

Acute, Subacute, and Chronic Myocardial Infarction: Quantitative Comparison of 2D and 3D Late Gadolinium Enhancement MR Imaging¹

Robert Goetti, MD
Sebastian Kozerke, PhD
Olivio F. Donati, MD
Daniel Sürder, MD
Paul Stolzmann, MD²
Philipp A. Kaufmann, MD
Thomas F. Lüscher, MD
Roberto Corti, MD
Robert Manka, MD

¹From the Department of Diagnostic Radiology (R.G., O.F.D., P.S.), Department of Cardiac Imaging (R.G., P.A.K., R.M.), and Cardiology Clinic (D.S., P.A.K., T.F.L., R.C., R.M.), University Hospital Zurich, Raemistrasse 100, CH-8091 Zurich, Switzerland; and Institute for Biomedical Engineering, University and ETH Zurich, Zurich, Switzerland (S.K., R.M.). Received November 9, 2010; revision requested December 13; revision received December 30; accepted January 31, 2011; final version accepted February 3.

Address correspondence to R.M. (e-mail: robert.manka@usz.ch).

²Current address: Cardiac MR PET CT Program, Massachusetts General Hospital and Harvard Medical School, Boston, Mass.

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Purpose:

To assess a late gadolinium enhancement (LGE) single-breath-hold three-dimensional (3D) inversion recovery magnetic resonance (MR) imaging sequence for the quantification of myocardial scar mass and transmural extent in comparison with a clinically established two-dimensional (2D) sequence.

Materials and Methods:

All patients gave written informed consent to participate in this institutional review board-approved study. Ninety patients (84 men; mean age, 54.4 years $\pm$ 10.8 [standard deviation]) with acute ($n = 30$), subacute ($n = 30$), or chronic ($n = 30$) myocardial infarction were included. Imaging was performed by using a 1.5-T clinical MR imaging system. Spatial resolution was identical for 3D and 2D images (1.5×1.5 mm²; section thickness, 8 mm; no section gap). Quantitative comparisons of myocardial mass (in grams), scar mass (in grams), and scar transmural extent (on a five-point scale) were performed by using the Pearson correlation and Bland-Altman analysis (for myocardial and scar mass) or κ statistics (for transmural extent).

Results:

There were no significant differences between 2D and 3D data sets in terms of mean myocardial mass (2D: 148.3 g $\pm$ 35.1; 3D: 148.1 g $\pm$ 34.6; $P = .76$) and scar tissue mass (2D: 31.8 g $\pm$ 14.6; 3D: 31.6 g $\pm$ 15.5; $P = .39$), with strong and significant correlation regarding both myocardial mass ($r = 0.982$; $P < .001$) and scar tissue mass ($r = 0.980$; $P < .001$). Bland-Altman analysis showed a mean difference of 0.21 g $\pm$ 6.64 (range, -19.64 to 18.44 g) for myocardial mass and a mean difference of 0.26 g $\pm$ 2.88 (range, -7.15 to 7.74 g) for scar mass between the 2D and 3D data sets. Agreement regarding scar transmural extent was good ($\kappa = 0.75$). Acquisition time was significantly shorter for 3D data sets (26.7 seconds $\pm$ 4.4 vs 367.7 seconds $\pm$ 56.4; $P < .001$).

Conclusion:

Three-dimensional LGE MR imaging enables quantitative evaluation of scar tissue mass and transmural extent in patients with acute, subacute, or chronic myocardial infarction at significantly reduced acquisition times compared with 2D LGE MR imaging.

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Late gadolinium enhancement (LGE) cardiac magnetic resonance (MR) imaging has been established as the standard of reference for assessment of myocardial viability and the transmural extent of myocardial infarction (1,2). The assessment of the degree of infarct transmural extent is of utmost clinical importance as it is a predictor of prognosis for restoration of myocardial contractile function after revascularization (3,4). The principle of LGE imaging is based on the increased signal intensity of infarcted nonviable myocardium compared with that of healthy myocardium. This effect results from the delayed washout kinetics of contrast material in infarcted myocardium due to leakage into the interstitial space caused by microvascular damage (5). LGE imaging is typically performed 10–20 minutes after administration of gadolinium-containing contrast material by using an inversion recovery technique with the inversion time chosen to null the signal of normal myocardium, resulting in hyperintensity of the infarcted nonviable myocardium (2). Traditionally, a two-dimensional (2D) inversion recovery fast spoiled gradient-echo sequence is applied for LGE imaging, necessitating repetitive breath holds of approximately 15 seconds for the acquisition of each section (6). Recently, the use of three-dimensional (3D) acquisition techniques has been reported for LGE imaging; these enable image acquisition in a single breath hold (7,8) or during free breathing when a navigator-gated sequence is used (9–12). However, it has not yet been demonstrated that the 2D and 3D acquisition techniques

are comparable regarding the quantitative assessment of myocardial viability in a patient cohort with acute, subacute, or chronic myocardial infarction.

