University of Nottingham
UK | CHINA | MALAYSIA

SPMIC Sir Peter Mansfield Imaging Centre Nottingham

Intradialytic MRI of the heart and brain

Eleanor Cox

3rd International Symposium on Functional Renal Imaging, Nottingham, 15-17th October 2019

Background

- Cardiovascular disease is the leading cause of mortality in dialysis patients
- Haemodialysis (HD) causes repetitive circulatory stress affecting the heart, but also other organs
- The full extent of organ dysfunction brought about by HD is not fully understood

Background

- MRI has been used in studies assessing organ dysfunction in HD patients:
  - Effects of starting on dialysis
  - Effects of long term dialysis
  - Intradialytic effects
  - Effect of treatment

CAMRID: Cardiac MRI in Dialysis

We performed the first study of intradialytic MRI to directly assess the cardiovascular effects of dialysis

CLINICAL RESEARCH www.jasn.org

Intradialytic Cardiac Magnetic Resonance Imaging to Assess Cardiovascular Responses in a Short-Term Trial of Hemodiafiltration and Hemodialysis

Charlotte Buchanan,* Azharuddin Mohammed,† Eleanor Cox,* Katrin Köhler,‡ Bernard Canaud,‡ Maarten W. Taal,† Nicholas M. Selby,† Susan Francis,* and Chris W. McIntyre§‖

J Am Soc Nephrol 28: 1269–1277, 2017. doi: 10.1681/ASN.2016060686

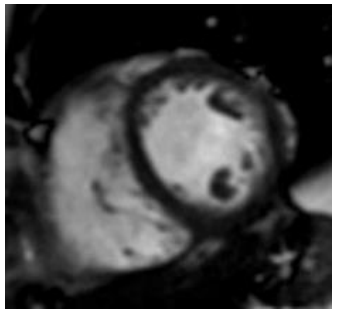
J Am Soc Nephrol. 2017 Apr; 28(4): 1013–1015.
Published online 2017 Feb 9. doi: 10.1681/ASN.2016111257
PMCID: PMC5373466
PMID: 28183725

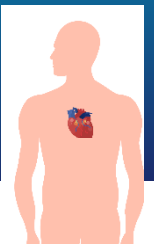
Changes in Cardiac Output and Perfusion during Hemodialysis and Hemodiafiltration Treatments Determined by Cardiac Magnetic Resonance Imaging

Peter J. Blankestijn* and Andrew Davenport†

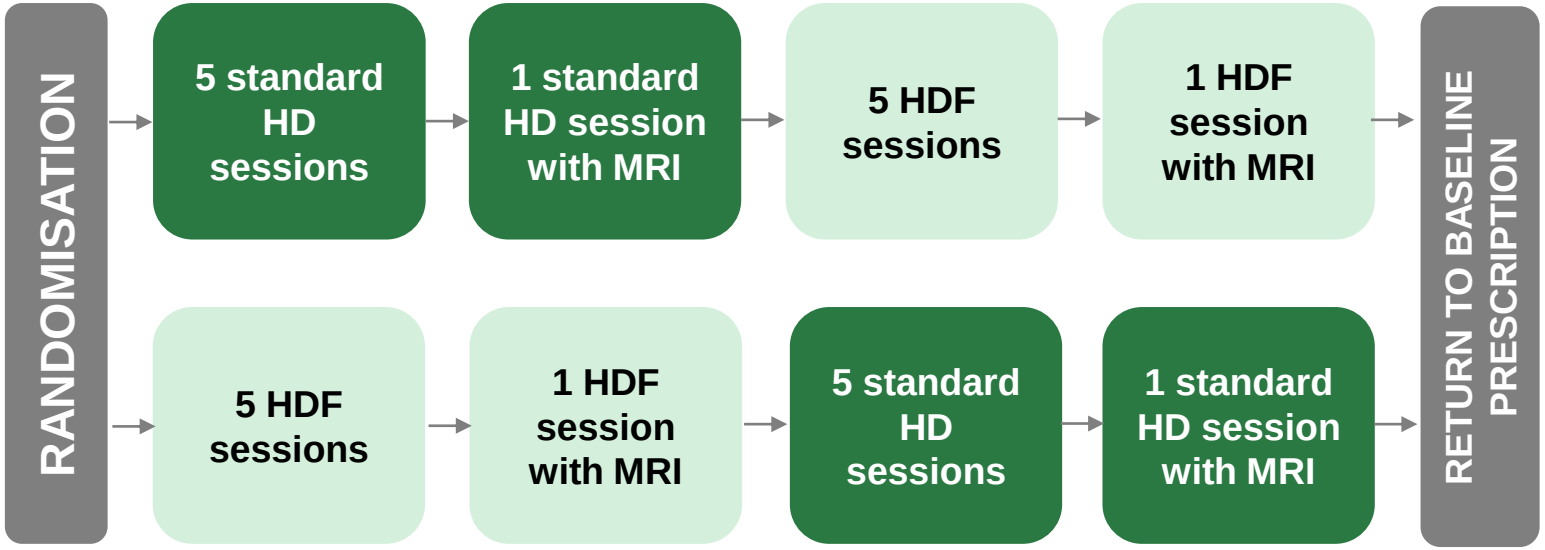
Buchanan *et al.* should be congratulated on performing magnetic resonance imaging (MRI) studies during a dialysis treatment, and transforming hospital domestic water to ultrapure water for dialysis with water treatment, including reverse osmosis.[1] They compared various aspects of cardiac function

- Do changes occur in cardiac structure, function and perfusion during dialysis?
- Is haemodiafiltration (HDF) relatively cardio-protective compared to haemodialysis (HD)?

