MAJOR PAPER

Ovarian Masses: MR Imaging with T₁-weighted 3-dimensional Gradient-echo IDEAL Water-fat Separation Sequence at 3T

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Purpose: We retrospectively compared the efficacy of 3-dimensional (3D) gradient-echo magnetic resonance T₁-weighted sequence using the iterative decomposition of water and fat with echo asymmetry and least-squares estimation (IDEAL) technique with the efficacy of conventional 3D gradient-echo sequences for diagnosing ovarian masses at 3T.

Materials and Methods: In images of 32 women (mean age, 45.3 years) with ovarian masses who underwent T₁-weighted imaging with both IDEAL and conventional techniques, we quantitatively analyzed signal-to-noise ratio (SNR) and contrast between gluteal muscle and T₁-weighted high-signal materials within lesions and assessed image quality. Two radiologists independently evaluated fat detection.

Results: Mean SNR of subcutaneous fat did not differ significantly between IDEAL and conventional techniques for both fat-suppressed (P = .32) and non-fat-suppressed (P = .85) images. Mean absolute contrast between gluteal muscle and T₁-weighted high signal materials within teratomas (n = 15) was significantly higher with IDEAL on fat-suppressed images (P = .002) and lower with IDEAL on non-fat-suppressed images (P = .010). Fat suppression was significantly superior with IDEAL (P < .0001). Readers’ assessments of fat detection did not differ between IDEAL and conventional sequences.

Conclusion: The quality of T₁-weighted fat-suppressed images of ovarian masses was better with 3D gradient-echo IDEAL than conventional 3D gradient-echo sequences.

Keywords: endometriosis; genital neoplasms, female; magnetic resonance imaging; ovarian neoplasms; teratoma, cystic

Introduction

Ovarian masses comprise pathologies from non-neoplasms to neoplasms, from benign conditions to malignant conditions. Transvaginal ultrasonography, computed tomography (CT), and magnetic resonance (MR) imaging are useful for diagnosing ovarian masses. In particular, MR imaging can provide accurate information about hemorrhage, fat, and collagen that enables specific diagnosis of certain pathologic types.¹ Differentiation of teratomas and endometriosis is important,² and fat-suppression techniques are useful for this purpose because they help distinguish blood and fat within ovarian masses.³ Typical features of endometriomas include high signal intensity on both T₁-weighted and fat-suppressed T₁-weighted images.⁴ In contrast, the fatty portion of teratomas shows hyperintensity on T₁-weighted images⁵ and marked signal suppression on fat-suppressed T₁-weighted images.⁶ Fat suppression is also useful for visualizing more and smaller endometriomas.⁴

Various types of fat-suppression techniques⁷ have been used, including chemical shift selective (CHESS),⁸ short-tau inversion-recovery (STIR),⁹ chemical shift selective inversion recovery (CSS-IR),¹⁰ and Dixon¹¹ techniques. In recent years, the Dixon technique has attracted attention because of its robust fat suppression and ability to quantify fat.¹² Technical advances have overcome several major difficulties associated with the original Dixon technique to improve image quality.¹³ The technique permits simultaneous acquisition of in-phase,
opposed-phase, water-only, and fat-only images in a single acquisition.

Iterative decomposition of water and fat with echo asymmetry and least-squares estimation (IDEAL) is a variant of the 3-point Dixon method.\textsuperscript{14,15} IDEAL imaging provides uniform and robust fat suppression by minimizing the effect of B\textsubscript{0} field inhomogeneity and maximizing noise performance,\textsuperscript{15} can be combined with either fast spin-echo or gradient-echo imaging,\textsuperscript{16} and has been used successfully for imaging many regions, including the musculoskeletal system, spine, artery, and body.\textsuperscript{17-23} However, we believe no study has investigated the efficacy of the T\textsubscript{1}-weighted 3-dimensional (3D) gradient-echo IDEAL water-fat separation sequence for the evaluation of ovarian masses. We undertook this retrospective study to compare efficacy for diagnosis of ovarian masses between 3D gradient-echo T\textsubscript{1}-weighted IDEAL sequence and conventional 3D gradient-echo sequences with and without fat suppression using CSS-IR technique at 3T, focusing on image quality, contrast, and fat detection.

