How I do It: Deep Resolve Sharp and Gain

Theodore J. Kryzer R.T., R, MR, CT; Houchun H. Hu, Ph.D.; Charles P. Ho, Ph.D., M.D.; Leslie D. Sisney R.T., R, CT, MR; Alex N. Merkle M.D.

UCHealth Steadman Hawkins Clinic Denver, Englewood, CO, USA

Introduction

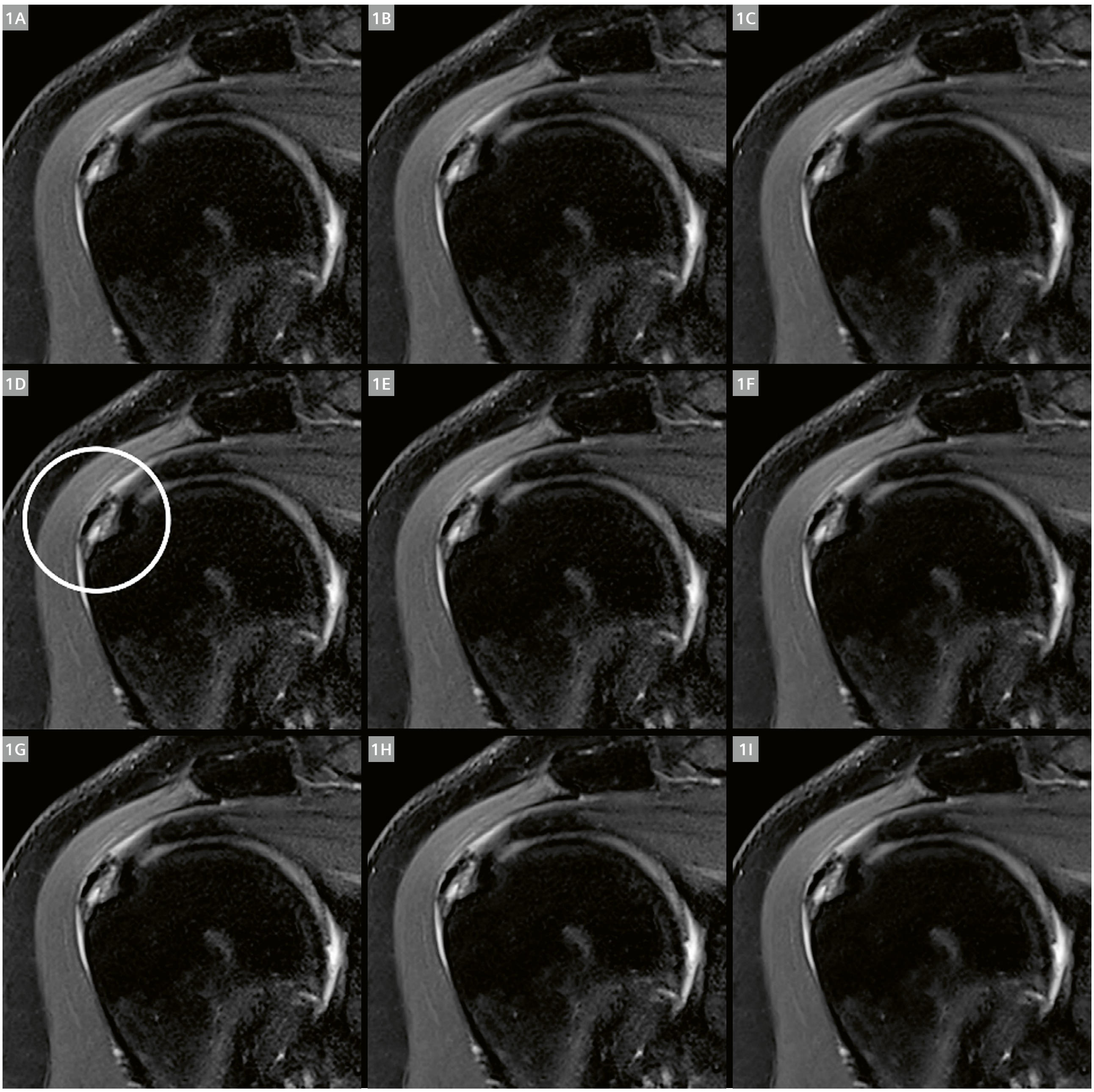
Current and future healthcare practices require more effective use of limited resources, and this axiom applies to medical imaging. Increasing imaging efficiency while maintaining image quality requires tradeoffs that historically have been challenging to balance. Aside from hardware-centric advancements in field strength, magnet and coil quality, and advanced *k*-space acquisition techniques, post-purchase improvements in efficiency have historically relied on innovative protocol designs that reduce sequence length, utilize novel sequences, or eliminate sequences. Unfortunately, these techniques often reduce the amount of diagnostic information acquired, potentially resulting in lower diagnostic quality by reducing signal-to-noise ratio (SNR). Promising new techniques using artificial intelligence (AI) deep learning reconstruction (DLR) algorithms are helping mitigate or even eliminate these tradeoffs. Deep Resolve Sharp and Gain (DRSG) from Siemens Healthineers is a vendor-developed and supported software package including AI technology. It enhances low SNR images using an iterative, targeted denoising technique that employs individually generated noise maps (Deep Resolve Gain). It also provides higher-resolution reconstructions from raw data acquired with a lower resolution through a neural network that was trained on matched pairs of low- and high-resolution data, while incorporating the raw data to maintain fidelity for each patient (Deep Resolve Sharp).

