National Institute for Health Research Cardiovascular Biomedical Research Unit at Barts

Imaging heart

UK Biobank Annual Meeting
13th June 2016

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Disclosures

- Consultancy, Circle Cardiovascular Imaging Inc., Calgary, Canada
- Consultancy, GSK

UK Biobank imaging

Journal of Cardiovascular Magnetic Resonance

REVIEW **Open Access**

Imaging in population science: cardiovascular magnetic resonance in 100,000 participants of UK Biobank - rationale, challenges and approaches

Steffen E Petersen[1*], Paul M Matthews[2,3], Fabian Bamberg[4], David A Bluemke[5], Jane M Francis[6], Matthias G Friedrich[7], Paul Leeson[6], Eike Nagel[8], Sven Plein[9], Frank E Rademakers[10], Alistair A Young[11], Steve Garratt[12], Tim Peakman[12], Jonathan Sellors[12], Rory Collins[12] and Stefan Neubauer[6]

Population based studies (large scale) using CMR

Table 1 Previously developed prospective population studies with CMR imaging (including at least 1000 participants)

	Age of cohort (y)	MRI brain	CMR	MRI body
Jackson Heart Study	35-84		2,000	
SHIP	20-79		4,000	4,000
MESA	45-84		5,000	
Framingham Heart Study	38-88	2,500	1,800	
Dallas Heart Study	18-65	3,000	3,000	3,000
AGES Reykjavik	>70	5,000	1,000	

CMR: Cardiovascular Magnetic Resonance.

