IDEAL ASSIST (Automated Spine Survey Iterative Scan Technique): Metastasis Detection

K. L. Weiss[1], R. S. Cornelius[2], E. E. Lower[3], J. L. Weiss[4], D. Sun[5], J. Ying[6], B. W. Mahoney[2], M. I. Altbach[7], and M. Fernandez[2]

[1]University of Cincinnati, Cincinnati, OH, United States, [2]Department of Radiology, University of Cincinnati, Cincinnati, Ohio, United States, [3]Department of Hematology and Oncology, University of Cincinnati, Cincinnati, Ohio, United States, [4]Division of Research, WestImage, Cincinnati, Ohio, United States, [5]College of Computer and Information Technology, Beijing Jiaotong University, People's Republic of China, [6] Internal Medicine, University of Cincinnati, Cincinnati, Ohio, United States, [7]Department of Radiology, University of Arizona, Tucson, Arizona, United States

Introduction

Multi-parametric MRI of the entire spine is technologist-dependent, time consuming, and often limited by inhomogeneous fat suppression. We prospectively tested a recently developed technique (1) in breast cancer patients to provide rapid automated total spine MRI metastasis screening with improved tissue contrast through optimized fat-water separation.

Materials and Methods

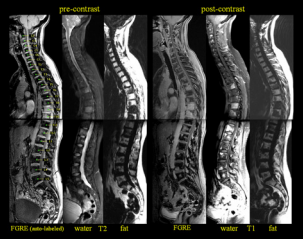
Subjects:
IRB approval and informed consent was obtained for all subjects. 22 subjects, median (range) age of 53 (37, 91) with known breast cancer were prospectively studied at 3.0 T; 2 received follow-up IDEAL ASSIST (Automated Spine Survey Iterative Scan Technique) (2) exams. Seven subjects received contrast, as part of a concurrent clinical MRI exam. (Fig 1) 15/22 subjects underwent PET-CT in a median (range) interval of 16 (2, 45) days before/after MRI.

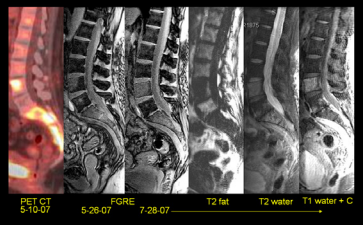
Image Acquisition:
The entire spine was auto-imaged in two contiguous 35 cm FOV sagittal stations (4mm skip 1mm), utilizing out-of-phase FGRE (TR/TE =57/1.4 ms, flip angle =30, BW=±62.5 kHz, 512 x 352 matrix, 11 slices, 21 sec breath hold) and T1 (TR/TE=700/12.3 ms, ETL= 3, BW=±31.2 KHz, 320 x 256 matrix, anterior sat, 11 slices, scan time =4:04 min) and/or T2 weighted (TR/TE=2150/ 60.9 ms, ETL= 9, BW ±35.7 KHz, 512 x 320 matrix, FC, anterior sat, 13 slices, scan time=4:31 min) FSE IDEAL (Iterative Decomposition of Water and Fat with Echo Asymmetric and Least-squares Estimation) sequencing.(3)

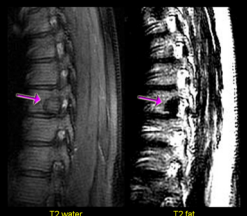
Analysis:
MRIs were independently evaluated for metastasis by two blinded neuroradiologists and run through ASSIST analysis software for automated vertebral numbering; discordant readings were re-evaluated by two raters together to reach MRI consensus. PET-CTs were evaluated by a third blinded radiologist with fellowship training in PET-CT. Final diagnosis of each case was based upon consensus of the three raters using all available imaging and clinical information, including conventional MRI, bone scans, PET, and CT exams performed before and after the investigational exam and biopsy reports; and was considered the reference standard.

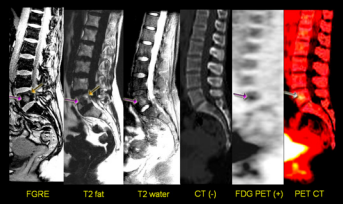
Results

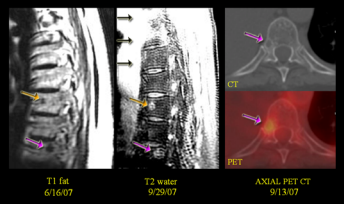
Spinal metastases were identified in eight (8/24 or 33.3%) cases using the reference standard, with 6 (6/24 or 25%) cases showing metastases in more than one level. (Fig 1) MRI correctly identified 7 metastasis positive cases and 13 metastasis negative cases with a sensitivity of 87.5% and a specificity of 81.3% respectively. Among 15 cases with PET-CT scans, the PET-CT correctly identified 2 out of 4 metastasis cases, with a sensitivity of 50% and 9 out of 11 non metastasis with a specificity of 81.8%. (Figs 2-6). Two MRI raters agreed on a total of 22 out of 24 cases, with a Kappa statistics ±standard error (SE) of 0.82 ± 0.12, suggesting an outstanding inter-rater agreement. Among the 15 case subset, PET-CT and MRI were concordant on 12 cases, with a Kappa statistics ± SE of 0.53 ± 0.24, suggesting a moderate agreement between these two imaging modalities. FSE IDEAL provided uniform fat and water separation throughout the entire 70 cm FOV in all 24 studies. FGRE ASSIST afforded subminute submillimeter in-plane resolution of the entire spine with high contrast between discs and vertebrae at 3.0T. Marrow signal abnormalities could be particularly well characterized with IDEAL and derived parametric images.

