# Multi-view 3D Fusion Echocardiography Using a Novel Transducer and Respiratory Tracking Technique: First Results in Humans

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## Background

- Despite the many advances to 3D echocardiography (3DE), limitations exist such as i) relatively poor field-of-view (FOV) compared to 2D echocardiography (2DE) and ii) relatively poor endocardial border definition (EBD) compared to 2DE
- Poor EBD is largely explained by weakly reflected signals owing to non-perpendicular angles of insonation relative to important surfaces like the LV EBD
- Multi-view 3D Fusion Echocardiography combines 3DE datasets from different acoustic windows that contain partially redundant but complementary information
- In preclinical studies, M3DFE results in improved contrast, contrast-to-noise ratio (CNR), signal-to-noise ratio (SNR) and EBD

However, two important challenges face M3DFE:

1. A clinically feasible method of spatially aligning datasets does not exist
2. There is no consensus on the best method to fuse datasets

**Purpose of study**: Address these challenges through:

1. Developing a quantitative respiratory tracking technique which aids in spatial alignment of datasets
2. Testing a promising fusion method called wavelet decomposition

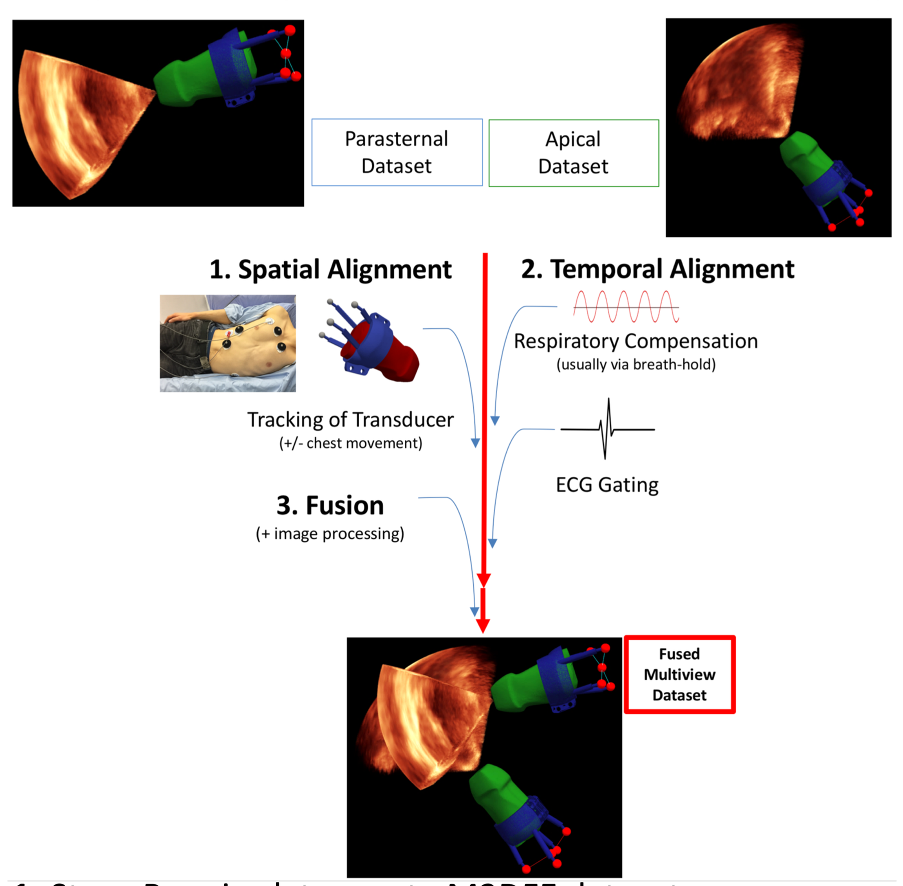


**Figure 1:** Steps Required to create M3DFE dataset


**Figure 2:** Components of our M3DFE setup. Top row – Optical tracking device. Middle Row – Transducer with mount and markers (left). Note these markers are depicted in red in figures 1 and 4;, Chest markers (right). Bottom Row – Relationship between components