Petersen SE et al. JCMR 2013
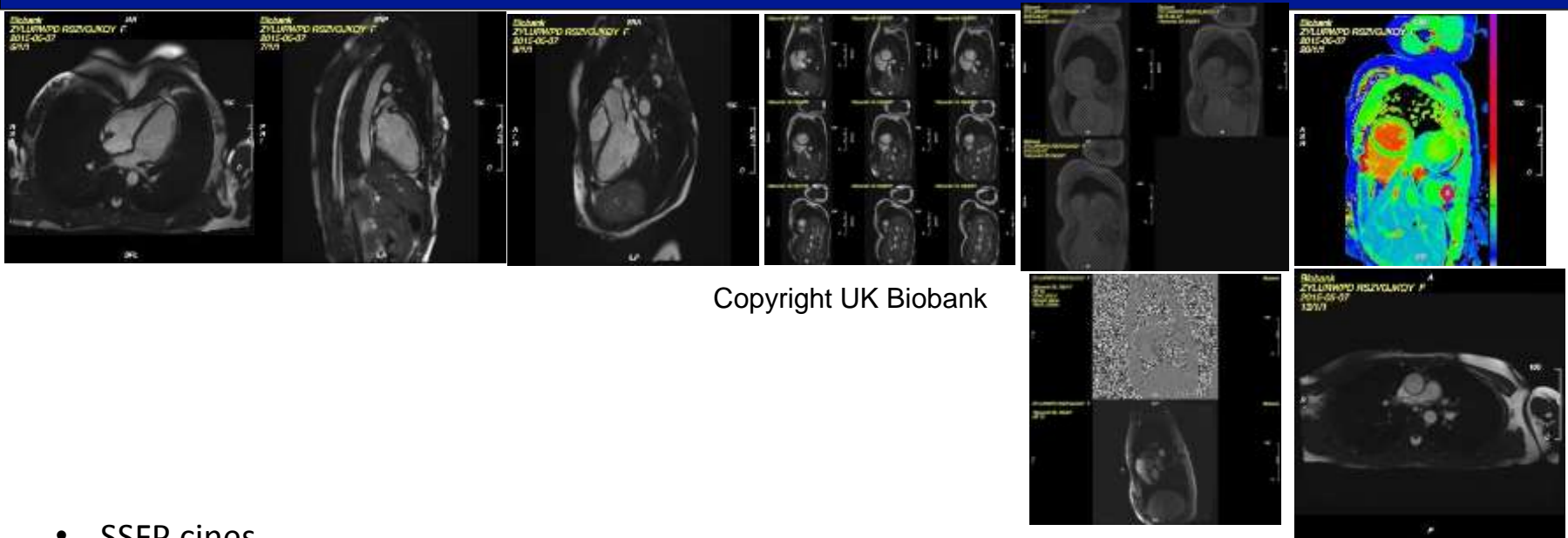
UK Biobank

- Part of **Comprehensive imaging enhancement visit**: CMR, abdominal MRI, brain MRI, 3D Carotid US, DEXA + repeat baseline and 12 lead ECG (~**3hrs 30min)**
- Target 100,000 participants of 500,000 UK Biobank cohort
- 20 minutes for CMR
- Safety: no contrast, no stressor

- n=9411 (10/06/2016)

20 min UK Biobank CMR protocol

Copyright UK Biobank

- SSFP cines

    - 3 long axes   →   Atrial volumes and function

    - LV/RV short axis stack   →   LV/RV volumes and function

- Tagging (basal, mid and apical short axis, grid)   →   Systolic and diastolic strain

- Native T1 mapping   →   LV tissue characterisation (fibrosis, scar)

- Aortic valve flow   →   Aortic valve function

- Aortic distensibility (level of pulmonary artery/trunk)   →   Vascular function

UK Biobank imaging

STUDY PROTOCOL

Open Access

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UK Biobank's cardiovascular magnetic resonance protocol

Steffen E. Petersen[1*], Paul M. Matthews[2], Jane M. Francis[3], Matthew D. Robson[3], Filip Zemrak[1], Redha Boubertakh[1], Alistair A. Young[4], Sarah Hudson[5], Peter Weale[6], Steve Garratt[5], Rory Collins[5], Stefan Piechnik[3] and Stefan Neubauer[3]
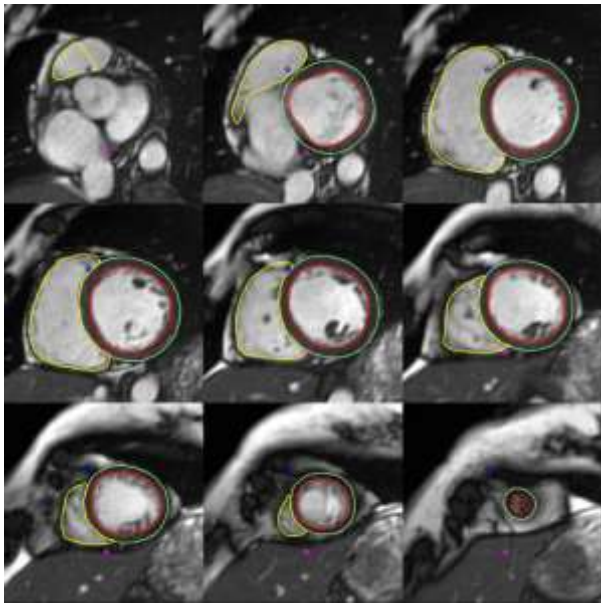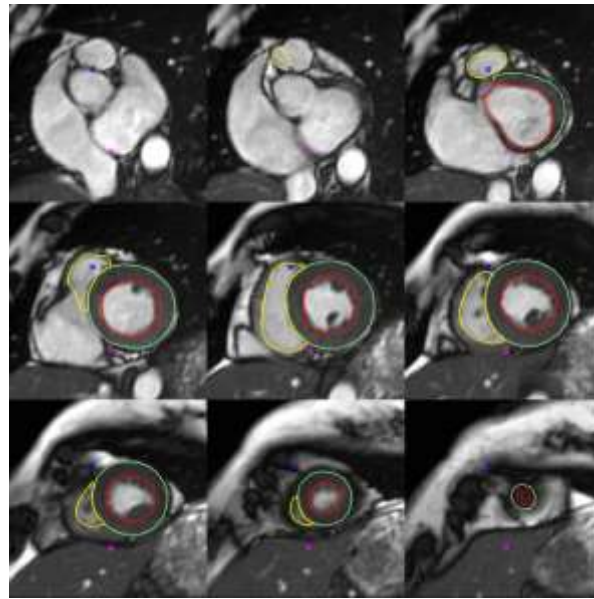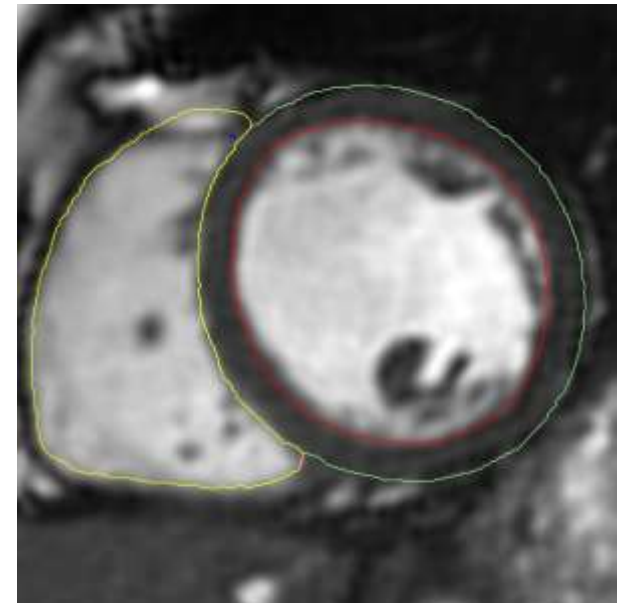
CMR analysis core labs

