Intradialytic Cardiac MRI To Assess Cardiovascular Responses In A Randomized Controlled Trial Of Haemodiafiltration Vs. Hemodialysis

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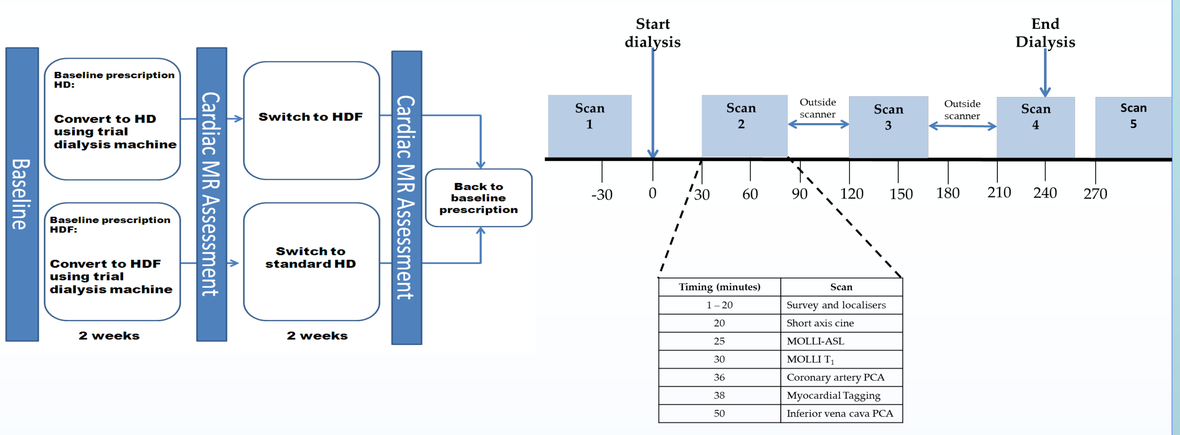
Introduction

Studies utilizing echocardiography and positron emission tomography (PET) have identified that hemodynamic stress during haemodialysis (HD) results in recurrent segmental ischaemic injury (myocardial stunning) driving cumulative cardiac injury. Here, we perform the first study of intradialytic cardiac magnetic resonance imaging (MRI) to assess the cardiovascular effects of dialysis, and to compare standard haemodialysis with haemodiafiltration.

Methods

12 established HD patients (32-72 years, all with AV fistula) were randomly allocated to either HD or HDF. Patients were stabilized on either modality for two weeks before undergoing serial cardiac MR assessment during dialysis (Phillips 3T Achieva). Patients then crossed-over to the other modality, and were rescanned after a further two weeks (Fig.1) Measurements included hemodynamic response (cardiac index (CI), stroke volume index (SVI)), global contractile function (ejection fraction, cardiac strain), segmental function (acute cardiac injury), blood pool return (IVC blood flow), myocardial fibrosis (T_1 mapping), and myocardial hemodynamics (coronary artery flow and myocardial perfusion using arterial spin labeling).



Timing (minutes)	Scan
1 – 20	Survey and localisers
20	Short axis cine
25	MOLLI-ASL
30	MOLLI T_1
36	Coronary artery PCA
38	Myocardial Tagging
50	Inferior vena cava PCA

Figure 1: Flow chart of study design and individual study sessions

Technical considerations:

- Dialysis machine in adjacent room, approx. 3m away in field of ~5Gauss
- Lines through waveguides
- Lines lengthened and insulated (3 x 1.5m extensions, extra volume 66ml)
- Water treatment unit installed in MR centre to deliver ultrapure dialysate
- Non-ferrous silicon dialysis cannulae used
- During the 4 hours of dialysis, participants able to move freely from the scanner bed into MR safe dialysis chair

Figure 2. Patient undergoing MRI whilst also receiving dialysis

Results

Ultrafiltration rate was 3.8±2.9ml/kg/hr and 4.4 ±2.5ml/kg/hr in HD and HDF respectively, p=0.29. Tympanic temperature fell by -1±0.4^{0}C in both arms, p=0.98. BP was generally well maintained, with no significant differences between modalities (Table 1). Maximum SBP fall was 18.1±10mmHg during HD and 19.5±11mmHg during HDF (p=0.70).