The purpose of our study was to assess a single-breath-hold 3D inversion-recovery sequence for the detection and quantification of acute, subacute, and chronic myocardial infarction in comparison with a clinically established 2D acquisition sequence.

Materials and Methods

Study Population

From January 2008 until May 2010, three groups of 30 consecutive patients with acute ($n = 30$), subacute ($n = 30$), or chronic ($n = 30$) myocardial infarction as diagnosed at electrocardiography, cardiac marker testing, and conventional coronary angiography were included in the study. Therefore, a total of 90 patients (84 men; mean age, $54.4 \text{ years} \pm 10.8$ [standard deviation]; mean body mass index [BMI], $27.8 \text{ kg/m}^2 \pm 4.5$) were enrolled. Exclusion criteria for the study were as follows: MR imaging-incompatible metallic implants ($n = 2$), atrial fibrillation ($n = 3$), and claustrophobia ($n = 1$). Therefore, an additional six patients who were eligible for the study were excluded. Acute myocardial infarction was defined as occurring less than 30 days, subacute as occurring between 30 days and 1 year, and chronic as occurring more than 1 year since the initial presentation of the patient with acute coronary syndrome. The study was approved by the institutional review board, and all participants gave written informed consent.

Cardiac MR Imaging Data Acquisition

All imaging was performed by using a 1.5-T clinical MR imaging system (Achieva;

Philips Healthcare, Best, the Netherlands). A dedicated five-element cardiac phased-array receiver coil was used for signal reception. All data were acquired during breath holding in end inspiration. The imaging protocol included assessment of myocardial function and LGE imaging. After survey images and coil calibration data were acquired, short-axis images covering the entire left ventricle (LV) were acquired by using a balanced steady-state free precession sequence (field of view, $350 \times 350 \text{ mm}^2$; matrix, 300×300 ; repetition time msec/echo time msec, 4.0/2.0; in-plane resolution, $1.2 \times 1.2 \text{ mm}^2$; number of cardiac phases, 20; section thickness, 8 mm; and 13–16 contiguous sections to assess global LV function). LGE images covering the entire LV were acquired 15 minutes after administration of a bolus of 0.25 mmol of gadobutrol (Gadovist; Bayer Schering Pharma, Zurich, Switzerland) per kilogram of body weight. This high dose was applied to minimize the difference in signal intensity in the sequential acquisitions of 2D and 3D data by exploiting the nonlinear relationship between signal intensity and contrast material concentration at high dose. Two-dimensional LGE images were acquired in short-axis views by using an inversion recovery

Advance in Knowledge

- Late gadolinium enhancement (LGE) MR imaging performed by using a single-breath-hold three-dimensional acquisition technique enables quantitative evaluation of scar tissue mass and transmural extent in patients with acute, subacute, or chronic myocardial infarction with a high degree of agreement compared with the clinical standard of two-dimensional imaging.

Implication for Patient Care

- Three-dimensional single-breath-hold acquisition significantly reduces the examination time for LGE MR imaging ($26.7 \text{ seconds} \pm 4.4$ vs $367.7 \text{ seconds} \pm 56.4$; $P < .001$).

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Abbreviations:

BMI = body mass index
CNR = contrast-to-noise ratio
LGE = late gadolinium enhancement
LV = left ventricle
ROI = region of interest
3D = three-dimensional
2D = two-dimensional

Author contributions:

Guarantors of integrity of entire study, R.C., R.M.; study concepts/study design or data acquisition or data analysis/interpretation, all authors; manuscript drafting or manuscript revision for important intellectual content, all authors; manuscript final version approval, all authors; literature research, R.G., O.F.D., D.S., P.S., R.C., R.M.; clinical studies, O.F.D., D.S., P.S., R.C., R.M.; statistical analysis, R.G., O.F.D., D.S., P.S., P.A.K., R.M.; and manuscript editing, R.G., S.K., O.F.D., D.S., P.S., P.A.K., R.C., R.M.