Oxford

London

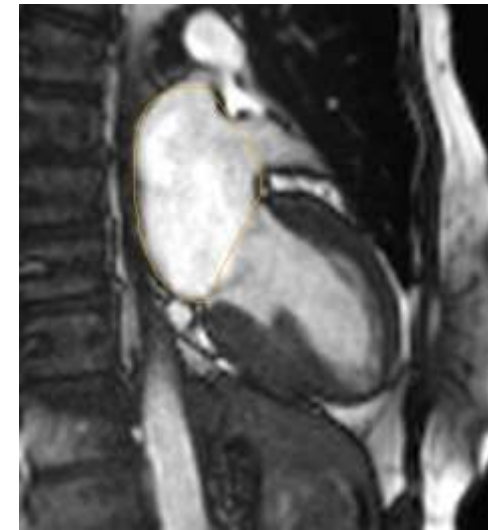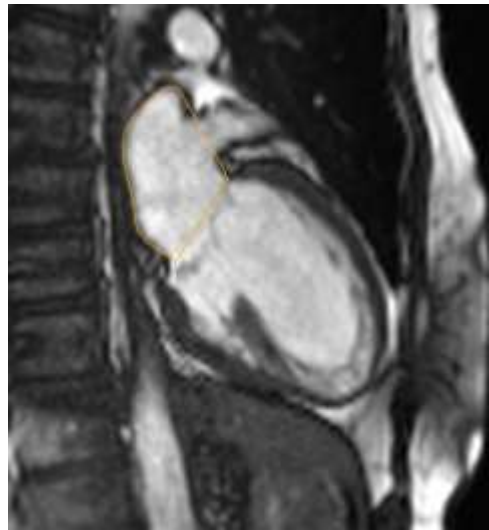# Creation of CMR reference standard LV and RV contours
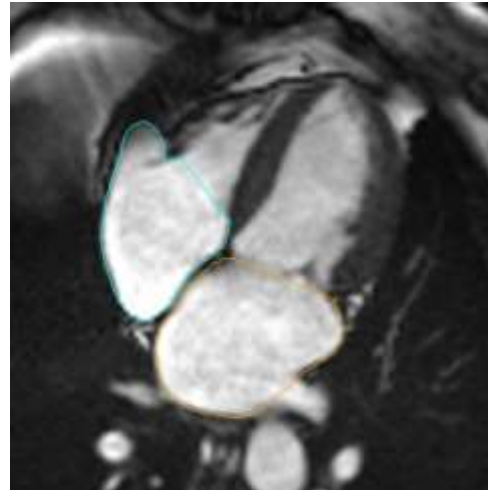