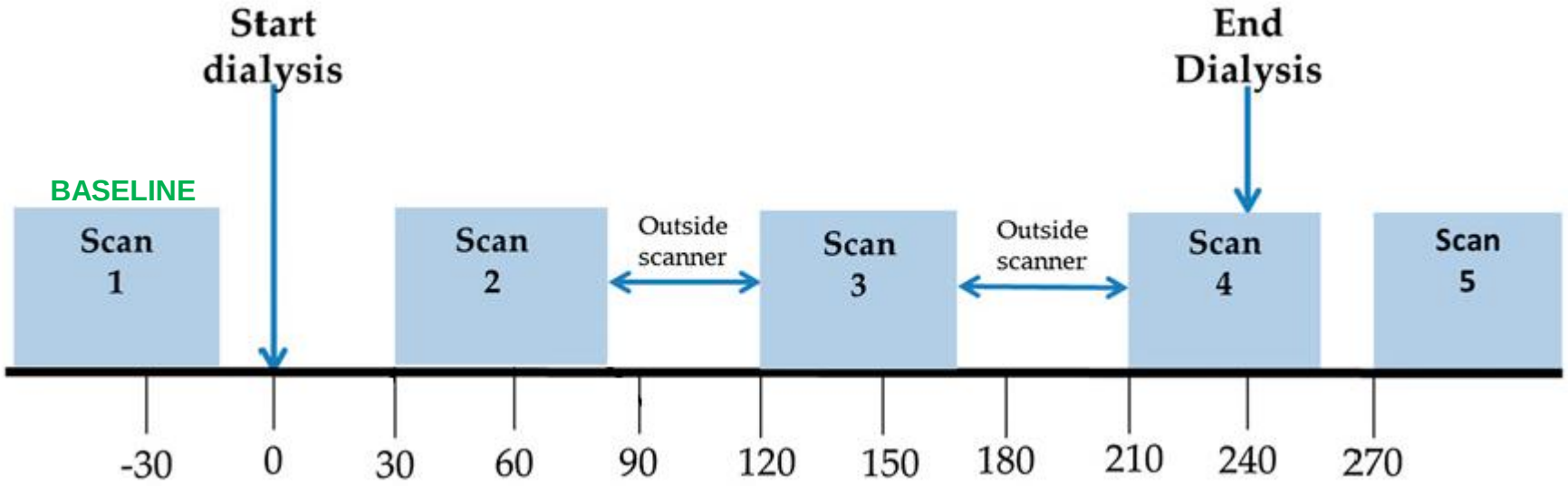




- 12 patients on HD
- 10 male
- age 53 ± 12 years
- dialysis vintage 56 ± 6 months



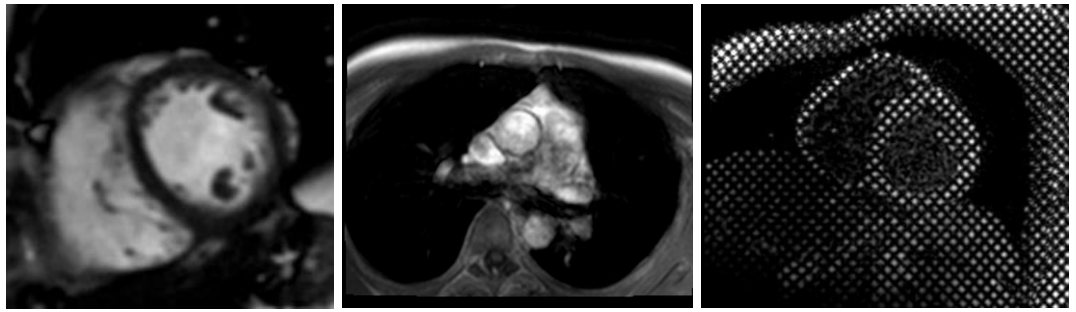
- 3T Philips Achieva scanner
- Dialysis performed inside MR scanner
- Standard dialysis machine positioned ~ 3m from scanner using 4.5m blood line extensions (66ml increase in extracorporeal circuit volume)
- Blood pressure and heart rate measured throughout



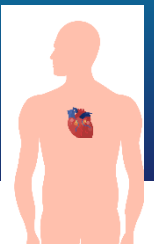
Time (minutes)

MR measures:

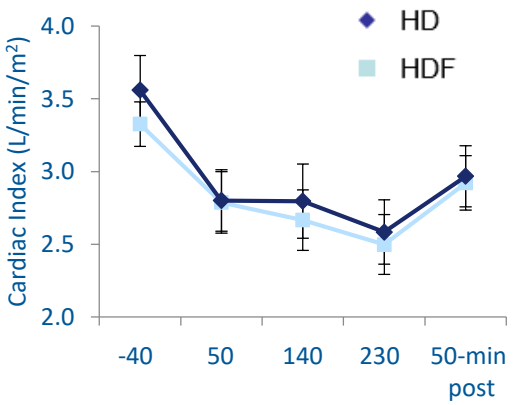
- Aortic flow
  - Stroke volume
  - Cardiac output
- IVC flux
- Heart rate
- Myocardial tagging
  - Tissue strain



