

**WORKSHOP PRESENTATION**

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# A T1 and ECV phantom for global T1 mapping quality assurance: The T<sub>1</sub> mapping and ECV standardisation in CMR (T1MES) program

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## Background

Myocardial T1 and extracellular volume (ECV) estimates have applications in a range of myocardial diseases. Factors responsible for systematic inaccuracies in T1 mapping are beginning to be known<sup>1-4</sup> but little is known about its delivery at 'health-care system' scale and there is no global quality assurance (QA) system. Agarose phantoms are common in MRI and nickel ions preferred for lower temperature sensitivity<sup>5</sup>. This program aims to

1 Create a partnership to design 1.5/3T phantoms for any manufacturer/sequence reflecting myocardial/blood T1 pre/post-contrast

2 Test and mass produce phantoms to regulatory standards

3 Distribute globally

4 Analyse serial scans to understand T1 mapping at scale

5 Publish recipes

6 Explore delivery of a 'T1/ECV Standard' via local calibration

We report results of steps 1-3.

## Methods

A design collaboration was created (clinicians/physicists/regulatory bodies/SME). After identifying critical design factors (Fig 1A) and discarding models with excessive  $B_0/B_1$  distortion, the layout in Fig 1B was adopted. 9 tubes with differently doped agarose were embedded in a gel matrix and high-density polyethylene (HDPE)

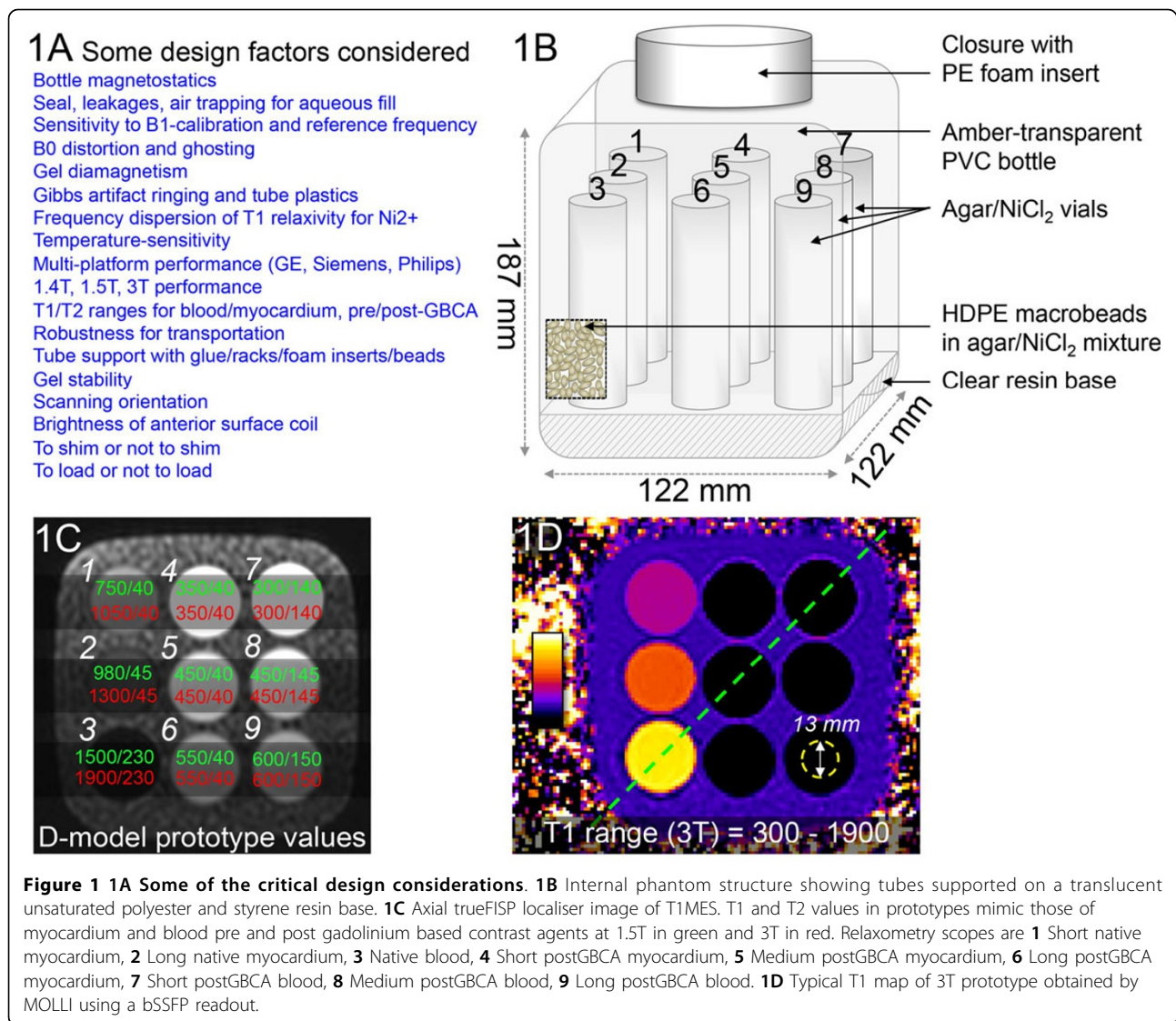
macrobeads added for  $B_1$  homogeneity. Tube diameter >20 mm was needed for regions of interest to exclude Gibbs artifacts.  $B_0/B_1$  homogeneity was mapped to evaluate distortion. We hypothesised that dilution of dielectric permittivity by HDPE beads would reduce  $B_1$  inhomogeneity. This design was compared to ones using sodium chloride ( $NaCl$ ) for increased conductivity, sucrose for reduced permittivity or poly methyl-methacrylate (PMMA) microbeads. Tubes with T1 = 250-1900 ms and T2 = 45-250 ms were reproducibly manufactured and separate ranges adopted for 1.5/3T (Fig 1C). 10 Prototypes were fabricated (5 each for 1.5/3T) for gold standard measurements: T1 by inversion-recovery spin echo (IRSE, 8 inversion times, 25>3200 ms); T2 by SE(8 echo times, 10>640 ms). Prototypes were then distributed to 9 experienced/regulatory centres for further testing.

## Results

T1 maps were free from off-resonance artifacts (Fig 1D). The bottle geometry, coaxial with  $z$  and imaged transversely, showed  $< \pm 0.3$  ppm  $B_0$  uniformity (Fig 2A). HDPE beads flattened the  $B_1$  field at 3T (Fig 2B) especially compared to  $NaCl$ , sucrose and PMMA beads. T1 increased with temperature (0.19-1.54% change/°C) while T2 decreased(-0.93-1.45% change/°C). Comparison of gold standard values (Fig 2C,D) between prototypes confirmed reproducible manufacturing(coefficients of variation T1 0.97/1.35%, T2 1.25/2.73% for 1.5T/3T). Recipes were submitted for regulatory approval and manufacture will be complete by Sep'15.

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## Conclusions

We created a collaboration to develop CE/FDA-approved phantoms for QA of T1 and ECV protocols. 70 revised phantoms with a multi-vendor user manual are now being distributed to centres worldwide for a 1-year academic exploration of T1 mapping sequences, platform performance and stability.

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