End-Diastole

End-Systole

Creation of CMR reference standard LA and RA contours
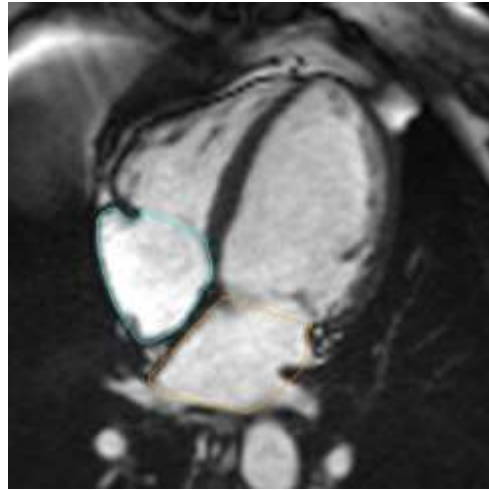
End-Diastole   End-Systole

CMR data analysis
in UK Biobank

- Tested in pilot phase as part of QC

- Analysis of first 5000 CMR scans funded by British Heart Foundation

- Cross-disciplinary consortium established (first meeting 8/14 at Wellcome Trust)

- Cardiac imaging analysis consortium established

- Necessity and opportunity to develop robust automated image analysis algorithms, machine learning etc.
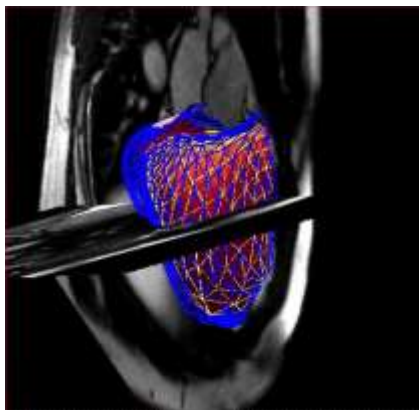
Courtesy of
Alistair Young, Auckland

Normal ranges
left and right ventricle

Ventricular measurements adjusted by BSA in men

Age Groups	40-50	51-60	61-70	71-80
LVEDV (mean)	87	87	83	79
LVEDV (95% CI)	83-91	84-90	81-86	73-85
LVESV (mean)	36	36	35	32
LVESV (95% CI)	33-38	35-38	34-36	28-37
LVSV (mean)	52	50	48	47
LVSV (95% CI)	49-54	49-52	47-50	43-50
LVM (mean)	54	53	53	49
LVM (95% CI)	51-57	52-55	51-55	44-54
LVEF (mean)	59	58	58	60
LVEF (95% CI)	58-61	57-59	57-59	57-62
RVEDV (mean)	98	95	91	87
RVEDV (95% CI)	93-102	92-98	88-94	79-95
RVESV (mean)	46	44	42	39
RVESV (95% CI)	43-49	42-46	40-44	34-45
RVSV (mean)	52	51	49	48
RVSV (95% CI)	50-55	49-53	47-51	44-51
RVEF (mean)	54	54	54	55
RVEF (95% CI)	52-55	53-55	53-55	52-59

Ventricular measurements adjusted by BSA in women

Age Groups	40-50	51-60	61-70	71-80
LVEDV (mean)	79	75	72	72
LVEDV (95% CI)	76-81	73-76	70-73	67-77
LVESV (mean)	31	30	28	28
LVESV (95% CI)	30-33	29-31	27-29	25-30
LVSV (mean)	48	45	44	44
LVSV (95% CI)	46-49	44-46	43-45	41-47
LVM (mean)	41	42	41	41
LVM (95% CI)	40-43	41-43	40-42	38-43
LVEF (mean)	61	61	61	62
LVEF (95% CI)	59-62	60-61	60-62	60-63
RVEDV (mean)	81	78	75	74
RVEDV (95% CI)	78-85	77-80	73-77	69-79
RVESV (mean)	35	34	32	30
RVESV (95% CI)	33-37	32-35	31-33	27-33
RVSV (mean)	46	45	44	44
RVSV (95% CI)	44-48	44-46	42-45	41-48
RVEF (mean)	57	58	58	60
RVEF (95% CI)	56-59	57-58	57-59	57-62

