motion artifacts. However, these approaches carry increased medical risks and additional costs [1]. Various strategies have been implemented to minimize motion in non-sedated pediatric MRI. These include patient preparation through educational videos, involvement with child life specialists, the use of MRI mock scanners and MRI-compatible audiovisual equipment [1, 2]. Additionally, modifications in MRI data acquisition can enhance motion robustness. Techniques like BLADE/PROPELLER [3] reduce susceptibility to motion by repeatedly traversing the center of *k*-space but often lead to increased scan time and altered image contrast and appearance compared to Cartesian acquisitions. Furthermore, reducing scan time has proven beneficial in non-sedated pediatric MRI. Emerging deep learning methods enable higher acceleration factors without compromising signal-to-noise ratio (SNR) or introducing reconstruction artifacts, making them increasingly common in clinical practice. However, while faster scanning may decrease the likelihood of motion, it cannot entirely eliminate patient motion [4, 5]. Moreover, highly accelerated acquisitions may exacerbate the appearance of motion artifacts compared to scans with moderate acceleration [6, 7].

Motion correction techniques offer a promising solution, however, no single method has yet gained widespread clinical acceptance due to the stringent requirements for robustness, reliability, and seamless integration into clinical workflows. Data-driven retrospective motion correction [8] offers a promising solution to these challenges. It derives the motion trajectory information from the acquired *k*-space data of the imaging sequence and produces the motion-corrected images without the need for additional tracking hardware or disruptive sequence modifications. Moreover, a significant advantage over prospective techniques is that radiologists can directly compare the motion-modeled reconstruction with the original, non-corrected images.



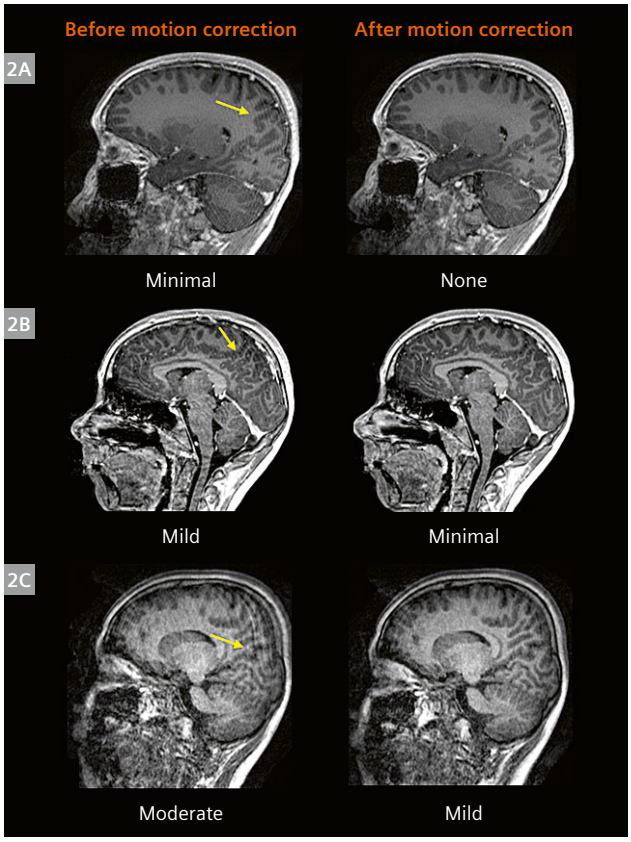
1 **Illustration of SAMER motion correction for MPRAGE.**
The rapid pre-scan (scout) and motion guidance lines acquired in every TR facilitate very rapid estimation of the six-degrees of rigid-body motion. Once all motion parameters across all TRs have been estimated, the motion-corrected images are computed by inverting a generalized forward model that takes into account the previously estimated motion trajectory. Moreover, the original, non-corrected images can be reconstructed.

