# Fast 3D Cine Steady-State Free Precession Imaging with Sensitivity Encoding for Assessment of Left Ventricular Function in a Single Breath-hold

N. B. Mascarenhas[1], R. Muthupillai[2,3], B. Cheong[2,4], M. Pereyra[2], S. D. Flamm[1,2]

[1]Baylor College of Medicine, Houston, Texas, United States, [2]Department of Radiology, St. Luke's Episcopal Hospital/Texas Heart Institute, Houston, Texas, United States, [3]Philips Medical Systems, Cleveland, Ohio, United States, [4]Department of Cardiology, St. Luke's Episcopal Hospital/Texas Heart Institute, Houston, Texas, United States

**Introduction**

The sequence of choice for obtaining cine views of the heart for evaluation of LV function is steady-state free precession (SSFP) due to its high signal intensity and myocardium-to-blood contrast and superior temporal resolution (1). However, conventional techniques require multiple breath-holds that lead to increased examination time, patient discomfort, and potential slice misregistration. A shortened acquisition time is desirable, especially if it permits comparable quantification of LV function in a single breath-hold. Parallel imaging techniques, such as sensitivity encoding (SENSE), utilize multiple receiver coils to obtain images more rapidly but have a decreased signal-to-noise ratio (SNR) (2). Compared to 2D imaging, 3D imaging offers increased signal intensity because a larger volume of tissue is excited with each pulse. The combination of 3D imaging with SENSE may enable a single breath-hold examination because the higher signal intensity intrinsic to 3D imaging can be traded for even greater acceleration with SENSE.

**Methods**

Twelve volunteers and 11 patients were scanned on a 1.5-T MR imager (Achieva, Philips Medical Systems) with a five-element synergy cardiac coil. All participants were imaged with a 2D SSFP sequence (10-14 slices, 8 mm thickness, 2 mm gap) and a 3D SSFP with SENSE sequence (10-14 slices, 10 mm thickness, 0 mm gap). Imaging parameters for the 2D SSFP sequence were as follows: TR/TE/flip=2.7-3.1 msec/1.4-1.5 msec/65; temporal resolution 25-39 msec; mean spatial resolution 2.2 mm x 2.2 mm (depending on patient size); breath-hold duration 10-12 heartbeats per slice. Imaging parameters for the 3D SSFP with SENSE sequence were as follows: TR/TE/flip=2.4-2.6 msec/1.2-1.3 msec/55; temporal resolution 40-53 msec; mean spatial resolution 2.5 mm x 2.5 mm (depending on patient size); breath-hold duration 18-20 heartbeats for full acquisition of LV volume; SENSE factor of 3. All data sets were transferred to a post-processing workstation (EasyVision, Philips Medical Systems) for LV function analysis by the same observer (BC). End diastolic volume (EDV), end systolic volume (ESV), ejection fraction (EF), and LV mass were calculated using voxel summation. Mean values and standard deviations were calculated for each parameter, agreement between the two methods was assessed with Bland-Altman analysis (3), and results were compared using paired Student *t* tests ($P$-value < 0.05).

**Results**

Figure 1 shows representative LV short-axis images from the same patient using the standard 2D SSFP sequence and the 3D SSFP sequence with SENSE. Bland-Altman analysis indicated close agreement between the two methods with respect to EF (mean bias, -0.9% ± 2.8) and LV mass (mean bias, -2.3 g ± 11.1). There was no significant difference in EDV, ESV, EF, or LV mass (Table 1). There was a significant difference in both blood SNR (2D SSFP mean value, 49.6; 3D SSFP with SENSE mean value, 31.7; $P < 0.001$) and blood-to-muscle contrast-to-noise ratio (CNR). Summary data are presented in Table 2. Acquisition time was 102 seconds ± 7 (10 breath-holds) with the 2D sequence and 17 seconds ± 2 (single breath-hold) with the 3D sequence ($P < 0.001$), indicating an 83% reduction. For the total scan time (including breathing instructions for 2D and reference scan for 3D), the reduction was 66%.

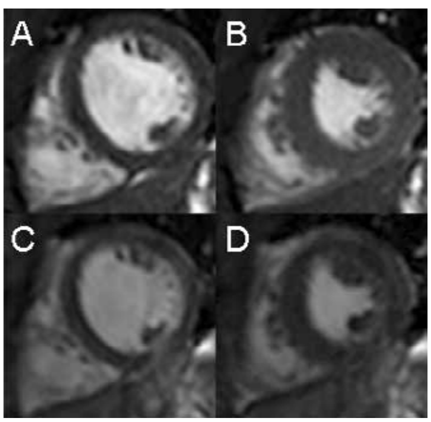


**Figure 1** (left)
End diastolic and end systolic short-axis images acquired with 2D SSFP (A, B) and 3D SSFP with SENSE (C, D) sequences.

**Table 1**
Mean values and Bias of Cardiac Function Measurements for the 2D SSFP and 3D SSFP with SENSE methods

| | LV EDV (mL) | LV ESV (mL) | LV EF(%) | LV Mass (g) |
|---|---|---|---|---|
| 2D SSFP | 159.7± 56.4 | 82.3 ± 58.5 | 53.8 ± 15.2 | 87.7 ± 50.2 |
| 3D SSFP w/ SENSE | 156.4 ± 55.9 | 80.0 ± 50.6 | 52.9 ± 13.7 | 85.4 ± 44.4 |
| *P*-value | 0.385 | 0.314 | 0.134 | 0.336 |
| Mean Bias ± 2SD | -3.3 ± 35.8 | -2.3 ± 21.4 | -0.9 ± 5.6 | -2.3 ± 22.2 |

**Table 2**
SNR and CNR for the 2D SSFP and 3D SSFP with SENSE Methods

| | SNR | CNR |
|---|---|---|
| 2D SSFP | 49.6 ± 18.1 | 39.7 ± 15.7 |
| 3D SSFP w/ SENSE | 31.7 ± 9.5 | 23.2 ± 7.4 |
| *P*-value | < 0.001 | < 0.001 |

**Conclusion**

3D SSFP imaging with SENSE can reduce acquisition time to a single breath-hold and provide LV function assessment comparable to that obtained with conventional 2D SSFP imaging. The 3D SSFP technique entailed a noticeable reduction in blood SNR and blood-to-myocardial CNR because of increased blood signal saturation associated with volumetric excitation. Despite this reduction, the 3D SSFP technique with SENSE provided quantitative parameters describing LV function that were similar to the 2D SSFP technique.

**References**

1. J Barkhausen et al: Radiology 219:264-269 (2001); 2. KP Pruessmann et al: MRM 42:952-962 (1999); 3. JM Bland et al: Lancet 1:307-310 (1986)