## Methods

- **Subjects:** 11 Healthy Volunteers Recruited
- **Materials:** Siemens Acuson SC2000 scanner, 4Z1c transducer
- **Real-time 3D** recordings used in this study
- **Subjective parameters**: Spatial alignment (yes/no), Endocardial Border Definition (three level scale of 0-2)
- **Objective parameters:** Contrast, contrast-to-noise and signal-to-noise ratios, field-of-view

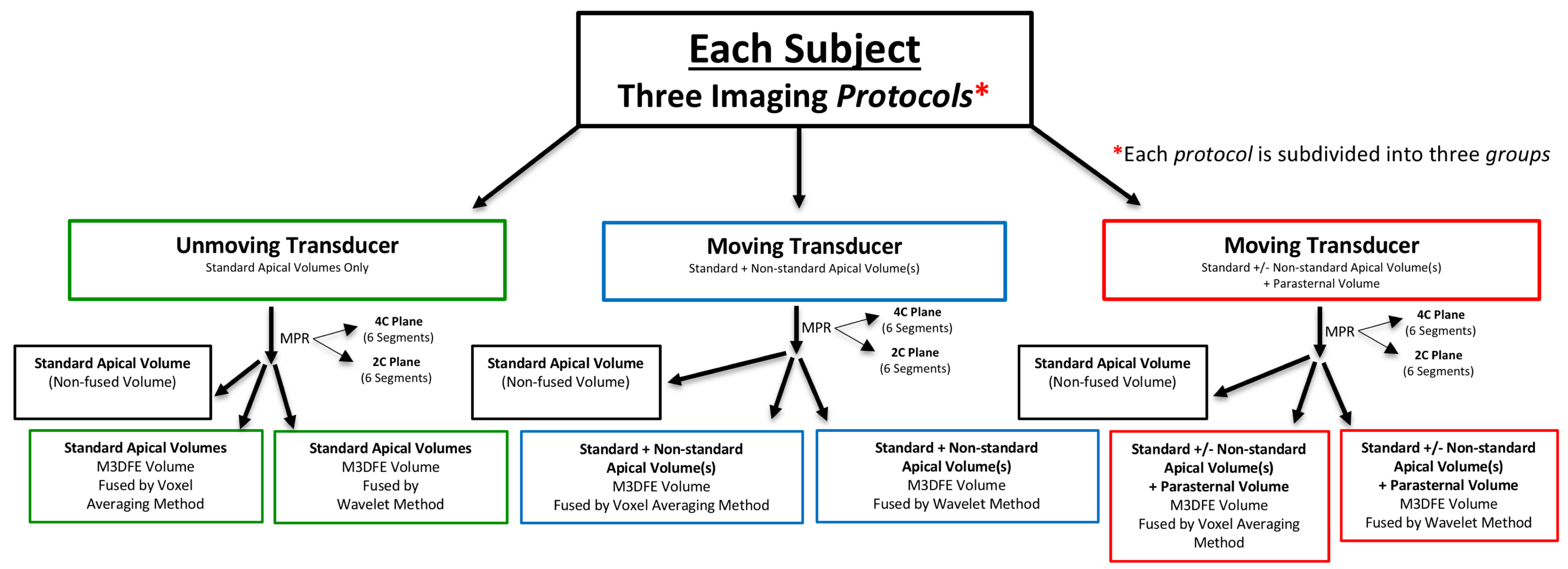


**Figure 3:** Study Design

**Quantitative respiratory tracking screening procedure:**

- Optical tracking of chest markers during 3DE recordings
- For M3DFE datasets: mean chest marker difference must be <1.5mm otherwise the M3DFE dataset is excluded