Potential conflicts of interest are listed at the end of this article.

gradient-echo MR imaging sequence with the following parameters: field of view, 350×350 mm²; matrix, 256×256 ; 7.4/4.3; inversion time, 180–300 msec (individually optimized); flip angle, 20°; in-plane resolution, 1.5×1.5 mm²; section thickness, 8 mm without gaps; and temporal resolution, 223 msec. Three-dimensional LGE images were acquired by using an inversion recovery gradient-echo MR sequence with the following parameters: field of view, 350×350 mm²; matrix, 256×256 ; 3.7/1.8; sensitivity encoding factor, two; inversion time, 180–300 msec (individually optimized); flip angle, 15°; in-plane resolution, 1.5×1.5 mm²; section thickness, 8 mm without gaps; and temporal resolution, 181 msec. Two-dimensional and 3D image acquisitions were performed in random order, and optimal inversion recovery prepulse delays were determined by using a Look-Locker sequence and were adjusted accordingly (13). Acquisition times for 2D and 3D sequences were noted.

Cardiac MR Imaging Data Analysis

For all quantitative analyses, commercially available software (QMass MR, version 7.2.; Medis Medical Imaging Systems, Leiden, the Netherlands) was used. First, LV function assessment was performed by a radiologist (R.G., with 2 years of experience in cardiac imaging) who was blinded to patient information and clinical data and who used calculations from manually marked endocardial contours in end-systolic and end-diastolic short-axis steady-state free precession cine images. In a separate session, subjective image quality analysis and quantitative cardiac MR imaging data analysis of LGE 2D and 3D images were performed in random order. Furthermore, images were evaluated for the presence of intraventricular thrombi by using the same LGE image sets with inversion times optimized for myocardial nulling. For 15 patients (five randomly chosen patients in each group), quantitative analysis of LGE 2D and 3D images was performed again by the same radiologist after 4 weeks to assess intraobserver agreement and was performed by a second radiologist (O.F.D., with

3 years of experience in cardiac imaging) to assess interobserver agreement.

Image quality assessment.—The image quality of each data set was graded by using a five-point scale (where a score of 1 indicated excellent; a score of 2, good; a score of 3, moderate; a score of 4, poor; and a score of 5, nondiagnostic). For any score other than 1, the reason for impaired image quality was noted and categorized as being due to (a) motion artifacts or blurring, (b) low contrast or high noise, (c) inadequate myocardial nulling, or (d) folding artifacts. Signal intensities and their standard deviations were measured in regions of interest (ROIs) that covered areas of hyperenhanced myocardium, as well as areas of remote normal-appearing myocardium, and contrast was defined as the difference between the mean signal intensity of both ROIs. Image noise was defined as the standard deviation of the signal intensity in the normal-appearing myocardium ROI. Contrast-to-noise ratios (CNRs) were calculated by using these values.

Quantitative LGE evaluation.—A semiautomated approach was used for quantification of hyperenhanced myocardium: On both the 2D and 3D LGE images, endocardial and epicardial contours were manually marked, and ROIs were placed in hyperenhanced and normal-appearing remote myocardium by the software and reviewed by the reader. The areas of hyperenhancing myocardium were then automatically segmented by using a full-width at half-maximum algorithm as previously validated (14,15). The threshold could be manually overridden for a specific location only if necessary to exclude obvious artifacts, such as folding artifacts. After segmentation, myocardial and scar tissue mass (in grams), as well as scar tissue volume (in milliliters), were calculated. Furthermore, scar tissue volume and transmural (each expressed as a percentage) were automatically calculated for each segment of a 16-segment model of the myocardium that corresponded to the 17-segment model proposed by the American Heart Association (16), excluding the apex. Infarct transmural was quantitatively calculated by the software as the per-

centage of tissue with a higher transmural than the specified threshold (ie, 50%) plus the connected normal tissue along a chord within each segment and was then graded by using a five-point scale derived from the quantitative results where a score of 0 indicated no delayed enhancement (0% transmural); a score of 1, delayed enhancement and 1%–24% transmural; a score of 2, 25%–49% transmural; a score of 3, 50%–74% transmural; and a score of 4, 75%–100% transmural.

Statistical Analyses

Quantitative data are expressed as means $\pm$ standard deviations, and categorical data are expressed as proportions or percentages.

The sample size of two groups of 90 patients with 1440 myocardial segments was calculated by using power analysis for two proportions to reach a statistical power of more than 80% to detect differences of 5%, using the pessimistic assumption of 30% scar tissue per segment and an α error level of .05.