**Materials and Methods**

**Patients**

Our institutional review board approved this retrospective study, and informed consent was waived. From our hospital medical records, we identified 107 consecutive women who underwent ovarian MR imaging between November 2009 and June 2010. We included for study those women with 4-mm-thick T\textsubscript{1}-weighted 3D gradient-echo images obtained using both IDEAL and conventional (liver acquisition with volume acceleration, LAVA) techniques on a 3T MR scanner (Signa HDxt 3.0T; GE Healthcare, Milwaukee, WI, USA). We excluded 75 of these 107 women—27 who underwent MR imaging using a different scanner at our hospital, whose images were of slice thickness other than 4 mm, two without IDEAL images, nine with tumors other than ovarian, five with no intrapelvic mass, one treated for ovarian masses prior to MR imaging, 26 with no pathologic evidence for ovarian masses, and one with insufficient medical records. Our final study population thus consisted of 32 women (mean age, 45.3 ± 13.8 years [standard deviation], range 26 to 73 years, Table 1). One of the 32 women had 2 types of ovarian masses, both fibrothecoma and mature cystic teratoma.

**MR examination**

MR imaging was performed at 3T using a Signa HDxt 3.0T scanner with 8-channel body array coils; maximum gradient strength was 50 mT/m and maximum slew rate, 150 mT/m/ms. Unless contraindicated, patients received intramuscular administration of 20 mg of butylscopolamine to prevent artifacts from peristalsis (27 received butylscopolamine). To improve image homogeneity, a dielectric pad was placed on the patient’s body and an elliptically polarized radiofrequency (RF) field technique (EllipTX; GE Healthcare) was used.

<table>
<thead>
<tr>
<th>Table 1. Characteristics of study population (n = 32; mean age, 45.3 ± 13.8 years, range 26 to 73 years)</th>
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<tbody>
<tr>
<td>Serous tumors (n = 4)</td>
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<tr>
<td>Serous adenocarcinoma (n = 2, one of the 2 women had serous adenocarcinomas of the bilateral ovaries)</td>
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<td>Serous borderline tumor (n = 1)</td>
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<td>Serous cystadenoma (n = 1)</td>
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<td>Mucinous tumors (n = 3)</td>
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<tr>
<td>Mucinous borderline tumor (n = 1)</td>
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<tr>
<td>Mucinous cystadenoma (n = 2)</td>
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<td>Endometrioid adenocarcinoma (n = 1, the woman had endometrioid adenocarcinomas of the bilateral ovaries)</td>
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<tr>
<td>Undifferentiated carcinoma (n = 1)</td>
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<tr>
<td>Thecoma/fibrothecoma (n = 2, one patient had fibrothecoma concomitantly with mature cystic teratoma)</td>
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<td>Teratoma (n = 15)</td>
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<td>Immature teratoma (n = 1)</td>
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<tr>
<td>Mature cystic teratoma (n = 14, two of whom had mature cystic teratomas of the bilateral ovaries; one patient had fibrothecoma concomitantly with mature cystic teratoma)</td>
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<td>Endometriotic cyst (n = 7, two of the 7 women had endometriotic cysts of the bilateral ovaries)</td>
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</table>
bandwidth, 62.5 kHz; one signal acquired; 22-s acquisition time) and with fat suppression (CSS-IR technique; TR/TE/inversion time [TI], 3.7 ms/1.8 ms/5 ms; opposed-phase; 12° flip angle; receiver bandwidth, 83.3 kHz; one signal acquired; 19-s acquisition time). Images were obtained during quiet breathing (IDEAL) or breath-holding (LAVA). A parallel imaging technique (array spatial sensitivity encoding technique [ASSET]; GE Healthcare) with a reduction factor of 2 in the phase-encoding direction was used for each imaging sequence. At our institution, 3D gradient-echo LAVA sequences with and without fat suppression have been standard sequences for T1-weighted imaging; T1-weighted fast spin-echo imaging is not one of our standard protocols.

T2-weighted fast spin-echo images in the axial plane were also obtained (effective TR/effective TE, 8000 ms/80 ms; echo train length, 20; 512 × 256 matrix; 24-cm FOV; receiver bandwidth, 62.5 kHz; 200-s acquisition time; 2 signals acquired; 5-mm section thickness; one-mm spacing). Parallel imaging techniques were not used for T2-weighted imaging.