[1]*MR scanning has not been established as safe for imaging fetuses and infants less than two years of age. The responsible physician must evaluate the benefits of the MR examination compared to those of other imaging procedures.*

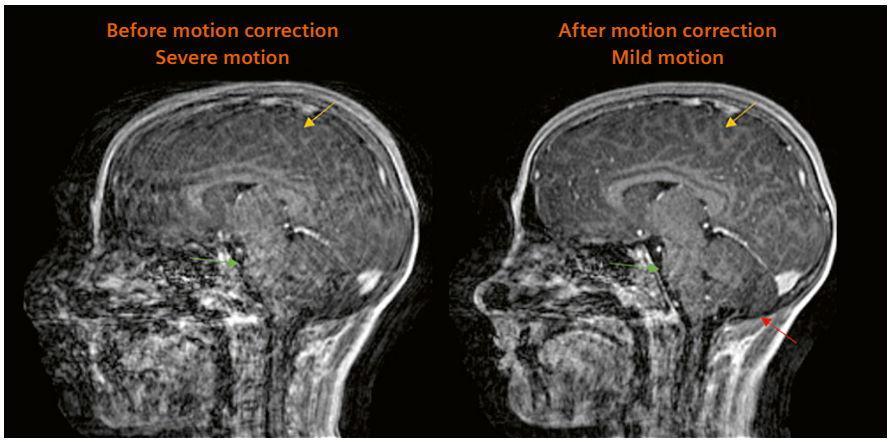
One such data-driven method is scout accelerated motion estimation and reduction (SAMER)[2] [6, 9, 10]. The SAMER technique is based on SENSE parallel imaging, utilizing a generalized forward model that accounts for motion effects. At the beginning of the SAMER scan, an ultra-fast, low-resolution scout image (TA ~1 second) is acquired, which is assumed to be motion-free (Fig. 1). The six degrees of rigid body motion (3× translation, 3× rotation) are estimated by comparing the scout image against a very small number of additional *k*-space encoding lines (motion guidance lines) acquired in every TR. Once all motion parameters from all TRs have been estimated, the motion-mitigated image is obtained by inverting a generalized forward model that incorporates the previously estimated motion trajectory. A key computational advantage of SAMER is its ability to estimate the subject's motion for each motion state independently, enabling very rapid computation times using standard scanner hardware.

We tested SAMER in non-sedated pediatric patients (<18 yrs old) undergoing outpatient clinical brain MRI examination on a 3T MRI system (MAGNETOM Prisma, Siemens Healthineers, Erlangen, Germany). The imaging protocols for all cases included the SAMER T1-weighted MPRAGE research sequence. The parameters for the MPRAGE sequence used for SAMER motion correction were: resolution = 1 × 1 × 1 mm^3, R = 2 × 2 and acquisition time 2:37 minutes. Since SAMER is a retrospective technique we can directly compare the motion corrected images against the original/standard reconstructed images.

Figure 2 presents T1 MPRAGE scans of awake pediatric patients imaged for various clinical indications, displaying motion artifacts from minimal to moderate. The SAMER method successfully reduced these artifacts, improving motion by one grade. In Figure 3, a case with severe motion is shown, where SAMER achieved a significant reduction in artifacts, improving motion by two grades.



2 **Representative cases:**
Sagittal T1 MPRAGE images in pediatric patients scanned for various clinical indications (top to bottom: adrenoleukodystrophy, seizure and headache) and had normal brain MRI.
(2A) Brain MRI in an 8-year-old boy with minimal motion artifact.
(2B) Brain MRI in a 9-year-old boy with mild motion artifact.
(2C) Brain MRI in a 9-year-old girl with moderate motion artifact.
Note that greater motion resulted in a greater degree of blurring of the gray/white matter junction. SAMER reconstruction improved motion by one grade, with motion grades following motion correction indicated on the right side of the figure.