The unit of all volumetric measurements is ml/m^2 EF in percentage

Unpublished data

Normal ranges
left and right atrium

Atrial measurements adjusted by BSA in men

Age Groups	40-50	51-60	61-70	71-80
Maximal LA volume (mean)	36	38	35	34
Maximal LA volume (95% CI)	33-39	37-40	34-37	29-39
Minimal LA volume (mean)	14	16	15	15
Minimal LA volume (95% CI)	13-16	15-17	14-15	11-18
LA stroke volume (mean)	22	23	21	19
LA stroke volume (95% CI)	20-23	22-24	20-22	16-22
LA EF (mean)	56	56	55	52
LA EF (95% CI)	52-59	54-58	53-57	45-59
Maximal RA volume (mean)	45	48	48	50
Maximal RA volume (95% CI)	41-49	46-51	46-50	46-55
Minimal RA volume (mean)	26	29	28	30
Minimal RA volume (95% CI)	24-29	27-30	27-30	26-35
RA stroke volume (mean)	18	20	20	20
RA stroke volume (95% CI)	17-20	18-21	18-21	17-23
RA EF (mean)	41	41	41	40
RA EF (95% CI)	38-43	39-42	39-42	35-46

Atrial measurements adjusted by BSA in women

Age Groups	40-50	51-60	61-70	71-80
Maximal LA volume (mean)	40	37	36	40
Maximal LA volume (95% CI)	37-42	36-38	34-37	37-43
Minimal LA volume (mean)	15	14	15	17
Minimal LA volume (95% CI)	14-16	14-15	14-16	15-19
LA stroke volume (mean)	25	22	21	23
LA stroke volume (95% CI)	23-26	22-23	20-22	21-24
LA EF (mean)	56	55	54	52
LA EF (95% CI)	53-58	53-57	53-56	47-57
Maximal RA volume (mean)	41	41	42	42
Maximal RA volume (95% CI)	39-44	40-42	41-43	38-46
Minimal RA volume (mean)	22	22	23	24
Minimal RA volume (95% CI)	20-23	21-23	22-23	21-27
RA stroke volume (mean)	20	19	19	18
RA stroke volume (95% CI)	18-21	18-20	18-20	16-20
RA EF (mean)	48	46	46	43
RA EF (95% CI)	45-50	45-48	45-47	39-46

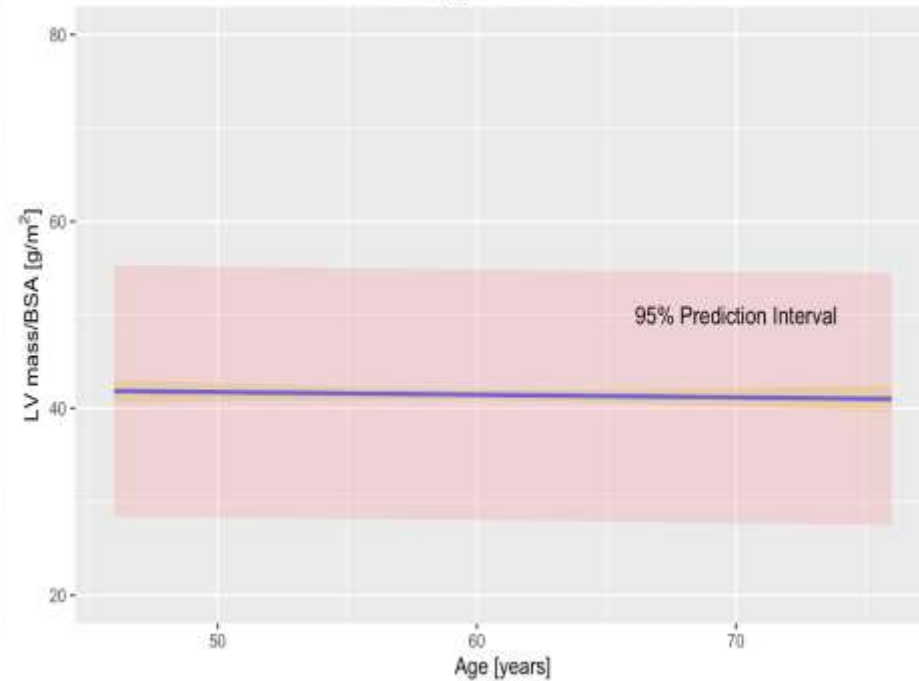The unit of all volumetric measurements is ml/m^2 EF in percentage