Imaging Analysis

Quantitative analysis

All images were transferred to a workstation (Advantage Workstation 4.2; GE Healthcare). One radiologist with 16 years’ experience in genitourinary imaging quantitatively analyzed images obtained using IDEAL and LAVA sequences. The images were analyzed using measurements of mean signal intensity in operator-defined regions of interest (ROIs) in subcutaneous fat (n = 32; mean area ± standard deviation, 1.59 cm² ± 0.29; range, 0.65 to 2.25 cm²) and gluteal muscle (n = 32; 1.56 cm² ± 0.31; range, 0.59 to 2.10 cm²). When materials of high signal intensity were observed within ovarian masses on non-fat-suppressed T1-weighted images, we measured the signal intensity of the material in areas showing the highest signal intensity on a representative T1-weighted image (n = 25; 1.33 cm² ± 0.53; 0.17 to 1.86 cm²). Measurements included evaluation of only one lesion in each case, even if the patient had masses of bilateral ovaries. Signal intensities were measured in areas devoid of focal changes in signal intensity or prominent artifacts. Care was taken to make ROI size and placement consistent for the same patient. Use of the parallel imaging technique precluded the usual measurements of signal-to-noise (SNR) or contrast-to-noise ratio (CNR).24 Instead, we used a previously reported method and estimated SNR by calculating the ratio between the mean signal intensity and standard deviation (SD) of the signal intensity of the same ROI of subcutaneous fat.25,26 We estimated absolute contrasts (C) between (a) gluteal muscle and subcutaneous fat, (b) gluteal muscle and T1-weighted high signal materials within ovarian teratomas, and (c) gluteal muscle and T1-weighted high signal materials within ovarian masses other than teratomas using the equation: C = |A − B|/(A + B), in which A represents the signal intensity of tissue A, and B represents the signal intensity of tissue B.

Qualitative analysis

By consensus, 2 radiologists, each with more than 10 years’ experience in genitourinary imaging, visually compared IDEAL in-phase and LAVA non-fat-suppressed in-phase images to evaluate overall image quality, susceptibility artifacts, motion artifacts, image blurring, and, based on visibility of structures within masses, conspicuity of lesion details. They graded image quality using a 3-point scale (1, better on images obtained with LAVA sequence; 2, quality equal between sequences; 3, better on images obtained with IDEAL sequence). The order of patients whose images were reviewed was randomized. IDEAL water-only images and fat-suppressed LAVA opposed-phase images were compared in a similar manner. Quality of fat suppression was also evaluated based on the degree and uniformity of fat suppression.

Detection of fat within masses

Two experienced radiologists, each with more than 6 years’ experience in genitourinary imaging, independently reviewed and assessed images for the presence of fat within ovarian masses. The readers were blinded to clinical information, histopathologic findings, and patient names. They conducted the review during 2 sessions 2 weeks apart. The patients were randomly divided into 2 groups to avoid order bias. The radiologists evaluated T2-weighted images combined with either IDEAL (Group 1, 16 patients) or LAVA (Group 2, 16 patients) images. Two weeks later, the same radiologists reviewed T2-weighted and LAVA images of patients in Group 1 and T2-weighted and IDEAL images of patients in Group 2. Four types of images (in-phase, opposed-phase, water-only, and fat-only) were presented for the evaluation of IDEAL images. For the evaluation of LAVA images, non-fat-suppressed in-phase images and fat-suppressed opposed-phase images were presented together. The readers assessed the presence of fat within the masses based on lesion content of materials that demonstrated (a) high intensity on in-phase T1-
weighted images and low intensity on fat-suppressed or water-only images, (b) high intensity on in-phase images that showed signal suppression on opposed-phase images, or (c) high intensity on fat-only images. For the 15 cases with ovarian teratomas, the 2 radiologists who performed qualitative analysis assessed in consensus whether a combination of in-phase and opposed-phase IDEAL images appeared superior to a combination of in-phase and water-only IDEAL images for detecting fat.