Methods and approach

UCHealth Steadman Hawkins Clinic Denver is a premier national orthopedic center that provides comprehensive diagnosis-to-recovery services. Its patients range from the general population to elite athletes, including most Denver-based professional sports teams and extreme sports athletes. DRSG was implemented as a trial software license on February 1, 2023, (software level *syngo* MR XA31) on the facility's onsite 3-Tesla MAGNETOM Vida (Siemens Healthineers, Erlangen, Germany). The goal during the trial was to evaluate how DRSG impacted image acquisition times and diagnostic quality, and to assess its effect on patient throughput.

A team comprising onsite UCHealth MRI technologists who predominantly scan musculoskeletal (MSK) examinations, and the lead University of Colorado MRI physicist, performed pre-implementation sequence and protocol development. The development team scanned volunteer patients while iteratively modifying relevant parameters: averages, parallel imaging factors, matrix size, and retro reconstruction values of DRSG that included edge enhancement level (1–5) and denoising strength (1–8) with Deep Resolve Sharp enabled. Image acquisition times were recorded for each sequence to determine the effects on imaging speed and patient throughput under each evaluated setting.

Fellowship-trained board-certified MSK attending radiologists at the University of Colorado reviewed the test images while clinically judging the image quality of commonly assessed anatomic structures, under each of the parameter conditions. The MSK radiologists then selected sequences that optimized acquisition time without degrading diagnostic quality. Each protocol was tested again on volunteers before the DRSG protocol was made the standard of care, followed by regular reassessment after implementation. Example test images of the shoulder using DRSG with Deep Resolve Sharp enabled under varying parameters are shown in Figure 1.

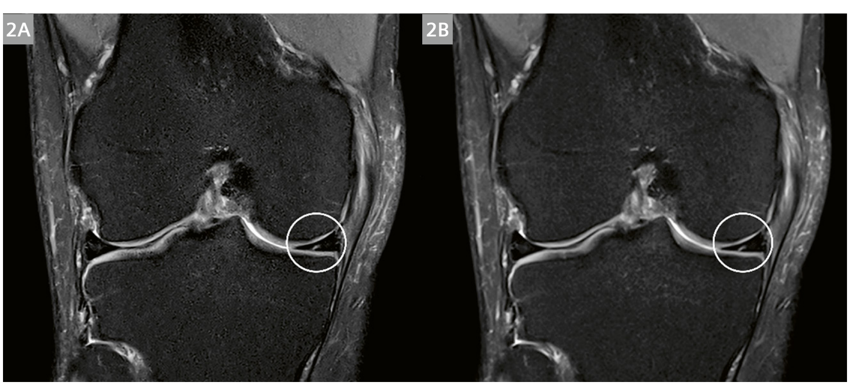


1 Comparison of multiple Edge Enhancement Levels (EEL) and Denoising Strengths (DS) with Deep Resolve Sharp and Gain on a coronal PD FS with a known rotator cuff tear seen within the circled region of interest in image (1D). Window and level settings are the same across all images. **(1A)** EEL: 1 DS: 1, **(1B)** EEL: 1 DS: 4, **(1C)** EEL: 1 DS: 8, **(1D)** EEL: 3 DS: 1, **(1E)** EEL: 3 DS: 4, **(1F)** EEL: 3 DS: 8, **(1G)** EEL: 5 DS: 1, **(1H)** EEL: 5 DS: 4, **(1I)** EEL: 5 DS: 8.