Image quality scores of the 2D and 3D data sets were compared by using the Mann-Whitney *U* test, and the difference in proportions of reasons for impaired image quality were evaluated by using the χ^2 test. Interobserver agreement regarding image quality scores was assessed by using Cohen κ statistics. A κ value greater than 0.81 was interpreted as excellent agreement, values of 0.61–0.80 as good agreement, values of 0.41–0.60 as moderate agreement, values of 0.21–0.40 as fair agreement, and values of less than 0.20 as poor agreement.

Statistical comparison of means of the normally distributed values of scar-myocardium signal intensity difference and myocardial mass, as well as scar mass and volume between the two acquisition techniques, was performed by using two-tailed paired *t* tests. Scar tissue percentages per segment, as well as CNRs, were compared by using the Wilcoxon signed rank test, as these values did not show normal distribution. The Kolmogorov-Smirnov test was used for normality testing. Agreement between the results of the two acquisition techniques regarding myocardial and scar tissue

Figure 1

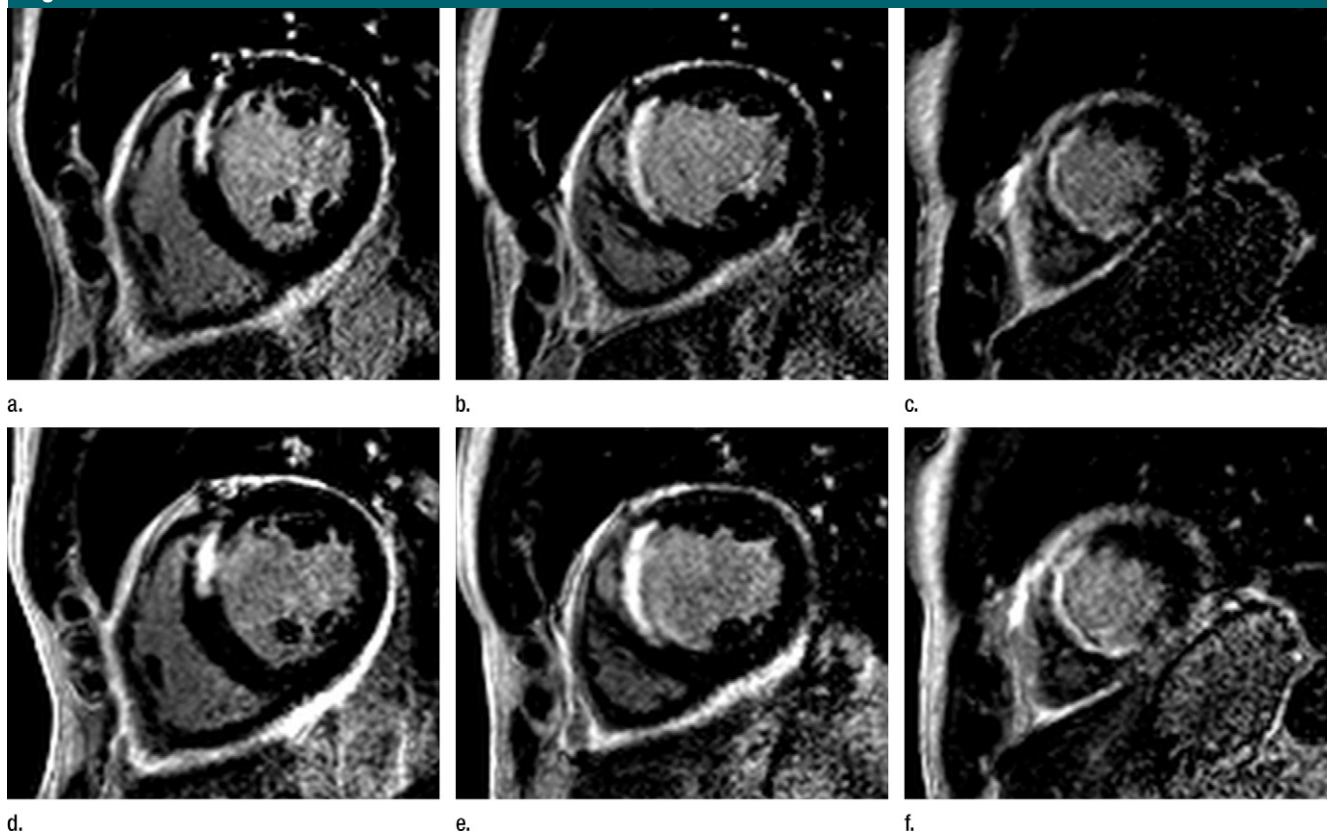


Figure 1: (a–f) Short-axis LGE MR images show excellent image quality for (a) basal, (b) midventricular, and (c) apical sections from 2D acquisitions and (d) basal, (e) midventricular, and (f) apical sections from 3D acquisitions in the same 60-year-old man with subacute myocardial infarction after occlusion of the left anterior descending artery.