Statistical analysis

We used paired t-test to compare SNR and absolute contrast and Wilcoxon signed-rank test to compare the 3-point scale scores for qualitative evaluation. To evaluate fat detection, we determined inter-reader agreement and intermodality agreement between IDEAL and LAVA imaging by calculating the respective $\kappa$ values, with $\kappa = 0$ indicating poor agreement; $\kappa = 0.01$ to 0.20, slight; $\kappa = 0.21$ to 0.40, fair; $\kappa = 0.41$ to 0.60, moderate; $\kappa = 0.61$ to 0.80, good; and $\kappa = 0.81$ to 1.00 excellent.27 A 2-tailed $P < .05$ was considered significant difference. We used statistical software (IBM SPSS 19.0 for Windows; IBM, Somers, NY, USA) for all analyses. We performed post hoc power analyses to assess detectable differences in absolute contrast between gluteal muscles and materials with high intensity on $T_1$-weighted images.

Results

Quantitative analysis

There were no statistically significant differences in mean SNR of subcutaneous fat between IDEAL and LAVA for both fat-suppressed (7.5 vs. 6.9; $P = .32$) and non-fat-suppressed images (16.4 vs. 16.5; $P = .85$) (Fig. 1).

For all 15 cases of teratoma, we calculated absolute contrasts between gluteal muscles and materials within masses demonstrating high signal intensity on $T_1$-weighted images. Mean absolute contrasts were significantly higher for IDEAL than for

Fig. 1. Box plots show results for signal-to-noise ratios (SNR) of subcutaneous fat (n = 32). Mean SNR did not differ significantly between iterative decomposition of water and fat with echo asymmetry and least-squares estimation (IDEAL) and liver acquisition with volume acceleration (LAVA) for either fat-suppressed or non-fat-suppressed images. Center line = median; top of box = 75th quartile; bottom of box = 25th quartile; whiskers = smallest and largest non-outlier values.

Fig. 2. Box plots show results of absolute contrast between gluteal muscle and $T_1$-weighted high signal material within ovarian teratomas (n=15). Mean absolute contrasts were significantly higher when obtained with iterative decomposition of water and fat with echo asymmetry and least-squares estimation (IDEAL) than with liver acquisition with volume acceleration (LAVA) sequences on fat-suppressed images and significantly lower when obtained with IDEAL on non-fat-suppressed images. The median ratio of the absolute contrasts for IDEAL images to that for LAVA images was 1.31 (95% confidence interval [CI]: 1.18, 1.51) for fat-suppressed images, and for non-fat-suppressed images, the median ratio of the absolute contrasts for LAVA images to that for IDEAL images was 1.16 (95% CI: 1.02, 1.41). Center line = median; top of box = 75th quartile; bottom of box = 25th quartile; whiskers = smallest and largest non-outlier values; + = outliers.
Magnetic resonance (MR) images of a 30-year-old woman with mature cystic teratoma of the left ovary. The mass (arrow) appears as high signal intensity on axial T1-weighted (a) liver acquisition with volume acceleration (LAVA), (c) in-phase iterative decomposition of water and fat with echo asymmetry and least-squares estimation (IDEAL), (e) opposed-phase IDEAL, and (f) fat-only IDEAL images and as low signal intensity on (b) fat-suppressed LAVA and (d) water-only IDEAL images. These findings indicate that the mass contains macroscopic fat. Fat suppression is more effectively achieved with IDEAL than LAVA on fat-suppressed images (b and d), and contrast between gluteal muscle and the ovarian mass is higher with IDEAL. A nodule can be seen in the wall of the mass (arrowhead). Motion artifact is more prominent on IDEAL images and obscures the nodule on (d) the water-only IDEAL image (curved arrow).

For ovarian masses other than teratomas (n = 18; one patient had fibrothecoma concomitantly with mature cystic teratoma), T1-weighted high signal materials were observed within the masses in 10 cases (7 endometriotic cysts, 3 mucinous tumors), and the absolute contrasts between gluteal muscles and T1-weighted high signal materials were calculated for 10 cases. Mean absolute contrasts did not differ significantly between IDEAL and LAVA sequences for either fat-suppressed (0.33 vs. 0.37; P = .25) or non-fat-suppressed images (0.30 vs. 0.28; P = .42) (Figs. 4, 5).