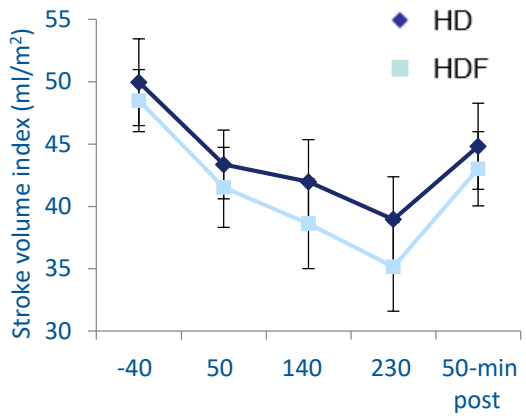
CAMRID Results



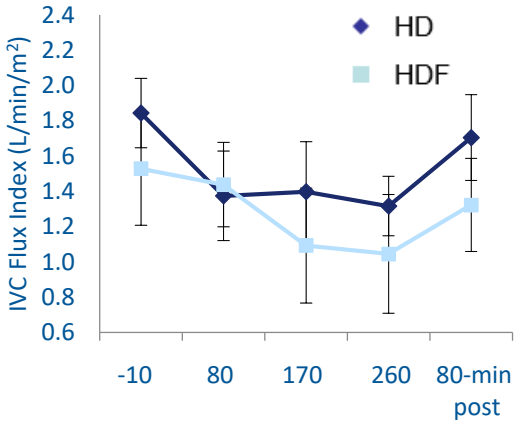
Cardiac index
= volume of blood pumped by the heart per minute (corrected for body surface area)



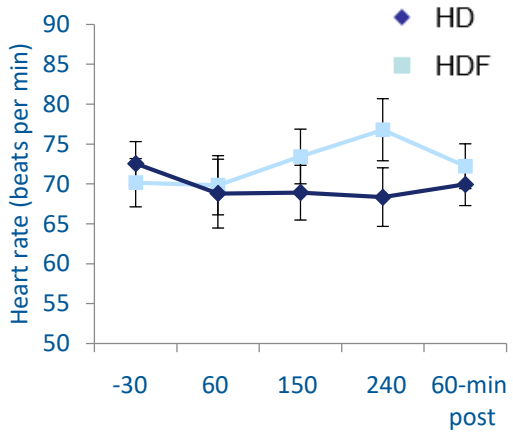
Stroke volume index
= volume of blood pumped from left ventricle per heart beat (corrected for body surface area)



Indexed IVC flux
(corrected for body surface area)



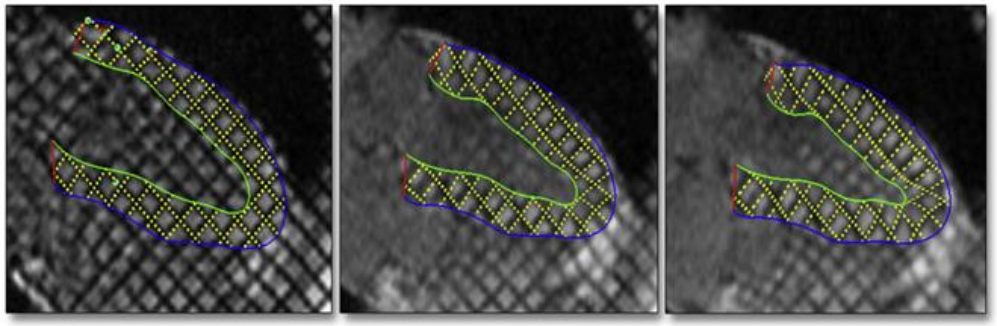
Heart rate



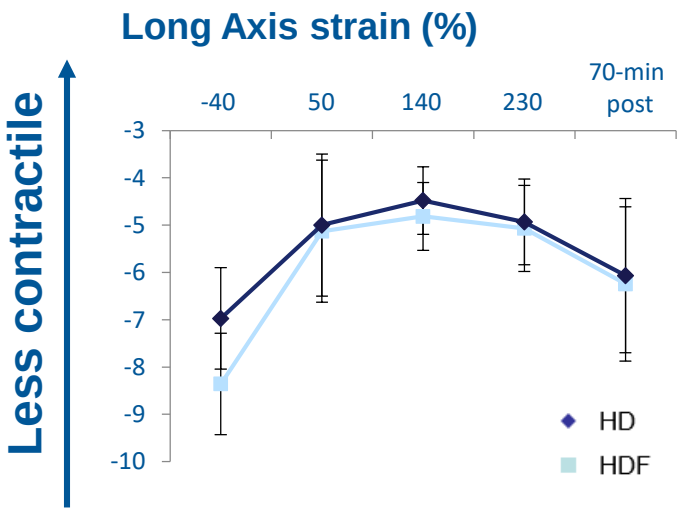
- **No difference between HD and HDF at baseline**
- **During dialysis cardiac index, stroke volume index and IVC flux all decreased, but no difference between HD and HDF**
- **Heart rate did not change significantly with either treatment**
  →However, at 240 min, it was significantly different between HD and HDF