mass was assessed by using the Pearson correlation coefficient and Bland-Altman analysis. Agreements between the two acquisition techniques, as well as inter- and intraobserver agreements regarding the detection of nonviable segments (defined as >50% scar tissue transmural) and the more detailed assessment using a previously described five-point transmural score (3), were assessed by using Cohen κ statistics.

All statistical analyses were performed using commercially available software (SPSS, release 17.0; SPSS, Chicago, Ill). $P < .05$ was considered to indicate statistical significance.

Results

Study Population

The three groups of 30 consecutive patients with acute ($n = 30$; 28 men; mean

age, $54.2 \text{ years} \pm 11.7$; mean BMI, $28.0 \text{ kg/m}^2 \pm 4.6$; mean ejection fraction, $49.3\% \pm 9.4$), subacute ($n = 30$; 29 men; mean age, $51.7 \text{ years} \pm 10.5$; mean BMI, $27.8 \text{ kg/m}^2 \pm 4.8$; mean ejection fraction, $48.6\% \pm 10.1$), and chronic ($n = 30$; 27 men; mean age, $57.4 \text{ years} \pm 9.6$; mean BMI, $27.5 \text{ kg/m}^2 \pm 4.1$; mean ejection fraction, $47.0\% \pm 14.0$) myocardial infarction were imaged without complications.

Image Quality

For 62 of 90 (68.8%) of the 2D data sets and 53 of 90 (58.9%) of the 3D data sets, image quality was graded as being excellent (score = 1; Fig 1). Mean image quality was slightly lower in 3D data sets (1.50 ± 0.675) compared with 2D data sets (1.41 ± 0.669); however, this difference was not statistically significant ($P = .26$). Image quality ranged from excellent (score: 1) to poor (score: 4)

in both groups. Nondiagnostic image quality (score: 5) was not found in either group. Interobserver agreement regarding image quality ratings was good ($\kappa = 0.67$). Table 1 provides an overview of the reasons for impaired image quality. Impaired image quality was significantly more often attributed to low contrast/high noise in 2D data sets ($P = .011$) and to motion/blurring in 3D data sets ($P = .006$).

Scar-myocardium signal intensity differences were significantly higher in 3D compared with 2D images (222.6 ± 60.9 vs 163.3 ± 44.3 ; $P < .001$); however, CNR (median, range) was not significantly different (2D: 20.6, 5.0–89.9; 3D: 20.3, 6.5–41.4; $P = .692$).

Intraventricular thrombi were found in three patients in both 2D and 3D images (Fig 2). There were no thrombi that were visible only in 2D or 3D acquisitions.

Table 2

Correlation of Myocardial and Scar Mass in 2D and 3D Acquisitions

Type of Myocardial Infarction*	Myocardium				Scar			
	2D Mass (g) [†]	3D Mass (g) [†]	Pearson Correlation Coefficient	PValue	2D Mass (g) [†]	3D Mass (g) [†]	Pearson Correlation Coefficient	PValue
Acute (n = 30)	159.6 ± 38.6	159.7 ± 37.7	0.972	<.001	39.2 ± 13.9	40.1 ± 14.2	0.980	<.001
Subacute (n = 30)	143.9 ± 34.6	142.7 ± 34.4	0.989	<.001	26.3 ± 13.4	25.1 ± 12.2	0.982	<.001
Chronic (n = 30)	141.5 ± 29.6	141.9 ± 29.2	0.985	<.001	29.9 ± 13.7	29.4 ± 13.2	0.980	<.001

* Acute indicates 0–30 days; subacute, 30 days to 1 year; and chronic, >1 year.

[†] Data are means ± standard deviations.

Table 1

Reasons for Impaired Subjective Image Quality Ratings

Reason for Impaired Image Quality	2D Acquisitions (n = 90)	3D Acquisitions (n = 90)
Motion artifacts/blurring	7	18
Low contrast/high noise	14	9
Inadequate myocardial nulling	2	4
Folding artifacts	5	6
Total	28	37

Note.—Data are numbers of ratings. Image quality was considered to be impaired when any rating other than excellent was assigned (ie, image quality rating score < 1).