We performed post hoc power analyses to determine minimum sample sizes that would provide 80% power and 5% significance level for detecting a mean difference of 20% in absolute contrast between gluteal muscles and T1-weighted high signal materials. We determined those sample sizes to be 8 patients for ovarian teratomas and 10 for masses other than teratomas.

**Qualitative analysis**

Tables 2 and 3 present results of direct comparisons in terms of overall quality, susceptibility artifacts, motion artifacts, blurring, and conspicuity of lesion details. Table 2 also lists results in terms of fat suppression for fat-suppressed (or water-only) LAVA sequences on fat-suppressed (or water-only) images (0.56 vs. 0.38; P = .002) and were significantly lower for IDEAL on non-fat-suppressed (or in-phase) images (0.21 vs. 0.24; P = .010) (Figs. 2, 3). The median ratio of the absolute contrasts for IDEAL images to that for LAVA images was 1.31 (95% confidence interval [CI]: 1.18, 1.51) for fat-suppressed images, and the corresponding ratio for LAVA images to that for IDEAL images was 1.16 (95% CI: 1.02, 1.41) for non-fat-suppressed images.
Fig. 4. Box plots show results of absolute contrast comparisons between gluteal muscle and T1-weighted high signal materials within ovarian masses other than teratomas (n = 10). There were no statistically significant differences in mean absolute contrasts between iterative decomposition of water and fat with echo asymmetry and least-squares estimation (IDEAL) and liver acquisition with volume acceleration (LAVA) sequences on either fat-suppressed images or non-fat-suppressed images. Center line = median; top of box = 75th quartile; bottom of box = 25th quartile; whiskers = smallest and largest nonoutlier values.

Discussion

In the original 2-point Dixon method for water-fat separation, in-phase and opposed-phase images were acquired, and water-only and fat-only images were generated from those images. However, with the original technique, water-fat separation fails if magnetic field homogeneity is inadequate. Improved dual-echo Dixon techniques that use a phase-correction algorithm have been developed to overcome this problem. The improved techniques have become available through major vendors only in recent years and are reportedly useful for imaging the female pelvis. Three-point methods, also improved forms of the Dixon technique, were proposed to overcome problems secondary to magnetic field inhomogeneity by acquiring 3 images, each with a different relative phase between the water and fat signals. IDEAL imaging, a variation of the 3-point Dixon methods, employs an iterative method to determine the B0 field homogeneity map, and echo times are chosen to maximize noise performance. Therefore, IDEAL imaging provides uniform and robust fat suppression throughout the body even if there is magnetic field inhomogeneity. In fact, our data for fat-suppressed images revealed significantly better image quality with the IDEAL technique in terms of overall quality, susceptibility artifacts, conspicuity of lesion details, and fat suppression. In addition, mean absolute contrast between gluteal muscles and fat in teratomas was significantly better on IDEAL than LAVA images.

However, overall image quality, motion artifacts, and image blurring were significantly worse for non-fat-suppressed images obtained with the IDEAL sequence than the LAVA sequence, probably because of the longer acquisition time needed for the IDEAL technique. Whereas LAVA imaging was performed during a single breath-hold, IDEAL imaging was performed during quiet breathing. We therefore believe that it is important to reduce motion artifacts to improve image quality of non-fat-suppressed images obtained with the IDEAL technique. This problem might be solved by adopting multiple breath-hold acquisitions by dividing the imaging volume into several parts instead of employing a long quiet-breathing acquisition. We think the method could be worth a try.