CAMRID Results

Longitudinal-axis assessment of the left ventricle

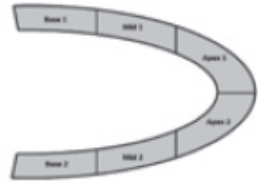


- **Strain** describes the contractility of the left ventricle



- Reduction (i.e. less negative, less strain) in longitudinal strain on both HD and HDF from 30 min onwards

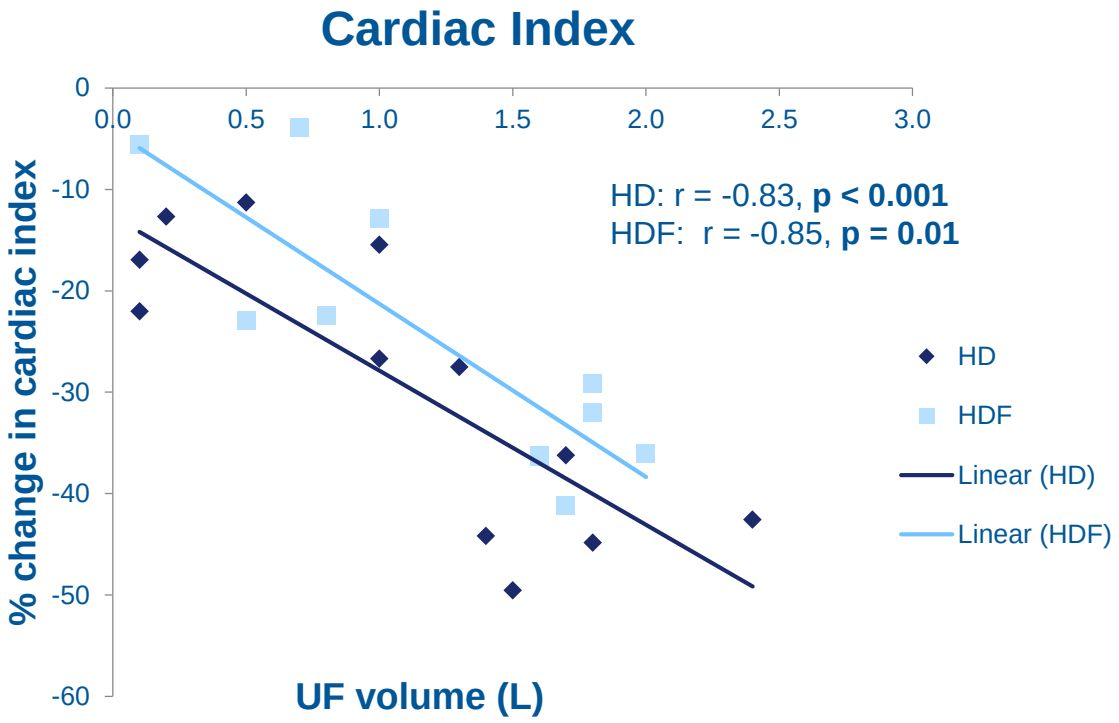
Stunning:

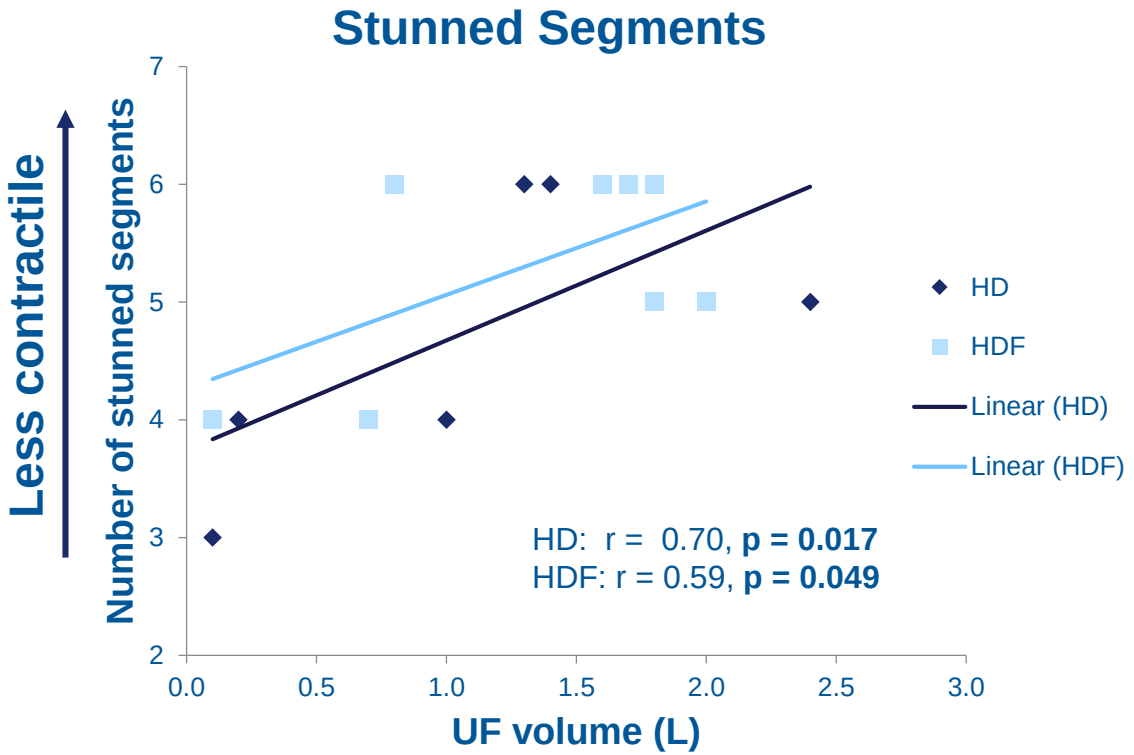


- >20% decrease in strain
- Split the long axis of the myocardium into 6 segments
- Stunned segments evident in all patients from 30 min onwards
- In each patient, it was the same segments that were stunned during HD and HDF
- No difference in strain or number of stunned segments between HD and HDF