SBP (mmHg)	Pre 150.2 ± 23.40	Pre 150.3 ± 22.78	0.43
	During 140.9 ± 6	During 142.2 ± 6	0.46
	Post 144.3 ± 18.20	Post 140.7 ± 21.26	0.25
DBP (mmHg)	Pre 80.58 ± 12.95	Pre 75.92 ± 13.05	0.93
	During 78.8 ± 12	During 77.0 ± 12	0.28
	Post 80.25 ± 14.69	Post 80.00 ± 12.21	0.21

Table 1: BP data

Haemodynamic response to HD and HDF treatments was identical, with significant fall in stroke volume index, cardiac index (fig 3) and IVC return (fig 4) during dialysis.

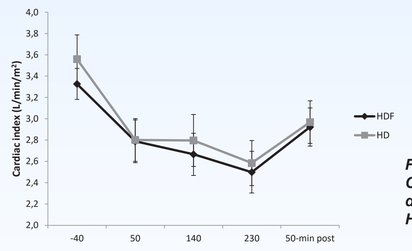


Figure 3. Cardiac index during HD and HDF

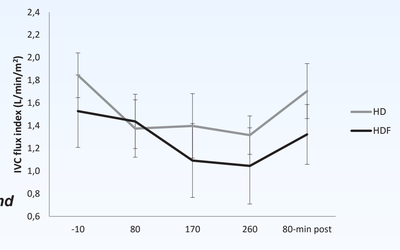


Figure 4. IVC flow during HD and HDF

During both HD and HDF, global systolic contractile function deteriorated: longitudinal strain changing from -7.7±0.9% at baseline to -4.5±0.8% at 160min (p=0.002) during HD c.f. -8.6±0.8% (baseline) and -4.7±1.0% (160min) for HDF, p=0.04. There were no differences between HD and HDF (fig 5A).

Regional strain was assessed in 12 LV segments, with eight patients demonstrating two or more dysfunctional segments during dialysis (fig 5B). Dysfunctional segments were detected at 70min, with the highest number at 160min/250min. 30min after the end of dialysis, strain returned to baseline in some but not all affected segments. Again, no differences were seen between HD and HDF.

Nadir perfusion during both HD and HDF was significantly reduced as compared to baseline (Fig. 5C). Coronary artery flow did not significantly change during dialysis and there was no effect of treatment modality. T_1 signals were relatively normal and did not change during dialysis.

Higher ultrafiltration volumes associated with higher number of dysfunctional LV segments, magnitude of fall in SVI and CI, and a trend towards association with greater fall in myocardial perfusion. Minimum BP during HD also associated with number of dysfunctional LV segments.

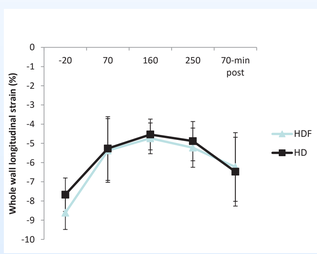


Figure 5A
Global longitudinal strain during HD and HDF

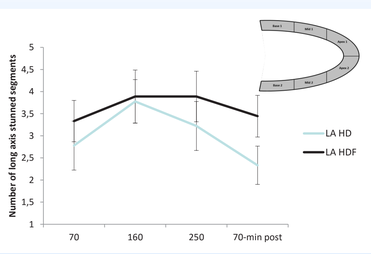


Figure 5B
Number of stunned segments during HD and HDF

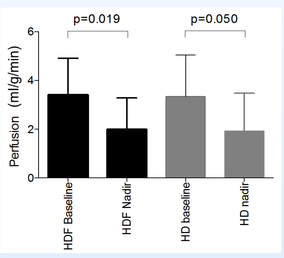


Figure 5C
Myocardial perfusion, at baseline and lowest during HD and HDF

Conclusion

Definitive intradialytic study of the cardiac response to dialysis has confirmed that myocardial stunning is common and strongly related to hemodynamic stress; intradialytic MRI now provides a model for mechanistic evaluation of dialysis-based interventions. HDF does not appear superior to HD in this setting of cooled, stable patients without significant CV co-morbidity.

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