Notes on Table 1: Acquisition options in CHD (the numbers relate to acquisitions listed along the top of the table).

Multislice scouts

1) Stacks of static multislice scout images should be acquired in transaxial ***and*** coronal ***and*** sagittal orientations. The coronal and sagittal stacks, at least, can be acquired in single breath holds using a multislice SSFP (bright blood) sequence. Bright blood transaxials show the pulmonary veins well, but for the sake of tissue characterisation, a transaxial stack may be acquired using a dark blood sequence.

Cines and stacks of cines. ***SSFP cines give good blood-tissue contrast. Jet flow can be well seen in such cines. Relatively bright signal from the jet core may be delineated by dark where a range of velocities in voxels of the shear layer cause dephasing. Because of the long, thin shape of voxels, the length being the slice thickness, thin structures such as valve leaflets or jet boundaries are seen clearly only where they are orientated perpendicular to the slice.***

2) The vertical long axis (VLA) slice is vertical in the body, orthogonal to transaxial, passing through the LV apex and the centre of the mitral valve. The horizontal long axis (HLA) passes through the LV apex and the centre of the mitral valve, orthogonal to the VLA. The HLA is rarely the same as the 4 chamber plane (see 4 below), which slopes down anteriorly.

3) Short axis (SA) stack: in ACHD it is important that the basal SA slice located through the basal myocardium of the right as well as the left ventricle at end diastole, as seen on the HLA and/or 4ch cine. SA slices are usually acquired at 10mm intervals from base to apex for routine calculation of ventricular volumes.

4) 4ch, LVOT and AoV slices: the 4ch plane is located most reproducibly if it passes through the apex of the LV, the centre of the mitral valve, and the 'costo-phrenic angle' of the RV free wall as seen in the third SA slice. The LVOT (or 3 chamber) plane is located though the LV apex, the centre of the mitral valve and the centre of the LVOT, as seen in the basal SA slice. A second, coronal, LVOT plane can be placed orthogonal to the first, aligned with flow through the LVOT and AoV. The AoV plane transects the aortic root to show the cusps. It is located to transect the axis of outflow at the level of early diastolic aortic coaptation. If required for end diastolic measurements of the aortic root, however, it should be aligned at the level of maximum aortic sinus width at end diastole.

5) Ao arch cine(s) are aligned with the arch and proximal descending aorta, with reference to the transaxial and coronal scouts. In the case of coarctation, a series of cross cut cine and velocity acquisitions is likely to be needed (see 14, below).

6) RVOT cine(s) are aligned with the RVOT and proximal MPA, with reference to the transaxial and coronal scouts. A cross cut aligned with the pulmonary outflow, orthogonal to the first, is recommended for pulmonary valve visualisation.

7) PA cines are aligned with the right and left PAs, orthogonal to the transaxial scouts. A PA bifurcation view may then be aligned relative to these, and to the coronal scouts.

8) Transaxial stack: a contiguous stack of transaxial cines, from the lower heart border, up to the aortic arch, if required. Parallel acquisition techniques may allow 2 or more slices to be acquires in each breath hold. A transaxial cine stack is easy to acquire and informative. A case could be made to begin CMR of every CHD patient in this way before moving on to the more specialised acquisitions, particularly if acquisition has to be delegated to a technician with limited experience of CHD.

9) Coronal stack: a contiguous stack of straight coronal cine images, from the front of the heart to the descending aorta.

10) An atrial short axis stack of 5mm contiguous cines is suitable for the visualisation of an atrial septal defect (ASD). The planes are aligned parallel to the ventricular short axis, from the A-V junction, through the atria until the SVC is seen.

11) Mitral stack: a contiguous stack of 5mm cines, orientated orthogonal to the central part of the line of mitral coaptation, starting from the more superior commissure and progressing down to the inferior. This is gives progressive coverage of all scallops (A1-P1, A2-P2 and A3-P3) of the mitral valve, and of any regurgitant jet(s).

Phase contrast velocity mapping. ***Understanding of the principles and pitfalls of phase contrast velocity mapping is needed for successful clinical application. The vessel region of interest should be located as close as possible to the centre of the magnet. Through-plane breath hold velocity mapping is used for most purposes, with a VENC set slightly above the expected peak velocity, and increased to avoid aliasing if necessary. In-plane velocity mapping can be useful as a preliminary step to identify the location of a jet prior to locating a through-plane velocity acquisition that is to be used for jet velocity or volume flow measurement.***

12) MPA flow (usually Qp) is measured through a plane transecting the pulmonary trunk between valve level and the bifurcation. Preliminary RVOT cines and PA bifurcation views (6 and 7, above) help to locate the appropriate level of measurement. However, in the case of non-Eisenmenger PDA, MPA flow = Qs, and the larger Ao flow = Qp.