Unpublished data

Normal range of indexed LV mass

Reference range of left ventricular mass in men
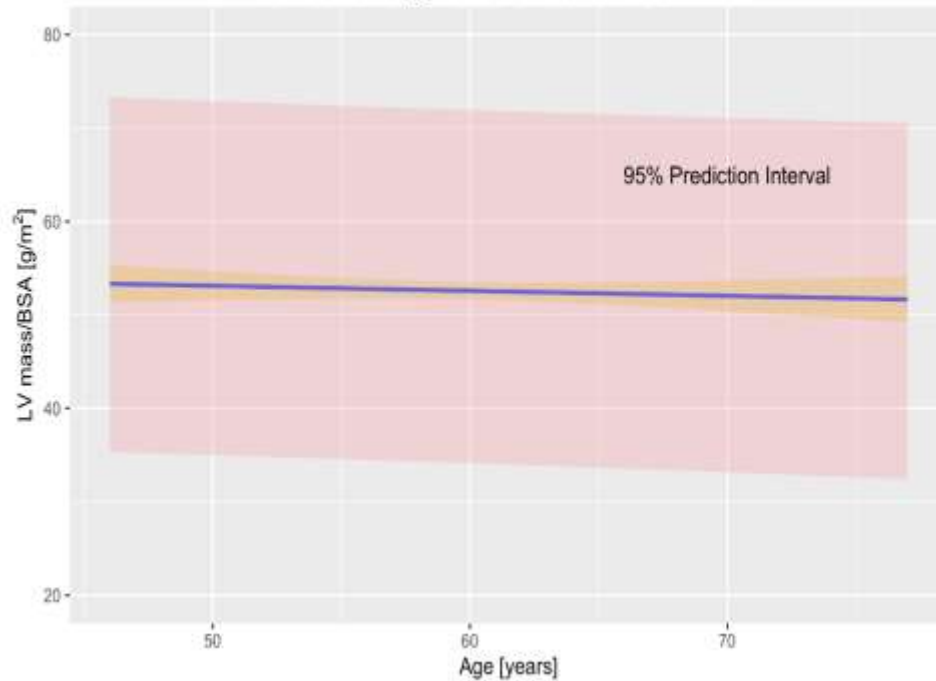
Reference range of LV mass in women

95% Prediction Interval

95% Prediction Interval

LV mass/BSA [g/m²]

Age [years]

Unpublished data

Inter- and Intra-observer variability
[measured by intraclass correlation coefficient]

Ventricular measurement	LVEDV	LVESV	LV mass	RVEDV	RVESV
Inter-observer variability	0.97	0.87	0.83	0.89	0.87
Intra-observer variability	0.99	0.97	0.97	0.99	0.97