CAMRID Results

Peak stress: Correlation with ultrafiltration (UF) volume

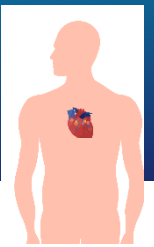




- Similar correlations for stroke volume index
  HD: r = -0.81, **p = 0.01**
  HDF: r = -0.84, **p = 0.01**
- No correlation with UF volume and heart rate

- Increase in UF volume leads to an increase in the number of stunned segments

CAMRID Summary



- During dialysis:
  - Reduced cardiac index, stroke volume index, indexed IVC flux, longitudinal strain
  - Stunned segments evident in all patients
- Higher UF volume → greater decrease in cardiac index, stroke volume index
  → more stunned segments

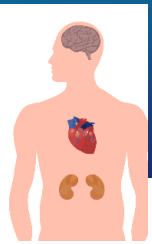
BUT….

- There were no intradialytic differences between HD and HDF

WHY?

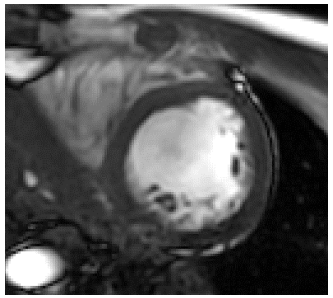
- Relatively healthy patients for the first intradialytic MRI study
  - Reasonably well preserved ejection fraction
  - Relatively stable intradialytic BP
  - Low UFV
- Fall in body temperature occurred during both study sessions
  - Dialysate cooling improves intradialytic hemodynamic stability and provides short- and long-term cardioprotection#

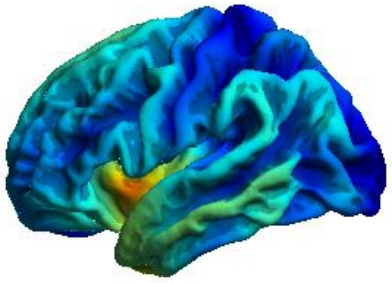
Odudu A et al. Clin J Am Soc Nephrol 10: 1408–1417(2015); Selby NM et al. Clin J Am Soc Nephrol 1: 1216–1225 (2006)



- **Haemodialysis interventions to reduce multi-organ dysfunction (HD-REMODEL)**

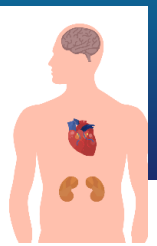
- Does cooled haemodialysis have a protective effect on organ perfusion and circulatory stress compared with standard haemodialysis?





University of Nottingham
UK | CHINA | MALAYSIA

HD-REMODEL



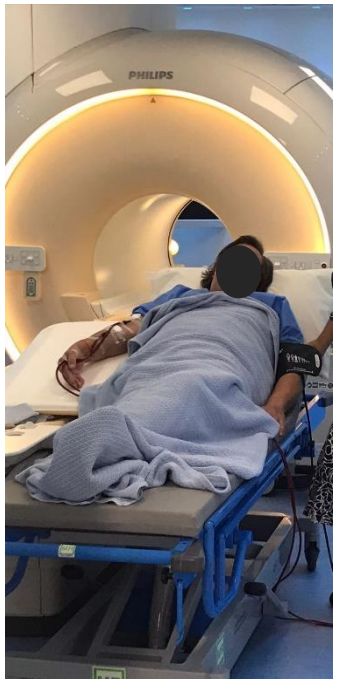
RANDOMISATION

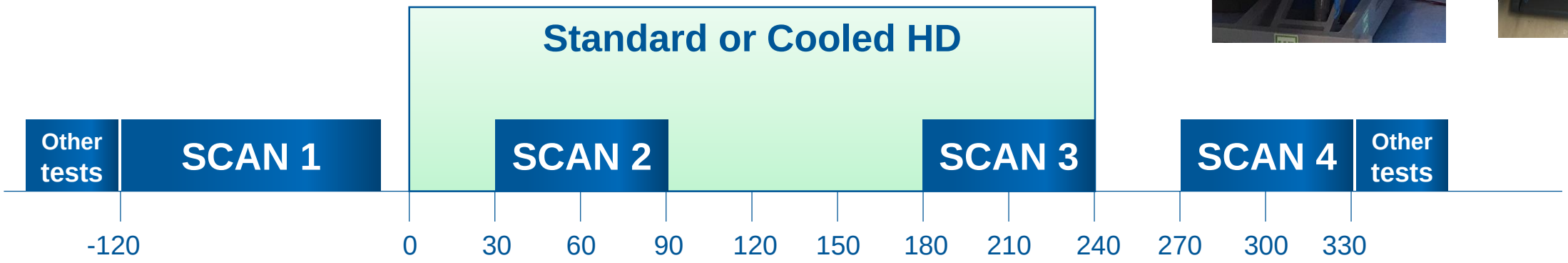
5 standard HD sessions → 1 standard HD session with MRI → 5 cooled HD sessions → 1 cooled HD session with MRI