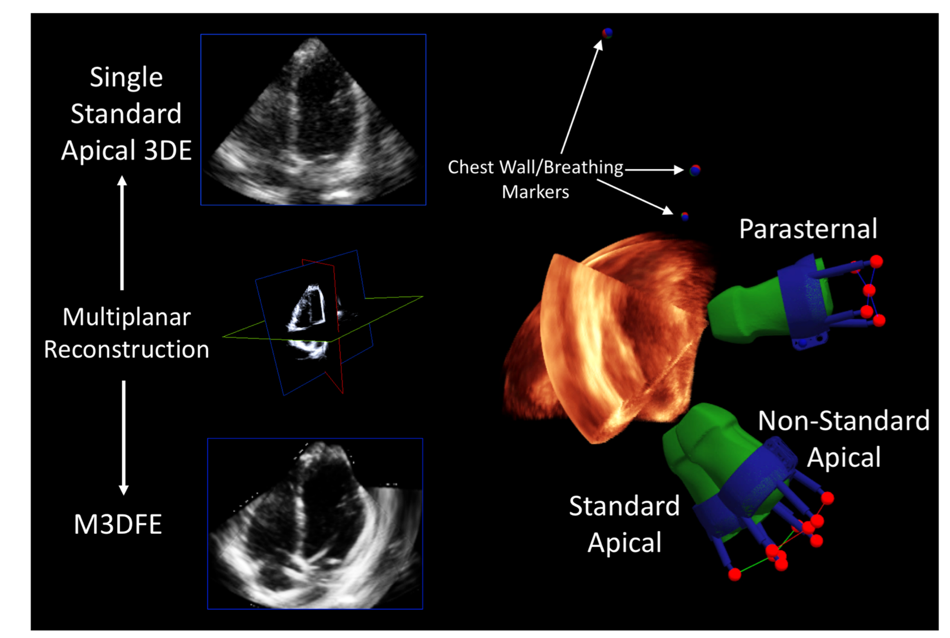


**Figure 4:** Left – Multi-planar reconstruction of M3DFE Dataset. Right – 3D display of Transducers and Chest Markers

## Results

| | Contrast<br>%Diff. in Means | CNR<br>%Diff. in Means | SNR<br>%Diff. in Means | EBD<br>%Diff. in Means |
|---|---|---|---|---|
| Unmoving Transducer:<br>**M3DFE (AVG) – SSA** | -0.9%<br>p = 0.55 | +57%<br>p < 0.0001 | +65%<br>p = 0.00001 | +24%<br>p = 0.0004 |
| Unmoving Transducer:<br>**M3DFE (WAV) – SSA** | +4.1%<br>p = 0.06 | +44%<br>p < 0.00001 | +50%<br>p < 0. 000001 | +30%<br>p < 0.00001 |
| Unmoving Transducer:<br>**M3DFE (WAV) – M3DFE (AVG)** | +4.9%<br>p = 0.02 | +12%<br>p = 0.25 | +18%<br>p = 0.14 | +14%<br>p = 0.03 |
| Moving Transducer: NSA<br>**M3DFE (AVG) – SSA** | -9.4%<br>p = 0.43 | +65%<br>p = 0.01 | +75%<br>p = 0.005 | 13%<br>p = 0.054 |
| Moving Transducer: NSA<br>**M3DFE (WAV) – SSA** | +0.9%<br>p = 0.49 | +32%<br>p = 0.03 | +42%<br>p = 0.006 | 25%<br>p = 0.0002 |
| Moving Transducer: NSA<br>**M3DFE (WAV) – M3DFE (AVG)** | +8.6%<br>p = 0.10 | -12%<br>p = 0.43 | -1.4%<br>p = 0.50 | +16%<br>p = 0.02 |
| Moving Transducer: AP<br>**M3DFE (AVG) – SSA** | -24%<br>p = 0.99 | +17%<br>p = 0.27 | +28%<br>p = 0.12 | +4%<br>p = 0.39 |
| Moving Transducer: AP<br>**M3DFE (WAV) – SSA** | +0.6%<br>p = 0.50 | +41%<br>p = 0.009 | +55%<br>p < 0.001 | +35%<br>p = 0.00001 |
| Moving Transducer: AP<br>**M3DFE (WAV) – M3DFE (AVG)** | +24%<br>p = 0.0001 | +31%<br>p = 0.07 | +42%<br>p = 0.03 | +32%<br>p < 0.0001 |

**Table 1:** Results of one-tailed ANOVA test with Tukey Honest Significant Difference post-hoc correction at end-systole. Statistically significant results which reject the null hypothesis are highlighted in green. M3DFE = Multi-view 3D Fusion Echocardiography, SSA = Single Standard Apical 3DE, AVG = fusion by voxel averaging, WAV = fusion by wavelet decomposition, NSA = non-standard apical protocol, AP = apical-parasternal protocol, CNR = contrast-to-noise ratio, SNR = signal-to-noise ratio, EBD = endocardial border definition.