Additional advantages of IDEAL imaging stem

Detection of fat within masses

The 2 readers agreed in all cases regarding the presence of fat within a mass. Moreover, their judgments based on IDEAL and on LAVA images were identical. Thus, both inter-reader and intermodality agreement for detecting fat within masses was perfect and calculated as κ = 1.00. None of the masses of the 17 cases without teratoma was judged to contain fat, but all the masses of the 15 cases with teratomas were judged to contain fat, and intratumoral fat showed high signal intensity on both in-phase and fat-only images. In one of the 15 cases with teratomas, a combination of in- and opposed-phase IDEAL images was judged better for detecting fat within the mass than a combination of in-phase and water-only IDEAL images (Fig. 7).
Fig. 5. Magnetic resonance (MR) images of a 51-year-old woman with endometriotic cyst of the right ovary. The mass (arrow) appears as high signal intensity on axial T₁-weighted (a) liver acquisition with volume acceleration (LAVA), (b) fat-suppressed LAVA, (c) in-phase iterative decomposition of water and fat with echo asymmetry and least-squares estimation (IDEAL), and (d) water-only IDEAL images. The mass appears as an extremely low signal on (e) fat-only IDEAL image. There were no prominent differences in gluteal muscle-to-ovarian mass contrast between LAVA and IDEAL sequences for either fat-suppressed or non-fat-suppressed images. The susceptibility artifact due to bowel gas is more prominent on fat-suppressed LAVA image (arrowhead).

Fig. 6. Magnetic resonance (MR) images of a 57-year-old woman with fibrothecoma of the left ovary. The multiloculated cystic mass (arrow) with solid parts is shown on axial T₁-weighted (a) fat-suppressed liver acquisition with volume acceleration (LAVA), (b) water-only iterative decomposition of water and fat with echo asymmetry and least-squares estimation (IDEAL), and (c) gadolinium-enhanced fat-suppressed LAVA images. The conspicuity of lesion details was judged to be better on water-only IDEAL image than on fat-suppressed LAVA image. Susceptibility artifact due to rectal gas is more prominent on fat-suppressed LAVA image (arrowheads in a and c), and motion artifact is more prominent on IDEAL images. Overall image quality obtained with the 2 techniques was judged equal in this case.
Table 2. Comparison of image quality of liver acquisition with volume acceleration (LAVA) and iterative decomposition of water and fat with echo asymmetry and least-squares estimation (IDEAL) sequences for fat-suppressed imaging

<table>
<thead>
<tr>
<th>Score</th>
<th>Overall quality</th>
<th>Susceptibility artifacts</th>
<th>Motion artifacts</th>
<th>Blurring</th>
<th>Conspicuity of lesion details</th>
<th>Fat suppression</th>
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<td></td>
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<tr>
<td>P value*</td>
<td>4.2 × 10^{-6}</td>
<td>7.9 × 10^{-4}</td>
<td>4.7 × 10^{-4}</td>
<td>.32(N.S.)</td>
<td>2.8 × 10^{-4}</td>
<td>5.3 × 10^{-7}</td>
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<td>3</td>
<td>24(75.0)</td>
<td>15(46.9)</td>
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<td>17(53.1)</td>
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<td>17(53.1)</td>
<td>16(50.0)</td>
<td>28(87.5)</td>
<td>15(46.9)</td>
<td>3( 9.4)</td>
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<td>1( 3.1)</td>
<td>0( 0.0)</td>
<td>16(50.0)</td>
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<td>Total</td>
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<td>32</td>
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<td>32</td>
<td>32</td>
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</table>

Note.—Data in parentheses show percentages. Image quality was graded using a 3-point scale: (3) better obtained with IDEAL sequence; (2) equal quality; (1) better obtained with LAVA sequence.

* P values were calculated with Wilcoxon signed-rank test.

Table 3. Comparison of image quality of liver acquisition with volume acceleration (LAVA) and iterative decomposition of water and fat with echo asymmetry and least-squares estimation (IDEAL) sequences for non-fat-suppressed imaging

<table>
<thead>
<tr>
<th>Score</th>
<th>Overall quality</th>
<th>Susceptibility artifacts</th>
<th>Motion artifacts</th>
<th>Blurring</th>
<th>Conspicuity of lesion details</th>
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<td>P value*</td>
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<td>2</td>
<td>15(46.9)</td>
<td>27(84.4)</td>
<td>17(53.1)</td>
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<td>25(78.1)</td>
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<td>1</td>
<td>17(53.1)</td>
<td>0( 0.0)</td>
<td>15(46.9)</td>
<td>30(93.8)</td>
<td>5(15.6)</td>
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<td>Total</td>
<td>32</td>
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<td>32</td>
<td>32</td>
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</table>

Note.—Data in parentheses show percentages. Image quality was graded using a 3-point scale: (3) better obtained with IDEAL sequence; (2) equal quality; (1) better obtained with LAVA sequence.