13) Ao flow (usually Qs) is probably measured most reproducibly through a plane transecting the Ao root at or immediately above the sino-tubular junction. This is used for measurement of Qs (although the plane described excludes coronary flow, which may be about 5% of the output), and for measurement of aortic regurgitant fraction (although any upward diastolic movement of the root through this plane causes the regurgitant volume to be underestimated, particularly if the root is dilated).

14) Jet velocity series: the jet should first be located using cine images, with cross cut cines aligned with the jet to show its location and orientation. Jet velocity can only be measured accurately by CMR if there is a jet core of sufficient size to contain several voxels located and orientated to lie within the jet core. To achieve this, it may be helpful to acquire an in-plane velocity map to locate the jet. Through-plane velocity mapping is then used for the measurement of jet velocity, the slice located to transect the line of the jet immediately downstream of the orifice.

15) ASD flow area. When flow across an ASD has been recognised on cine images (see 10 above), the ASD flow area is visualised by mapping velocities through a plane parallel to the atrial septum located to transect the ASD downstream of the orifice, usually the right atrial side, allowing dimensions, in mm, to be measured. A VENC of 1m/s is usually appropriate.

16) TR jet area. An effective way of identifying moderate or severe tricuspid regurgitation is to use velocity mapping to depict a cross section of the systolic regurgitant flow, with a VENC typically of 250 cm/s, encoded through a plane located the transect the stream immediately on the atrial side of the regurgitant orifice (see section on Ebstein anomaly and TR in text).

17) PR jet area. As in 15 and 16 above, a pulmonary regurgitant orifice are can be visualised by encoding velocities, VENC typically 150 cm/s, through a plane located to transect the regurgitant jet immediately proximal to the valve, as identified on RVOT cines (see 6 above).

3D SSFP acquisitions. ***Bright blood SSFP sequences are suitable for ECG gated 3D imaging of cardiovascular cavities and structures, without the need for contrast agent.The magnetic field should be optimally shimmed.***

18) Global 3D, using a non-contrast, ECG gated, diaphragm navigated, 3D SSFP sequence for acquisition of a bright blood block of data covering the whole heart and mediastinum. There are advantages in acquiring cubic (isotropic) voxels, typically with 1.5 to 2mm dimensions. This approach is currently limited by the lack of dynamic information and by extended acquisition times.

19) Coronary magnetic resonance angiography (MRA), for the identification of anomalous coronary origins. The non-contrast SSFP sequence is as for 18, with fat suppression, aiming for optimal spatial resolution in a block covering the origins and proximal course of the coronary arteries. Breath hold acquisitions may be adequate in some cases. Diaphragm navigated acquisitions take longer, but enable higher spatial resolution and/or signal to noise.

Contrast enhanced magnetic resonance angiography (CEMRA). ***Although there is a trade-off between temporal and spatial resolution, improvements of hardware and software are making 'dynamic' CEMRA highly effective. This allows acquisition of a series of angiograms with sequential opacification of pulmonary and systemic compartments. However, a more prolonged, bolus-timed, higher spatial resolution angiogram may be preferred, for example for clear depiction of aortic coarctation or aorto-pulmonary collaterals. Extra acquisitions in subsequent breath-holds are also possible.***

20) Pulmonary artery CEMRA for assessment of pulmonary artery stenoses and for the visualisation of aorto-pulmonary collateral arteries.

21) Pulmonary vein CEMRA. For assessment or exclusion of anomalous pulmonary venous connections, or in relation to left atrial ablation procedures.

22) Aortic arch CEMRA. Arguably indicated, at least once, in all cases of coarctation, unoperated or repaired.

Late gadolinium (Gd) enhancement imaging

23) Late gadolinium enhancement inversion recovery imaging is used for the identification of myocardial infarction and for LV viability assessment, if required. There is also preliminary evidence that the extent of RV fibrosis identified late after surgical repairs of tetralogy of Fallot or TGA could be relevant to arrhythmic risk stratification. However, localised enhancement in the regions of insertion of the RV free wall into the LV is a frequent and non-specific finding in ACHD.

Myocardial perfusion imaging

24) The acquisition and interpretation of CMR rest and adenosine stress myocardial perfusion imaging requires training and experience. Because CMR perfusion imaging does not subject patients to the long term hazards of ionising radiation, it is likely to gain a clinical role in the assessment of ischaemia in patients with CHD.