Cardiac magnetic resonance (CMR), by virtue of obtaining and combining anatomy, physiology and function, can be utilized to perform surgical planning - not solely by “showing” the cardiac defect to the surgeon but by actually performing “virtual” surgery and predicting outcome. This has obvious utility in making efficient use of cardiopulmonary bypass and deep hypothermic circulatory arrest times as well as optimizing potential results.

One example is the problem of the 1- versus 2-ventricle repair. Not infrequently, neonates are born with 2 ventricles where the suitability of separating the circulations with 2 pumping chambers is questioned. The left ventricle (LV) may be borderline in size. In a patient with double outlet right ventricle, a baffle placed between the ventricular septal defect to the aorta to direct LV blood to the systemic circulation may substantially decrease the right ventricular size below the limits of tolerability. The baffle may not even be feasible if atrioventricular valve chordal attachments are in the way. By utilizing a stack of cine steady state free precession (SSFP) images of both ventricles, a “virtual” baffle can be created and the ventricular volumes assessed; phase encoded velocity mapping is used as a check on this data. If the cardiac index from a ventricle, end-diastolic volume or ejection fraction is unacceptably low with the “virtual” baffle, a 2-ventricle repair may not be feasible and the patient may progress towards the single ventricle Fontan pathway.

In another example, the combination of 3-dimensional velocity mapping and static SSFP imaging allows for computational fluid dynamic modeling of the systemic venous (Fontan) pathway of single ventricles. A number of studies of these single ventricle patients have demonstrate power loss in the systemic venous pathway, flows can be visualized and relative contributions of caval blood to the branch pulmonary arteries can be accurately assessed. This approach not only can evaluate the present status of the circulation in-vivo but can also assess various structural modifications of the cardiovascular system. One study, published a few years ago, assessed the effect of left pulmonary artery stenosis on flow and power loss in single ventricles; this was followed by a “virtual angioplasty” and a reassessment of flow and power loss when the stenosis was removed.

With this notion, the idea that a surgeon, cardiologist or engineer can create “virtual” systemic venous baffles and assess the effect of flow and power loss in various geometries has been implemented in select patients. One clinical application is the single ventricle heterotaxy patient with an interrupted inferior vena cava with azygous continuation. A Kawashima operation in this type of patient connects the superior vena cava to the pulmonary arteries thereby diverting nearly all systemic blood flow except for hepatic venous flow to the lungs. Without hepatic venous blood, pulmonary arterio-venous malformations typically develop; however, when the hepatic veins are subsequently incorporated into the superior vena cava-pulmonary artery connection, flow phenomenon may occur which would preferentially stream hepatic flow to one lung allowing pulmonary arterio-venous malformations to occur in the contralateral lung. The figures below demonstrates one such patient prior to hepatic venous baffle construction with bilateral pulmonary arteriovenous malformations on cardiac catheterization. Hepatic venous baffles are virtually created on a workstation for a number of patient specific options. One is intra-atrial and one is extracardiac with 2 different geometries each; note how the power loss appear approximately the same for both yet the flow distribution of hepatic blood is much different. It is clear given that there are pulmonary arteriovenous malformations in both lungs that the nearly equal flow splits of hepatic venous blood using the intra-atrial approach is preferred. This example demonstrates how this approach can avoid
unilateral pulmonary arteriovenous malformations and subsequent hepatic venous baffle revision.
Extra-Cardiac Options

- Pressure drop from IVC
- Global Flow Structure
- IVC flow distribution