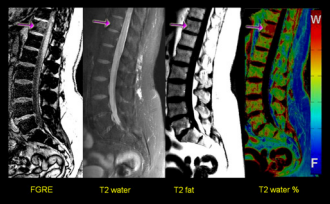


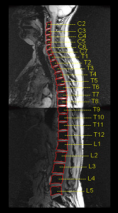












Discussion

The investigation demonstrates the potential for rapid automated MR imaging of the entire spine for metastasis screening with optimized tissue contrast afforded by uniform fat-water separation. As surface coil intensity correction (SCIC) was not functional in the investigation IDEAL software version tested, color-encoded parametric ratio maps such as W% (not prospectively used by the MRI raters) appear particularly helpful as they compensate for surface coil intensity drop-off and may accentuate differences in marrow composition. (Fig 6) Nonetheless, implementation of SCIC for IDEAL as it had been for the FGRE sequencing would be most desirable to facilitate standard image interpretation without the need to adjust window/level setting across the large FOVs.

While the sensitivity and specificity of IDEAL-ASSIST for detection of metastatic disease was good, accuracy would likely be improved if a rapid study were obtained at the time of initial diagnosis to serve as a baseline. This could include and perhaps for time/cost related issues be limited to, a subminute breath-hold ASSIST. So doing would be analogous to the current clinical standard of obtaining a baseline mammogram but applied to a much smaller population, those with a known primary malignancy that has a predilection for bone metastasis.

Other versions of IDEAL, such as RADIAL GRASE IDEAL(4) should be tested as well in conjunction with the ASSIST protocol and compared to determine optimal sequencing over a large spectrum of pathologies. Additionally, IDEAL sequencing should be compared to the rapid dual gradient echo Dixon sequencing and fat-water separation technique developed by Ma et al.(5,6) for integration with ASSIST. While the former affords more accurate fat-water quantification, the latter is much faster and might be substituted for the single echo FGRE technique described herein thereby permitting a fat-water decomposed sub-minute survey of the entire spine in two breath-hold sequences.

Regarding, automated spine image analysis, disc/vertebral identification and numbering are only the beginning. Refinements and extensions of such software should permit subsequent automated image prescriptions through regions of interest, generate measures of vertebral deformity(7) and provide automated multi-parametric tissue assessment. (1,8) (Fig 7)

Conclusion

IDEAL ASSIST is a promising MRI technique for metastasis surveillance; affording a rapid automated high resolution, high contrast survey of the entire spine with optimized tissue characterization.

References

1. Weiss KL, Cornelius RC, Sun DM,Weiss JL. IDEAL ASSIST. In: R G, ed. ASNR. Chicago, IL, 2007; 141.
2. Weiss KL, Storrs JM, Banto RB. Automated spine survey iterative scan technique. Radiology 2006; 239:255-262.
3. Reeder SB, Pineda AR, Wen Z, et al. Iterative decomposition of water and fat with echo asymmetry and least-squares estimation (IDEAL): application with fast spin-echo imaging. Magn Reson Med 2005; 54:636-644.
4. Altach M, Ll Z, Bilgin A, Weiss K. Fast Parametric Imaging of the Spine with Radial IDEAL-GRASE. In: John V. Crues III, ed. International Society of Magnetic Resonance Imaging. Berlin, Germany: John Wiley and Sons, 2007.
5. Ma J. Breath-hold water and fat imaging using a dual-echo two-point Dixon technique with an efficient and robust phase-correction algorithm. Magn Reson Med 2004; 52:415-419.
6. Ma J, Son J, Bankson J, Stafford R, Choi H, Ragan D. A fast spin echo two-point Dixon technique and its combination with sensitivity encoding for efficient T2-weighted imaging. Magn Reson Imaging 2005; 23:977-982.
7. Genant HK, Wu CY, van Kuijk C, Nevitt MC. Vertebral fracture assessment using a semiquantitative technique. J Bone Miner Res 1993; 8:1137-1148.
8. Weiss KL, H. P. Computer Automated Three-Step (CATS) Program for Brain MRI Prescription in Talairach Space. In:US Office of Patent and Copyright. USA: University of Cincinnati, 2004.
•KLW and JLW have proprietary interests in ASSIST- US Patent Pending

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