* P values were calculated with Wilcoxon signed-rank test.

from its capacity to acquire 4 types of images (in-phase, opposed-phase, water-only, and fat-only images) simultaneously. Cystic teratomas usually contain a liquid mixture of sebum, keratin, water, and hair. Although a vast majority of them contain abundant fat, some contain smaller amounts, and a combination of in-phase and opposed-phase images yields reportedly greater sensitivity for detecting small amounts.31,32 Therefore, IDEAL imaging may be useful for detecting small amounts of fat within ovarian teratomas and improving diagnostic accuracy for ovarian masses. As noted, for one of our cases, we considered fat detection better using a combination of in- and opposed-phase images than a combination of non-fat-suppressed and fat-suppressed images. However, the radiologists’ judgments did not differ between IDEAL and LAVA imaging for fat detection within masses. Another advantage for IDEAL is that it could simplify non-contrast-enhanced MR imaging protocols by replacing multiple conventional acquisitions with a single acquisition of in-phase, opposed-phase, water-only, and fat-only images.21

The dual-echo Dixon technique also allows acquisition of 4 similar types of images, and the recently developed 3D gradient-echo dual-echo Dixon technique with phase-reconstruction algorithms has been reported useful for imaging the female pelvis.29,30 However, it has been speculated that by compensating for the effect of magnetic inhomogeneity induced by the susceptibility effect, the IDEAL sequence can theoretically provide more reliable water-fat separation that the dual-echo Dixon sequence.20,21 Therefore, it might be a better choice, especially for pelvic imaging at 3T, because of the strong susceptibility effect in the pelvis due to bowel gas, the artifact of which is stronger at 3T than at 1.5T.33 This could be important with the increased use of 3T MR systems over the past several years to image a variety of areas, including the fe-
Fig. 7. Magnetic resonance (MR) images obtained with the iterative decomposition of water and fat with echo asymmetry and least-squares estimation (IDEAL) sequence of a 37-year-old woman with mature cystic teratoma of the left ovary. The mass (arrow) appears as slightly high signal intensity on (a) axial T1-weighted in-phase IDEAL image. The signal intensity of the mass is suppressed on (b) water-only and (c) opposed-phase IDEAL images (arrowheads). These findings suggest that the mass contains a small amount of fat. Fat within the mass is observed on (d) the fat-only IDEAL image (curved arrow).

male pelvis. However, acquisition time can be shorter with the dual-echo Dixon than the IDEAL technique, which requires 3 echoes, and thereby yield fewer motion artifacts. We think a comparison of pelvic imaging between the 2 techniques is needed.

Our study is limited because it is retrospective, and the sample size is relatively small. A prospective study with more patients is needed to validate the efficacy of the IDEAL sequence. Other limitations include the non-blinded manner by which we compared image quality, the possible suboptimal choice of sequence with which to compare the IDEAL technique or of imaging parameters used, the limited range of pathologies we assessed, and the absence of assessment of pelvic pathologies outside the ovary. In addition, the choice of a T1-weighted fast spin-echo sequence might have been more appropriate than LAVA to compare imaging techniques because fast spin-echo sequences are routinely used at some institutions. However, LAVA acquisitions have been standard techniques at our institution for ovarian MR imaging. Therefore, we used LAVA sequence as a standard technique to be compared in this study.

Conclusion

Compared with conventional T1-weighted 3D gradient-echo sequence using the CSS-IR technique, the 3D gradient-echo IDEAL sequence offers better quality T1-weighted fat-suppressed images for the diagnosis of ovarian masses. In- and opposed-phase images obtained simultaneously may also be useful for detecting small amounts of fat. Although motion artifacts and blurring were
worse for IDEAL than non-fat-suppressed conventional images, IDEAL sequence had certain benefits compared with conventional T1-weighted 3D gradient-echo sequences. A comparison of IDEAL with recently introduced 3D dual-echo Dixon methods using phase-reconstruction algorithms is warranted to judge whether IDEAL sufficiently improves image quality and diagnostic utility to justify its longer scan time.

References

28. Ma J. Breath-hold water and fat imaging using a dual-echo two-point Dixon technique with an