5 cooled HD sessions → 1 cooled HD session with MRI → 5 standard HD sessions → 1 standard HD session with MRI

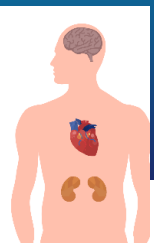
RETURN TO BASELINE PRESCRIPTION

3T Philips Ingenia

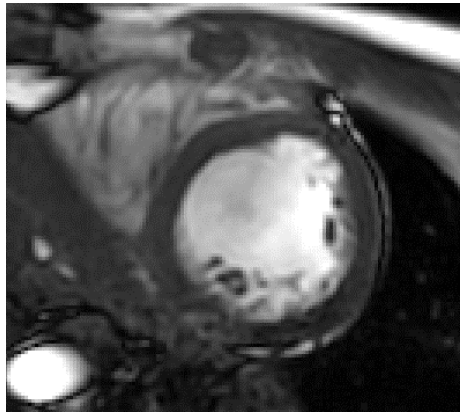




HD-REMODEL

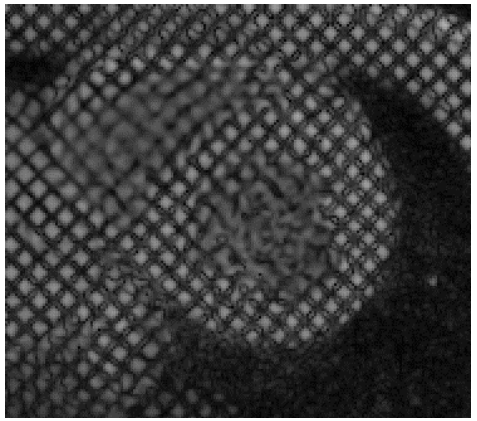


Ejection Fraction
Cardiac Index
Stroke Volume Index
LV wall mass
Diastolic Dysfunction