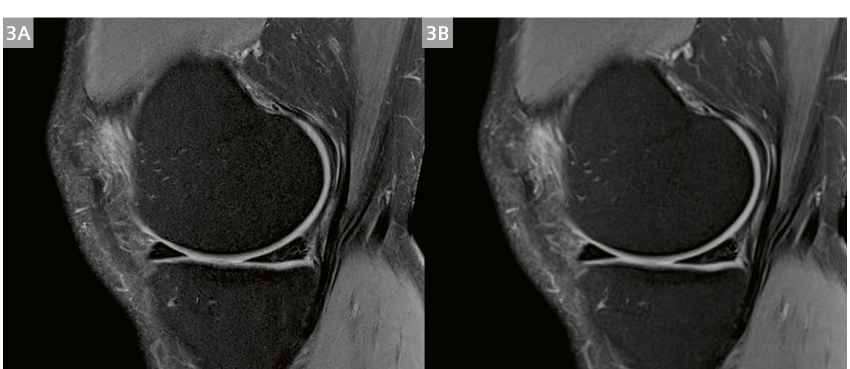
Standard non-contrast knee protocol examinations are performed with an 18-channel dedicated knee coil and utilize the following Turbo Spin-Echo (TSE) sequences: axial (Ax) T2, Ax Proton Density Fat Saturation (PD FS), sagittal (Sag) PD FS, coronal (Cor) PD FS, Cor T1, and a Sag anatomical T2 map that is unable to utilize DRSG.

Sequence	Time	FOV	Slices	Slice	Skip	Matrix	Averages	Acceleration	DR Gain	DR Denoise	DR Edge Enhancement	DR Edge Enhancement Level	DR Sharp
Right Ax T2 DRSG	1:54	130 × 130	40	3.5	10%	320 × 320	1	GRAPPA 2	Yes	6	Yes	2	Yes
Right Ax PD FS DRSG	2:27	130 × 130	40	3.5	10%	320 × 320	1	GRAPPA 2	Yes	6	Yes	2	Yes
Right Sag PD FS DRSG	1:54	140 × 140	34	3	10%	320 × 320	1	GRAPPA 2	Yes	6	Yes	2	Yes
Right Cor PD FS DRSG	2:49	140 × 140	34	3	10%	320 × 320	1	GRAPPA 2	Yes	6	Yes	2	Yes
Right Cor T1 DRSG	2:18	140 × 140	34	3	10%	320 × 320	2	GRAPPA 2	Yes	6	Yes	2	Yes
Right T2Map_anatomical	4:44	160 × 160	25	3.6	20%	269 × 384	1	None	No	NA	No	NA	No
Right Ax T2	3:01	130 × 130	40	3.5	10%	288 × 288	2	GRAPPA 2	No	NA	No	NA	No
Right Ax PD FS	3:20	130 × 130	40	3.5	10%	288 × 288	3	SMS 2	No	NA	No	NA	No
Right Sag PD FS	3:04	140 × 140	34	3	10%	288 × 288	2	GRAPPA 2	No	NA	No	NA	No
Right Cor PD FS	4:32	140 × 140	34	3	10%	288 × 288	2	GRAPPA 2	No	NA	No	NA	No
Right Cor T1	3:31	140 × 140	34	3	10%	288 × 288	4	GRAPPA 3	No	NA	No	NA	No
Right T2Map_anatomical	4:44	160 × 160	25	3.6	20%	269 × 384	1	None	No	NA	No	NA	No

Table 1: Comparison of the UCHealth Steadman Hawkins Clinic Denver standard knee protocol before and after the implementation of Deep Resolve Sharp and Gain.



2 Knee coronal PD FS comparison images with a medial meniscus tear seen in the circled region of interest.
(2A) With Deep Resolve Sharp and Gain, **(2B)** with conventional imaging.