Unpublished data

Blood pressure medications modify the effect of systolic blood pressure on indexed LV mass
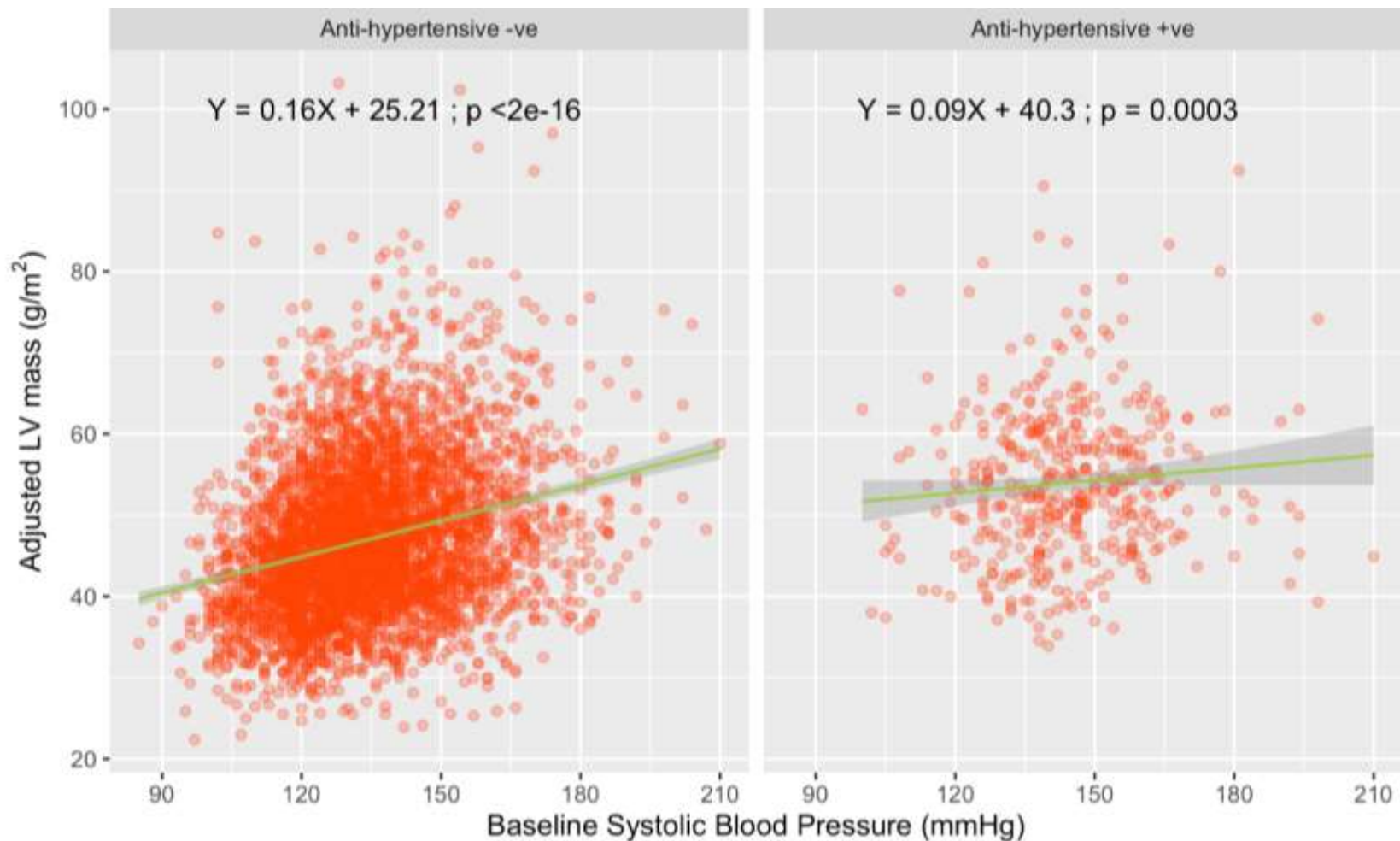
Effects of age and gender on blood pressure - LV mass relationship