Figure 2

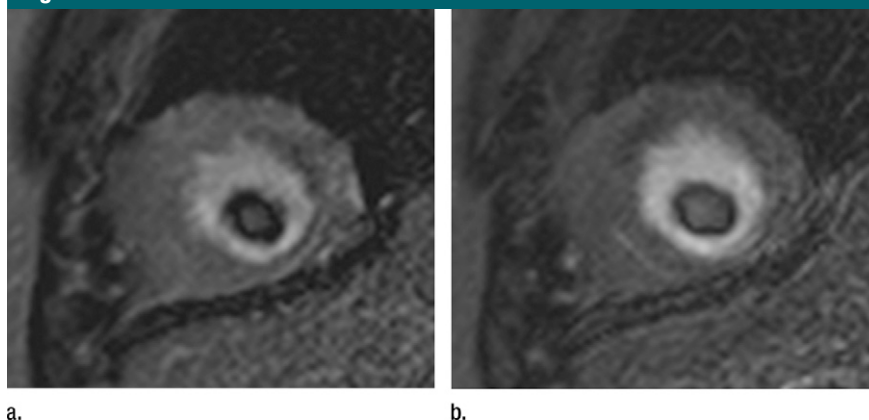


Figure 2: Apical thrombus is visualized in both (a) 2D and (b) 3D short-axis LGE MR images with inversion times optimized for myocardial nulling in 65-year-old man with subacute myocardial infarction.

Quantitative LGE Assessment

Scar mass and volume.—There were no significant differences between 2D and 3D data sets in mean myocardial mass (2D: 148.3 g ± 35.1; 3D: 148.1 g ± 34.6; $P = .76$) and scar tissue mass (2D: 31.8 g ± 14.6; 3D: 31.6 g ± 15.5; $P = .39$) and volume (2D: 30.3 mL ± 13.9; 3D: 30.1 mL ± 13.8; $P = .39$),

with no significant differences in scar tissue percentage per segment (median, range: 13.1%, 0%–97.6% for 2D; 13.6%, 0%–98.2% for 3D; $P = .13$). There was strong and significant correlation between 2D and 3D data sets regarding myocardial mass ($r = 0.982$; $P < .001$) and scar tissue mass ($r = 0.980$; $P < .001$) and volume ($r = 0.980$; $P < .001$).

This was also the case in the separate analysis of myocardial mass and scar tissue mass and volume in the three patient groups ($r = 0.972$ – 0.989 , each $P < .001$; Table 2). Bland-Altman analysis showed a mean difference of 0.21 g ± 6.64 (range, −19.64 to 18.44 g) for myocardial mass and a mean difference of 0.26 g ± 2.88 (range: −7.15 to 7.74 g) for scar mass between 2D and 3D data sets (Fig 3).

Scar transmural.—Agreement between the two acquisition techniques regarding scar transmural was excellent for the detection of nonviable segments (defined as > 50% scar tissue transmural) with $\kappa = 0.814$ and was good ($\kappa = 0.746$) for the more detailed assessment using the five-point transmural score. Inter- and intraobserver agreements were good to excellent (Table 3).