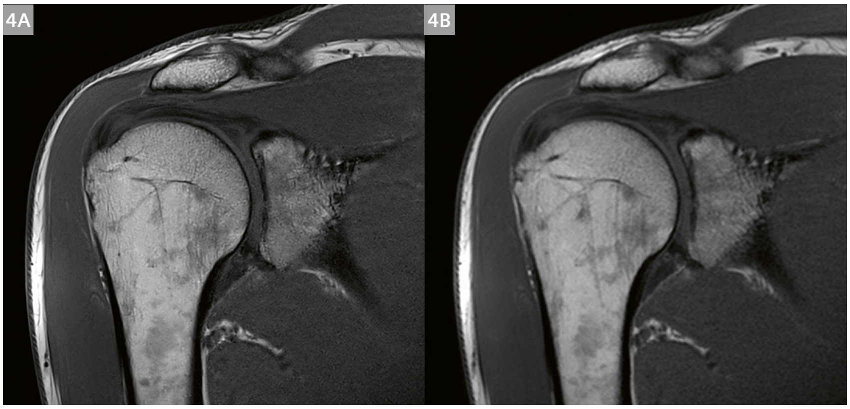


3 Knee sagittal PD FS comparison images.
(3A) With Deep Resolve Sharp and Gain, **(3B)** with conventional imaging.

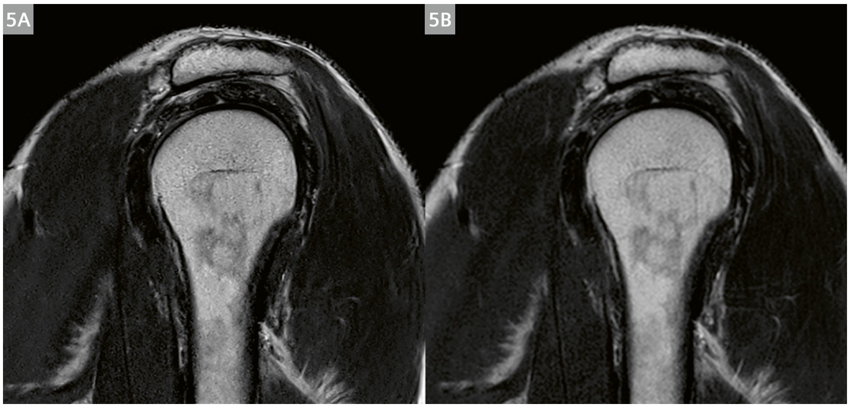
Standard non-contrast shoulder examinations utilize a dedicated 16-channel shoulder coil with Ax PD, Ax PD FS, Cor PD FS, Cor T1, Sag PD FS, and Sag T2. Without DRSG, UCHealth Steadman Hawkins Clinic Denver utilized a resolution of 256 × 256. Meanwhile, with DRSG, shoulder examinations utilized an imaging resolution of 320 × 320.

Sequence	Time	FOV	Slices	Slice	Skip	Matrix	Averages	Acceleration	DR Gain	DR Denoise	DR Edge Enhancement	DR Edge Enhancement Level	DR Sharp
Right Ax PD DRSG	1:40	150 × 150	32	3	10%	320 × 320	1	GRAPPA 2	Yes	6	Yes	2	Yes
Right Ax PD FS DRSG	2:34	150 × 150	32	3	10%	320 × 320	1	GRAPPA 2	Yes	6	Yes	2	Yes
Right Cor PD FS DRSG	2:12	150 × 150	28	3	10%	320 × 320	1	GRAPPA 2	Yes	6	Yes	2	Yes
Right Cor T1 DRSG	2:06	150 × 150	28	3	10%	320 × 320	1	GRAPPA 2	Yes	6	Yes	2	Yes
Right Sag PD SF DRSG	1:58	150 × 150	32	3	10%	320 × 320	1	GRAPPA 2	Yes	6	Yes	2	Yes
Right Sag T2 DRSG	2:04	150 × 150	32	3	10%	320 × 320	1	GRAPPA 2	Yes	6	Yes	2	Yes
Right Ax PD	2:17	150 × 150	32	3	10%	256 × 256	2	GRAPPA 2	No	NA	No	NA	No
Right Ax PD FS	3:40	150 × 150	32	3	10%	256 × 256	1	None	No	NA	No	NA	No
Right Cor PD SF	3:11	150 × 150	28	3	10%	256 × 256	2	GRAPPA 2	No	NA	No	NA	No
Right Cor T1	3:01	150 × 150	28	3	10%	256 × 256	2	GRAPPA 2	No	NA	No	NA	No
Right Sag PD SF	1:34	150 × 150	32	3	10%	256 × 256	1	GRAPPA 2	No	NA	No	NA	No
Right Sag T2	2:58	150 × 150	32	3	10%	256 × 256	3	GRAPPA 2	No	NA	No	NA	No

Table 2: Comparison of the UCHealth Steadman Hawkins Clinic Denver standard shoulder protocol before and after the implementation of Deep Resolve Sharp and Gain.



4 Shoulder coronal T1 comparison images. **(4A)** With Deep Resolve Sharp and Gain, **(4B)** with conventional imaging. Note the sharper appearance of boney structures with Deep Resolve Sharp and Gain.