3 Sagittal images of a 12-year-old boy show significantly improved motion artifacts by two grades on the motion-corrected SAMER (mild motion, grade 3) compared to the non-corrected (severe motion, grade 5) images. The brain cortex (yellow arrow), brainstem (green arrow), and posterior cranial fossa (red arrow) are better delineated and visualized on the SAMER images and are blurred and non-diagnostic on the non-corrected images.

[2] *Work in progress. The application is currently under development and is not for sale in the U.S. and in other countries. Its future availability cannot be ensured.*

In conclusion, SAMER enhances the diagnostic image quality of clinical brain MR exams when motion is present, with the most notable improvements occurring in cases of moderate to mild motion. Future research will aim to expand SAMER to other sequences and image contrasts, allowing more children to undergo imaging without the need for anesthesia or repeated examinations.

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Contact

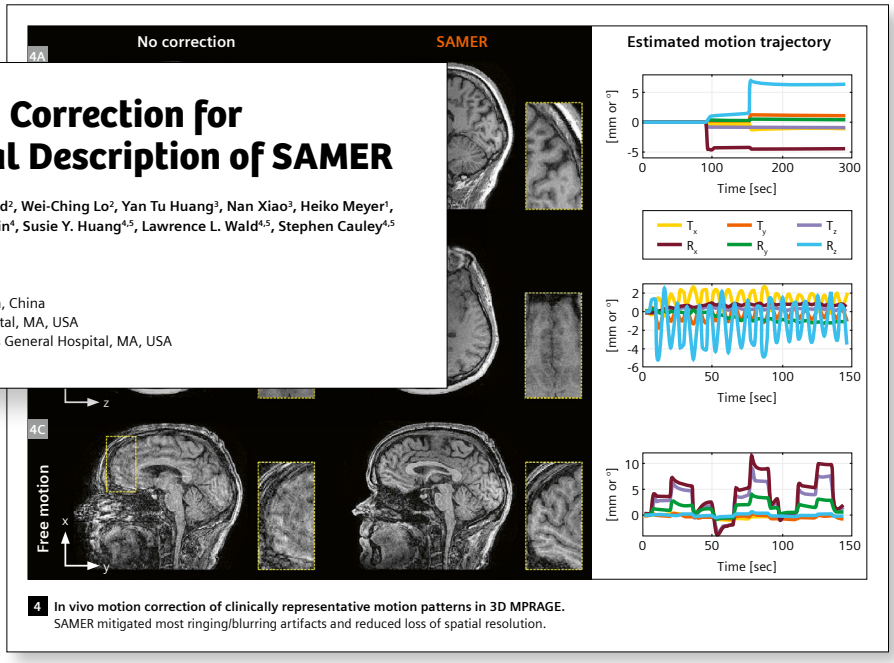
Azadeh Tabari, M.D.
Instructor in Radiology
Massachusetts General Hospital
Harvard Medical School
55 Fruit St.
Boston, MA, 02114
USA
atabari@mgh.harvard.edu

Further reading

Retrospective Motion Correction for Brain MRI: A Technical Description of SAMER

Daniel Polak[1], Daniel Nicolas Splitthoff[1], Bryan Clifford[2], Wei-Ching Lo[2], Yan Tu Huang[3], Nan Xiao[3], Heiko Meyer[1], Azadeh Tabari[4], Komal Awan[4], Min Lang[4], John Conklin[4], Susie Y. Huang[4,5], Lawrence L. Wald[4,5], Stephen Cauley[4,5]

[1]Siemens Healthcare GmbH, Erlangen, Germany
[2]Siemens Medical Solutions, Boston, MA, USA
[3]Siemens Shenzhen Magnetic Resonance Ltd., Shenzhen, China
[4]Department of Radiology, Massachusetts General Hospital, MA, USA
[5]Martinos Center for Biomedical Imaging, Massachusetts General Hospital, MA, USA



4 **In vivo motion correction of clinically representative motion patterns in 3D MPRAGE.** SAMER mitigated most ringing/blurring artifacts and reduced loss of spatial resolution.

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