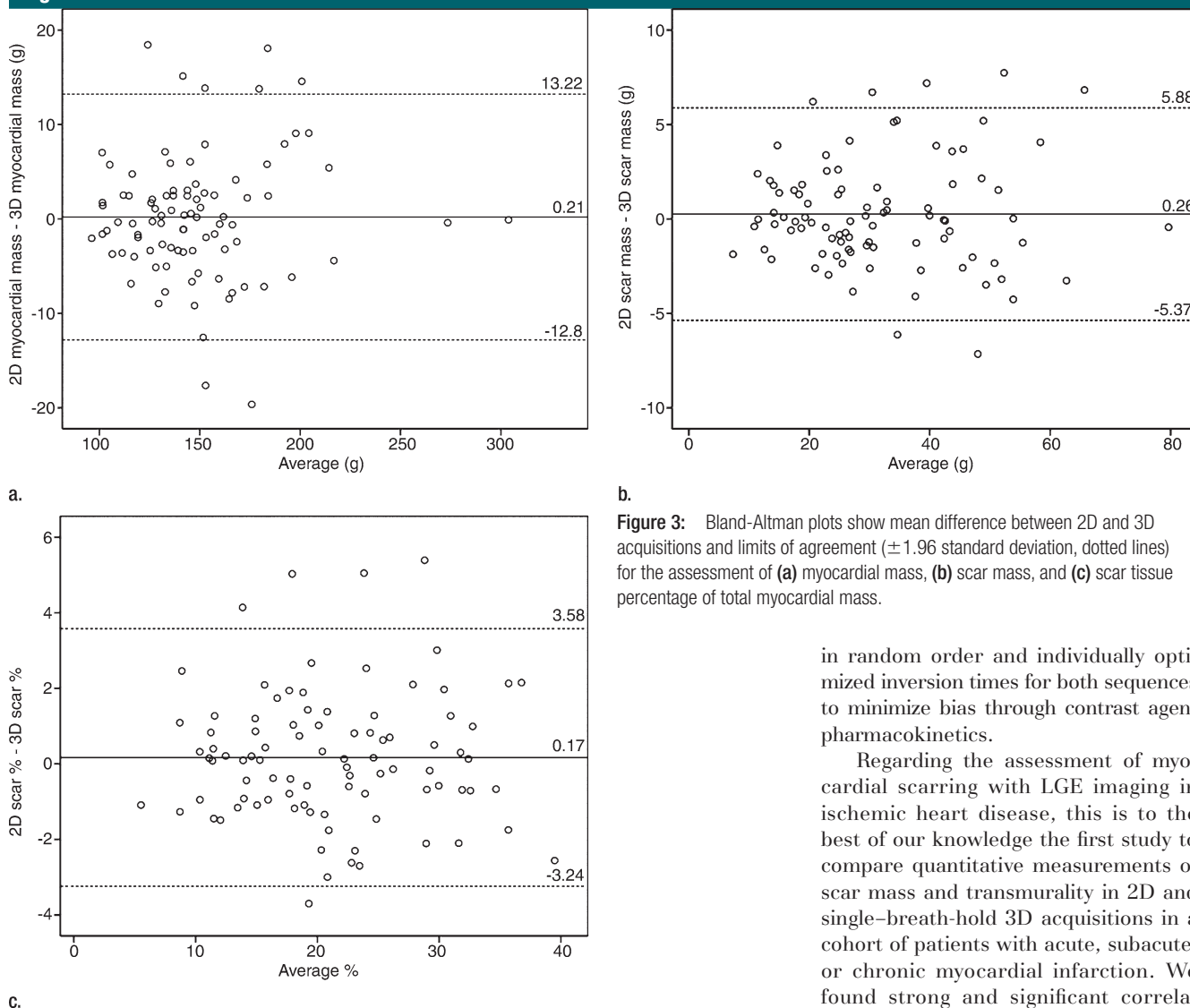
Acquisition time.—Acquisition time was significantly shorter for 3D data sets (26.7 seconds ± 4.4) compared with 2D data sets (367.7 seconds ± 56.4; $P < .001$).

Discussion

Our results demonstrate that in patients with acute, subacute, or chronic myocardial infarction, 3D LGE imaging enables quantitative evaluation of scar tissue mass and transmural with high agreement compared with 2D LGE imaging and similar image quality at significantly shorter acquisition times.

We found similar image quality in 2D and 3D acquisitions, while the reasons for impaired image quality differed. In 3D acquisitions, impaired image quality was more often attributed to blurring or

Figure 3



b.

Figure 3: Bland-Altman plots show mean difference between 2D and 3D acquisitions and limits of agreement (± 1.96 standard deviation, dotted lines) for the assessment of (a) myocardial mass, (b) scar mass, and (c) scar tissue percentage of total myocardial mass.

motion artifacts, possibly related to the longer single breath hold of 27 seconds compared with the repetitive shorter breath holds of 10–12 seconds in 2D acquisitions. On the other hand, impaired image quality in 2D images was more often attributed to low contrast (ie, low subjective scar-myocardium signal intensity differences). This is also reflected in the lower quantitative measurements of signal intensity differences between scar and remote normal myocardium we found in 2D images. Regarding CNR, however, there were no significant differences. Previous studies have reported

somewhat equivocal findings regarding CNR differences between 2D and 3D acquisitions in LGE imaging. While Foo et al (7) reported a significant improvement of CNR by a factor of 2 in 3D compared with 2D imaging, other studies found no significant differences (8,11,17). One reason for the differences found in the study conducted by Foo et al may have been the fact that all 2D acquisitions were performed 10–15 minutes after contrast agent administration, while all 3D images were acquired after 16–27 minutes using the same inversion time. We performed 2D and 3D acquisitions

in random order and individually optimized inversion times for both sequences to minimize bias through contrast agent pharmacokinetics.