5 Shoulder sagittal T2 comparison images. **(5A)** With Deep Resolve Sharp and Gain, **(5B)** with conventional imaging.

Results

Imaging time

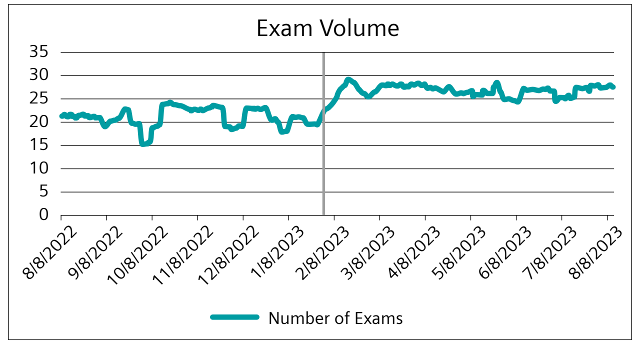
With these new protocols, UCHealth Steadman Hawkins Clinic Denver reduced acquisition times by 20–30% across the most common MSK examinations. With DRSG enabled on standard non-contrast knee examinations, we saw a reduction in imaging acquisition time from 22.2 minutes to 16.1 minutes, a time saving of 27% (6.1 minutes). On standard non-contrast shoulder examinations with DRSG enabled, we saw a reduction in imaging time from 16.9 minutes to 12.6 minutes, a time saving of 25% (4.3 minutes). Significant time gains were achieved by reducing the number of averages to one on most sequences. Depending on the sequence, we could turn on parallel imaging factors and decrease the imaging matrix size to produce a higher-resolution image; see Tables 1 and 2 for protocol specifications.

Protocol parameter preferences and quality assessment

The evaluating radiologists preferred a DRSG denoising strength of 6 and an enhancement level of 2, with Deep Resolve Sharp enabled; this was found to best balance image denoising and edge enhancement for standard MSK examinations. Under these conditions, the radiologists determined that no reduction in diagnostic quality was present clinically. No change to these parameters has been necessary upon regular reassessment for clinical quality improvement.

Patient throughput

By implementing DRSG in MSK examinations, the UCHealth Steadman Hawkins Clinic Denver location saw increased patient throughput. Before DRSG, the center routinely performed 22 to 24 daily examinations over a 14-hour period. Since the implementation of DRSG, it routinely performs 28 to 31 exams daily in the same 14-hour period.



6 Deep Resolve Sharp and Gain was installed on February 1, 2023, represented by the vertical line. This graph shows a ten-day rolling average and the increase in exam volume after the implementation of Deep Resolve Sharp and Gain.

Discussion and conclusions

Implementation of DRSG has improved clinical efficiency, capacity, and throughput at UCHealth Steadman Hawkins Clinic Denver, while preserving the quality of imaging. As a secondary benefit, DRSG has facilitated the availability of same-day urgent (STAT) examinations that previously may have waited for the next available appointment, leading to less efficient care and potential patient attrition.

Both the technologists and radiologists assessed the implementation of the software package as straightforward, requiring attention mainly for defining parameters appropriate for the population being scanned and the preferences of the reporting radiologists. The version of DRSG we evaluated can only be applied to TSE sequences, which were appropriate for the MSK protocols that dominate the scanning at our orthopedic center. However, newer DRSG versions and packages possess greater flexibility.

Since the trial implementation of DRSG in February 2023, the UCHealth Steadman Hawkins Clinic Denver location has purchased the complete DRSG software package and has upgraded from software level *syngo* MR XA31 to *syngo* MR XA50. With this software upgrade came the ability to utilize DSRG on an expanded range of sequences and techniques, including TSE Dixon and Simultaneous Multi-Slice (SMS); these added techniques are currently undergoing quality assessment prior to implementation, and results have been promising. Given the clinical improvements seen with DRSG, the UCHealth Steadman Hawkins Clinic Denver is enthusiastically preparing to implement the successor to DRSG: Deep Resolve Boost from Siemens Healthineers. With this new direct *k*-space-to-image deep learning reconstruction paradigm promising acquisition times for a routine knee examination of less than five minutes, we expect substantial imaging efficiency and patient throughput gains while preserving or improving the outstanding quality for which UCHealth Steadman Hawkins Clinic Denver is recognized.

Contact

Theodore Kryzer R.T., R, MR, CT
South Metro MRI Quality
Specialist and Educator
UCHealth Lonetree Medical Center
UCHealth Steadman Hawkins
UCHealth Highlands Ranch Hospital
1500 Park Central Drive
Highlands Ranch, CO 80129
USA
Tel.: +1 720 516 1030
Ted.Kryzer@UCHealth.org