LV Short Axis cine

HEART



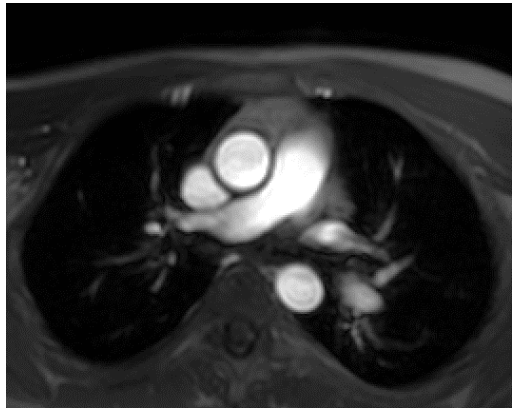
MR Tagging

Longitudinal Strain
Circumferential Strain

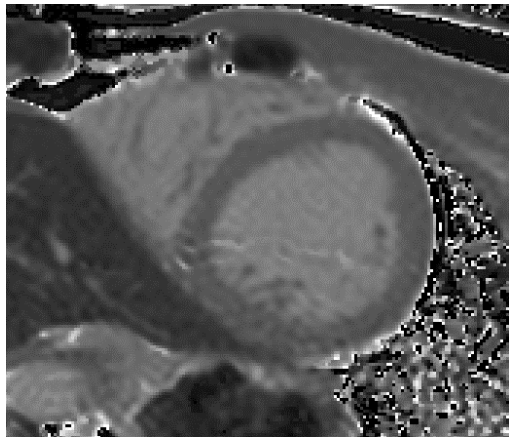
Haemodynamics

Structure

Blood flow velocity
Vessel area
Cardiac Index
Stroke Volume Index



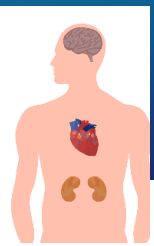
Ascending Aorta PC-MRI



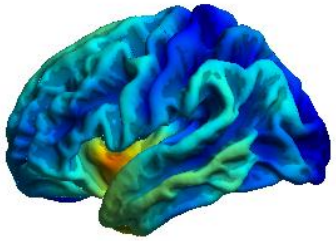
MOLLI

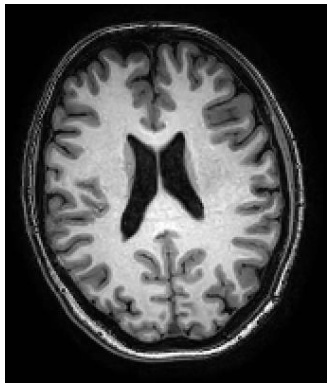
Myocardial T1
Myocardial perfusion

HD-REMODEL



Cortical thickness
Grey matter volumes

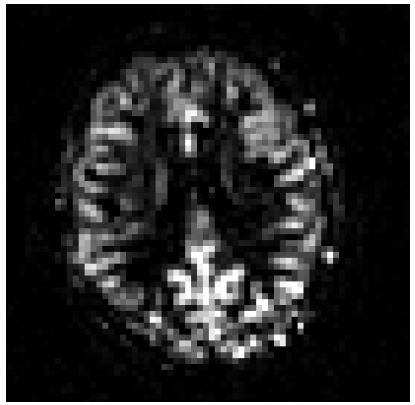




MPRAGE

Structure

BRAIN

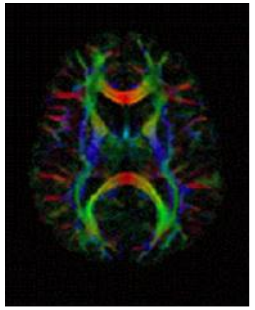


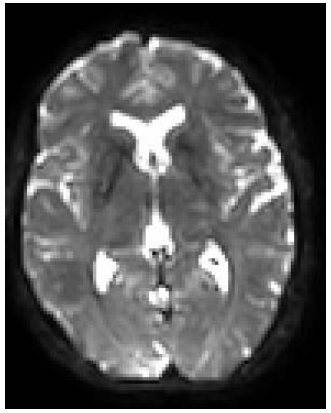
ASL

Perfusion

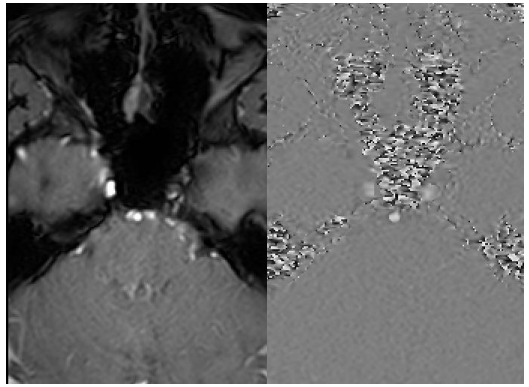
Haemodynamics

Fractional anisotropy





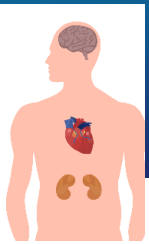
DTI

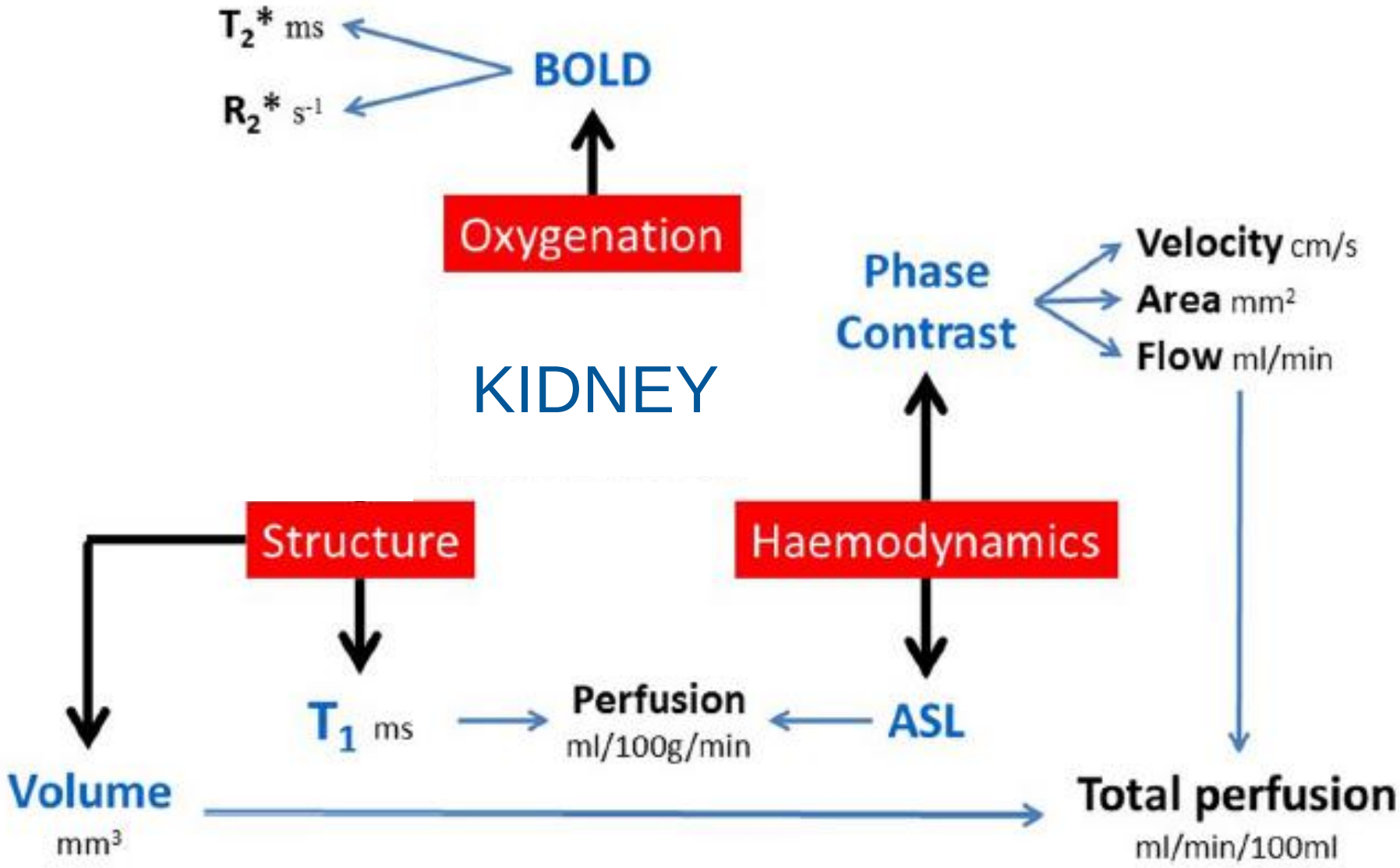