Regarding the assessment of myocardial scarring with LGE imaging in ischemic heart disease, this is to the best of our knowledge the first study to compare quantitative measurements of scar mass and transmuralities in 2D and single-breath-hold 3D acquisitions in a cohort of patients with acute, subacute, or chronic myocardial infarction. We found strong and significant correlations for all patient groups, as well as narrow limits of agreement between 2D and 3D acquisitions. These findings are comparable to the results of previous studies with smaller patient numbers. Dewey et al (8) reported a similarly strong and significant correlation ($r = 0.982$, $P < .001$) between 2D and single-breath-hold 3D LGE imaging in 13 patients with myocardial infarction imaged at 1.5 T, and Bauner et al (17) reported similar values in 15 patients using a 3D acquisition technique at 3 T with three consecutive 3D slabs covering the myocardium ($r = 0.99$, $P < .001$). One study that evaluated a single-breath-hold 3D acquisition sequence in 35 patients (7)

Table 3

 κ Values for Intra- and Interobserver Agreement Regarding Scar Transmurality

Agreement	2D Viability	2D Transmurality	3D Viability	3D Transmurality
Intraobserver	0.844	0.868	0.895	0.833
Interobserver	0.784	0.723	0.772	0.700

Note.—Viability indicates agreement regarding segments with greater than 50% scar tissue transmurality; transmurality indicates agreement regarding transmurality score (0 = no delayed enhancement [0% transmurality]; 1 = delayed enhancement of < 25%; 2, delayed enhancement of < 50%; 3, delayed enhancement of < 75%; and 4, delayed enhancement of 75%–100%).

also reported correct identification of all regions of myocardial infarction compared with 2D imaging; however, no quantitative scar assessment was performed.

Besides the assessment of the presence and quantification of scar mass, it is essential to consider the transmural extent of myocardial scarring in ischemic heart disease, as this is an important predictor of functional recovery after revascularization (3). For the quantitative assessment of scar transmurality we found excellent agreement ($\kappa = 0.814$) between 2D and 3D acquisitions for the presence of greater than 50% transmurality and a good agreement for the more detailed quantification in steps of 25% transmurality ($\kappa = 0.746$). Furthermore, inter- and intraobserver agreements were good to excellent, indicating a good reproducibility of the results obtained with the quantification software. Using the same five-point grading system—for subjective visual assessment of transmurality only, however—Dewey et al (8) found that 3D imaging correctly helped classify 31 of 34 segments with myocardial infarction, with 2D imaging as the standard of reference, resulting in an agreement of 98.6% for 289 evaluated segments. A different study (18) that found only fair agreement ($\kappa = 0.32$) between 2D and 3D acquisitions for the assessment of scar transmurality suffered from increased blurring of the 3D images, possibly caused by a longer acquisition time per heartbeat compared with the applied 2D sequence (293 vs 245 msec).

Total acquisition time is an important factor in LGE imaging for several reasons. First, a long time interval between the acquisition of the first and the last section in a 2D approach may

compromise the homogeneity of contrast because of varying inversion times, necessitating their optimization between acquisitions of individual sections. Secondly, minimizing the time spent within the imaging unit can be essential in imaging critically ill patients. Finally, short imaging times may be required at locations with limited MR imaging unit availability or for economic reasons. Our finding that 3D LGE imaging significantly reduces acquisition time compared with 2D imaging is in line with previous reports. Using single-breath-hold 3D acquisitions, imaging times of 21–22 seconds compared with 3–8 minutes for 2D imaging have been reported (7,8) (with slightly reduced spatial resolution in the 3D acquisitions, however). We chose equal spatial resolution in 2D and 3D acquisitions to assure comparability. Strategies other than single-breath-hold 3D imaging do not lead to such prominent reductions of acquisition time. For three consecutive 3D slab acquisitions covering the myocardium performed in three breath holds, Bauner et al (17) reported a mere halving of acquisition time compared with 2D imaging, although with improved spatial resolution in the 3D images. Using a navigator-gated free-breathing 3D acquisition technique, Nguyen et al (10) found a reduction of imaging time from roughly 7 to 4 minutes. Navigator gating may be beneficial in critically ill or noncompliant patients who are not able to hold their breath for the duration of the 20–30 seconds needed for single-breath-hold 3D imaging.

In conclusion, single-breath-hold 3D LGE imaging enables quantitative evaluation of scar tissue mass and transmurality in patients with acute, subacute, or

chronic myocardial infarction at significantly reduced acquisition time compared with 2D LGE imaging.

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