| | Contrast<br>%Diff. in Means | CNR<br>%Diff. in Means | SNR<br>%Diff. in Means | EBD<br>%Diff. in Means |
|---|---|---|---|---|
| Unmoving Transducer:<br>**M3DFE (AVG) – SSA** | -4.9%<br>p = 0.98 | +42%<br>p = 0.008 | +52%<br>p < 0.001 | +27%<br>p < 0.0001 |
| Unmoving Transducer:<br>**M3DFE (WAV) – SSA** | -0.8%<br>p = 0.45 | +31%<br>p = 0.005 | +41%<br>p = 0.0001 | +30%<br>p < 0. 000001 |
| Unmoving Transducer:<br>**M3DFE (WAV) – M3DFE (AVG)** | +4.1%<br>p = 0.046 | +2.5%<br>p = 0.49 | +9.8%<br>p = 0.36 | +10%<br>p = 0.07 |
| Moving Transducer: NSA<br>**M3DFE (AVG) – SSA** | -8.2%<br>p = 0.99 | +40%<br>p = 0.00072 | +45%<br>p < 0.001 | +18%<br>p = 0.002 |
| Moving Transducer: NSA<br>**M3DFE (WAV) – SSA** | -1.4%<br>p = 0.45 | +32%<br>p = 0.0002 | +41%<br>p < 0.0001 | +22%<br>p < 0.0001 |
| Moving Transducer: NSA<br>**M3DFE (WAV) – M3DFE (AVG)** | +6.9%<br>p = 0.03 | +5.0%<br>p = 0.43 | +14%<br>p = 0.20 | +8.1%<br>p = 0.12 |
| Moving Transducer: AP<br>**M3DFE (AVG) – SSA** | -18%<br>p = 0.99 | +34%<br>p = 0.01 | +42%<br>p < 0.001 | +4.8%<br>p = 0.35 |
| Moving Transducer: AP<br>**M3DFE (WAV) – SSA** | -3.1%<br>p = 0.38 | +32%<br>p = 0.003 | +47%<br>p < 0.00001 | +29%<br>p = 0.0001 |
| Moving Transducer: AP<br>**M3DFE (WAV) – M3DFE (AVG)** | +16%<br>p < 0.001 | +8.4%<br>p = 0.38 | +24%<br>p = 0.04 | +26%<br>p < 0.001 |

**Table 2:** Results of one-tailed ANOVA test with Tukey Honest Significant Difference post-hoc correction at end-diastole. Statistically significant results which reject the null hypothesis results are highlighted in green. M3DFE = Multi-view 3D Fusion Echocardiography, SSA = Single Standard Apical 3DE, AVG = fusion by voxel averaging, WAV = fusion by wavelet decomposition, NSA = non-standard apical protocol, AP-PS = apical-parasternal protocol, CNR = contrast-to-noise ratio, SNR = signal-to-noise ratio, EBD = endocardial border definition.