Carotid and Basilar arteries PC-MRI

Blood flow velocity
Vessel area

HD-REMODEL

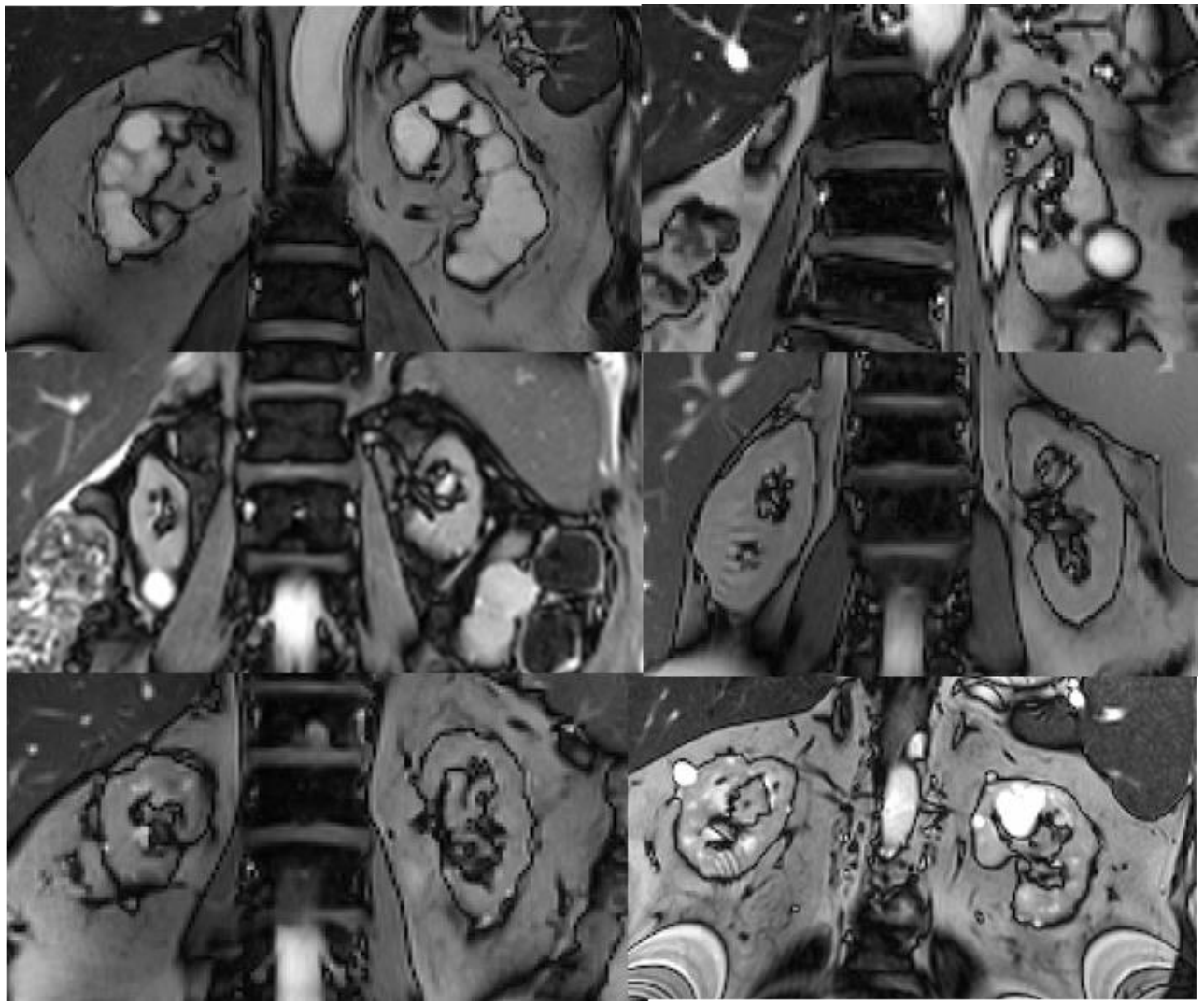


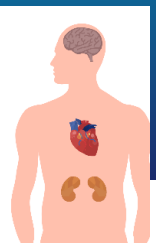


Cox EF et al. Front Physiol 8: 696 (2017)

University of Nottingham
UK | CHINA | MALAYSIA

HD-REMODEL





'A Randomized Cross-Over Trial Using Intradialytic MRI to Compare the Effects of Standard vs. Cooled Haemodialysis on Cerebral Blood Flow and Cardiac Function'

Late-Breaking Clinical Trials
November 7, 2019, 10:00 AM to 12:00 PM

Acknowledgements

Thank you to our Patients

SPMIC:
Sue Francis
Charlotte Buchanan
Chris Bradley
Ben Prestwich
Alex Daniel

Previous SPMIC:
Alex Gardener

CKRI:
Nick Selby
Maarten Taal
Latha Gullapudi
Isma Kazmi
Bethany Lucas
Rebecca Noble
Kelly White
Nurses and Technicians

Previous CKRI:
Chris McIntyre
Tobias Breidthardt
Azharuddin Mohammed
Huda Mahmoud