Effect of Systolic Blood Pressure on LV mass by age decades 40-50
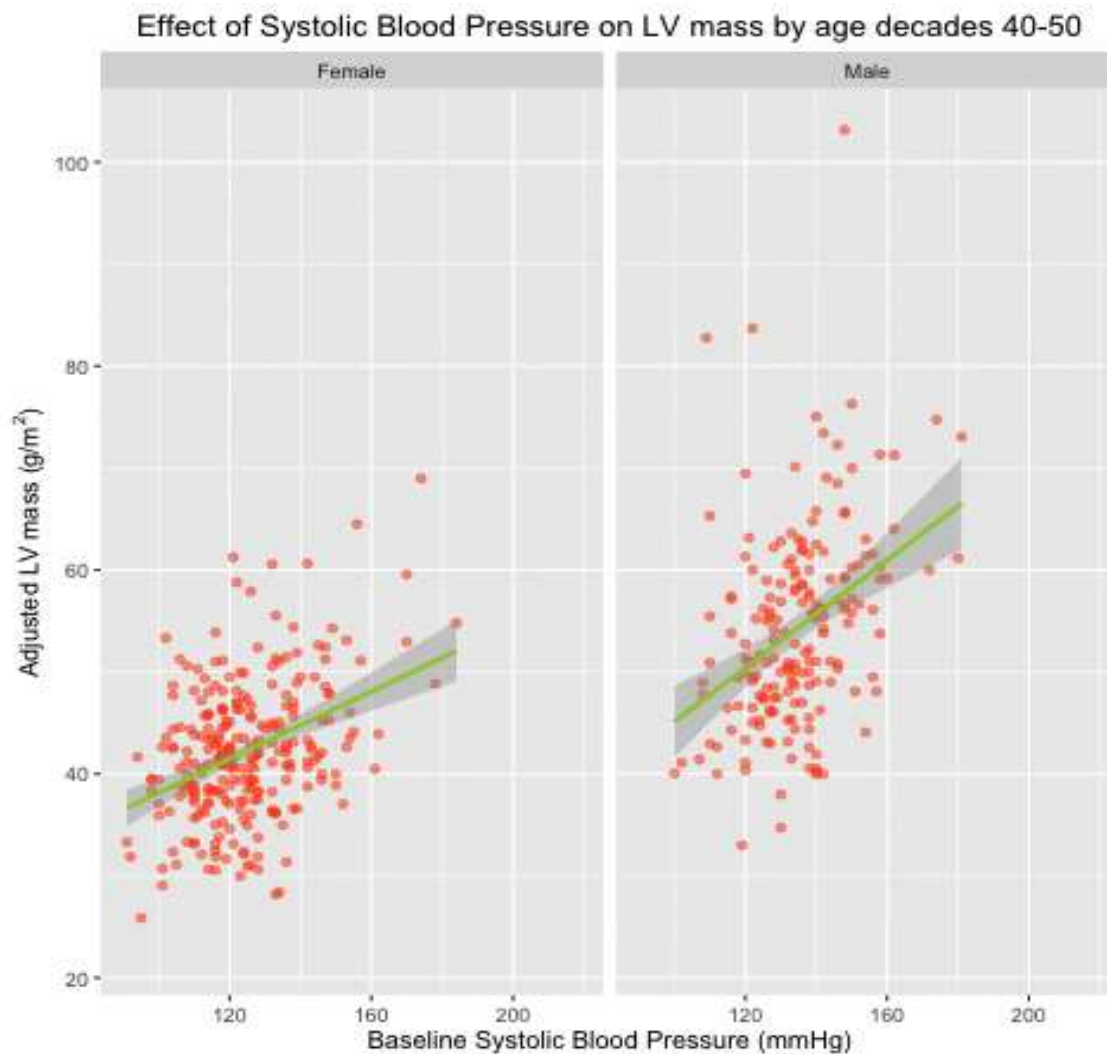
Summary

- Largest prospective study to date with imaging of the heart using MRI

- Analysis of heart images is a challenge – but UK Biobank provides a great opportunity to advance this field

- Collaborations forming amongst national and international academics and industry

- Palpable enthusiasm in heart imaging community

UK Biobank:
Cardiovascular Imaging
Implementation Team (before dedicated staff recruited)

- UK Biobank Principal Investigator & CEO
  - Rory Collins

- UK Biobank Imaging Enhancements Chairman
  - Paul Matthews, Imperial College London

- Cardiovascular Imaging
  - Steffen Petersen, QMUL (CMR Co-lead)
  - Stefan Neubauer, Oxford (CMR Co-lead)
  - Paul Leeson, Oxford (Carotid ultrasound lead)
  - Jane Francis, Oxford (radiographer)
  - Stefan Piechnik, Oxford (T1 mapping, image analysis)
  - Alistair Young, Auckland (image analysis)

- International UK Biobank Cardiac Imaging Advisory Panel
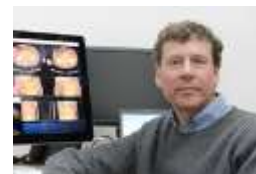
Thank you

- UK Biobank participants
- Funders