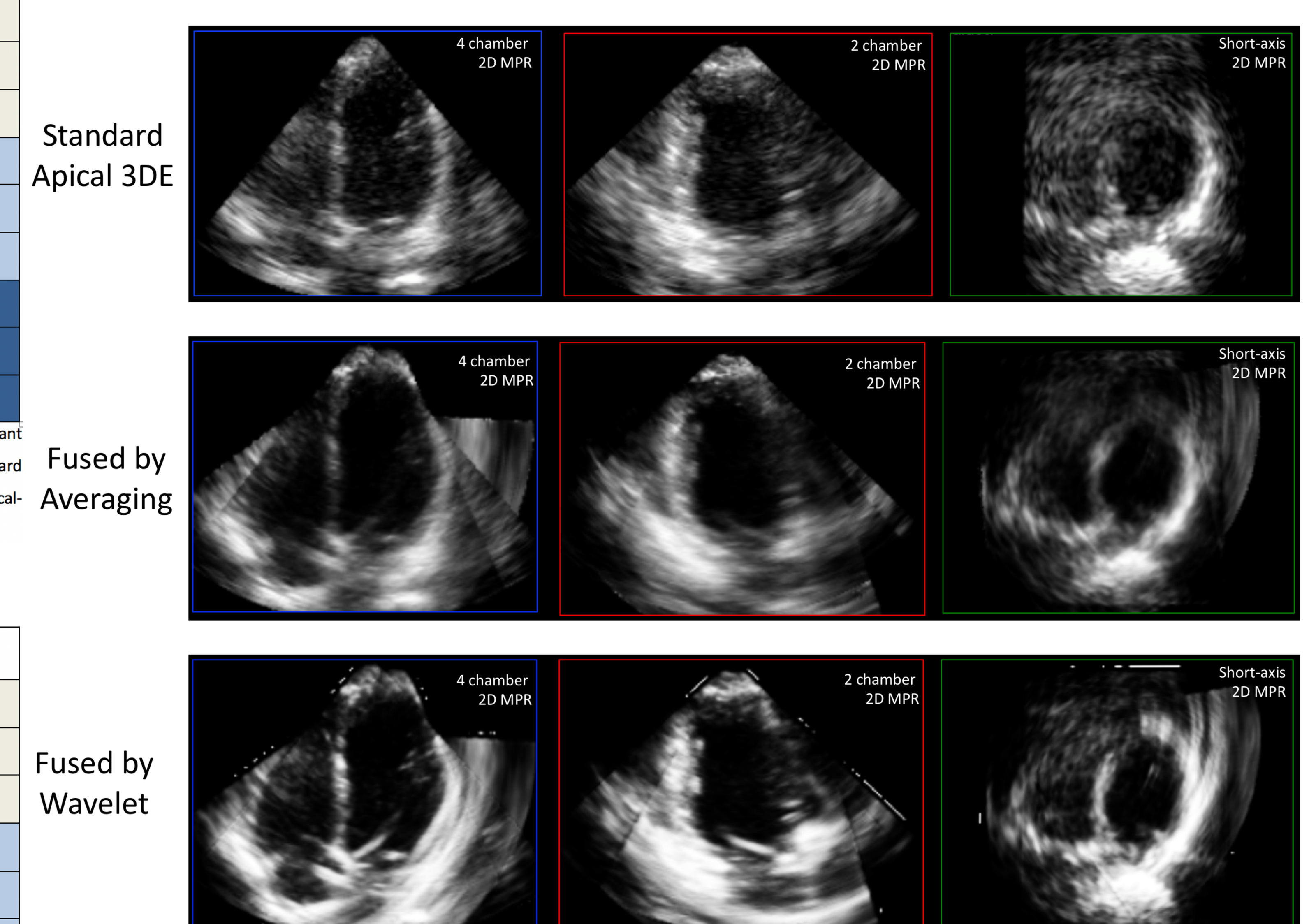


**Figure 5:** Example case comparing standard apical 3DE with fusion by voxel averaging and wavelet decomposition

## Results continued

- Field-of-view enhanced in all protocols, most prominently in apical-parasternal protocol (mean increase = 47%)
- >97% of M3DFE datasets passing the quantitative screening procedure were subjectively aligned and suitable for diagnostic purpose as judged by two echocardiographers (TL +HB)
- Results were generally supportive of the superiority of the wavelet decomposition fusion method

## Discussion

**Two major challenges facing M3DFE addressed:**

1. Creation of a clinically feasible and effective spatial alignment protocol using quantitative optical tracking of chest markers
2. Wavelet decomposition is probably superior to voxel averaging and should be considered for use in future clinical studies

## Limitations

- Small sample size BUT 1686 segments analyzed
- Healthy volunteers with good acoustic access/apical windows BUT benefits of M3DFE may actually be exaggerated in those with poor apical windows, structural heart disease (including large LV's)
- Whether results will translate into improvements in clinically useful measurements such as LV quantification remains uncertain BUT we expect enhanced reproducibility and accuracy compared to CMR, contrast 2DE → further validation of this hypothesis is required

## Conclusions

- **Our novel quantitative screening technique based on optical tracking of chest markers provides an efficient and clinically feasible method of performing spatial alignment in M3DFE**
- **Fusion by wavelet decomposition is generally superior to fusion by voxel averaging**