Arterial Pulmonary Flow Analysis Post Bi-Directional Glenn Procedure

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Purpose The purpose of this study is to use 4D MRI velocity mapping to analyze the flow features of Bi-directional Glenn procedures.

Background The Bi-directional Glenn procedure (BDG) is indicated in situations of cyanotic congential heart defects which effectively function as a single ventricle. BDGs are often performed as a palliative measure before performing a Fontan operation to bypass the right heart. This procedure involves removing the superior vena cava (SVC) from the right atrium and creating an anastomosis between the SVC and left or right pulmonary artery (LPA/RPA) (see Fig. 1). This serves to reduce the afterload placed on the ventricle and increases pulmonary blood flow resulting in an increased oxygen saturation of the blood (SO2).

Patients generally show positive results initially following BDGs. However some present with little-to-no improvement in status, increased systemic venous pressure, and retrograde SVC flow [1,2]. With 4D MRI velocity mapping, the visualization and quantification of flow patterns through the thoracic circulation is possible.

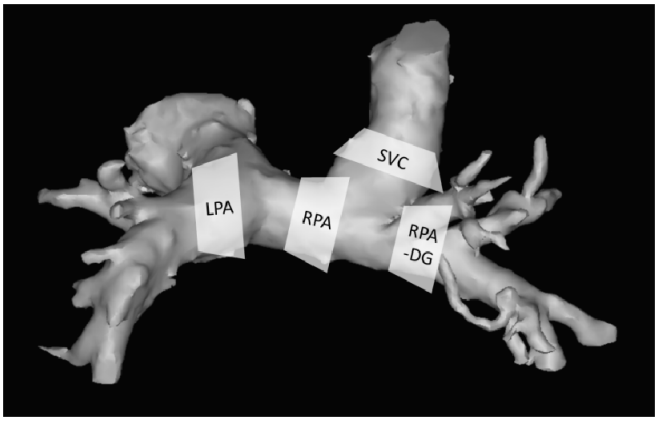

Fig. 1 Cutplane placement (coronal view dorsal to the thoracic circulation)

Materials and Methods PC VIPR data were acquired on 1.5T and 3T clinical systems (GE Healthcare, Waukesha, WI) after obtaining patient consent according to our IRB protocol in 3 patients (3yo/F, 8yo/M, 37yo/F) who had undergone a BDG. Scan parameters included: VENC (50, 80, 100cm/s), isotropic spatial resolution 1.25mm, TR/TE (6.4-9.1/2.3-3.2ms), flip angle (10-11 °). Adaptive respiratory gating with a 50% acceptance window lead to a scan time of approx. 11 min. Dynamic images were reconstructed using retrospective ECG gating with a temporal filter similar to view sharing in Cartesian acquisitions. Visualization was performed using MIMICS (Materialise, Ann Arbor, MI) for vessel segmentation and EnSight (CEI Inc., Apex, NC) for blood flow visualization with time-resolved velocity vectors (Fig. 2). 4D PC-VIPR data analysis was performed by manually placing cutplanes in the MPA, LPA, RPA, RPA-Distal to the Glenn (RPA-DG), & SVC (Fig. 1) using EnSight and subsequent export into a previously described MatLab-based tool for hemodynamic analysis [3].

Results Patient 1 (3yo/F) has a traditional BDG with no MPA. Evenly distributed, anterograde flow from the SVC into the RPA-DG and L/RPA with no retrograde flow in any segment was observed. In addition, the flow is characterized by a counter-clockwise rotation within the pulmonary arteries. SVC flow is pulsatile evident by an increase in flow mid-diastole.

Patient 2 (8yo/M) has a BDG with an open MPA ~90 degrees to the RPA. Anterograde flow in all segments during systole; retrograde flow in the LPA and RPA during diastole. SVC flow is evenly distributed into the RPA-DG and RPA during systole but RPA favored during diastole. SVC flow is again pulsatile and counter-clockwise rotation is seen in L/RPA. Two-fold increase in blood flow through the RPA-DG compared to the RPA.

Patient 3 (37yo/F) has a BDG with open MPA ~30 degrees to the RPA. Notable flow patterns observed were retrograde flow in the SVC during systole and anterograde flow in the RPA-DG and SVC during diastole. No significant increase in blood flow in the RPA-DG as compared to the RPA. Total SVC flow is essentially zero due to the reversal of flow during systole.

Conclusions The results of this preliminary study provide intriguing insight into the flow features of BDG patients, particularly in those with open MPAs. Traditional BDGs have no unexpected flow dynamics, and in this scenario, function as expected with continuous systolic flow toward the pulmonary circulation from the SVC. Conversely, BDGs with open MPAs have varied flow dynamics including reversal of flow in the SVC, as previously reported [1,2]. 4D MRI velocity mapping has the potential to be used as a post-operative analysis tool to ensure the desired flow has been achieved within the thoracic circulation. It also may be used in future studies to search for trends in flow dynamics that can lead to complications following the BDG procedure.

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References [1] Neema PK Ann Card Anaesth 2009. [2] Radha AS Indian Heart J 2003; 55: 373–375. [3] Stalder MRM 2008

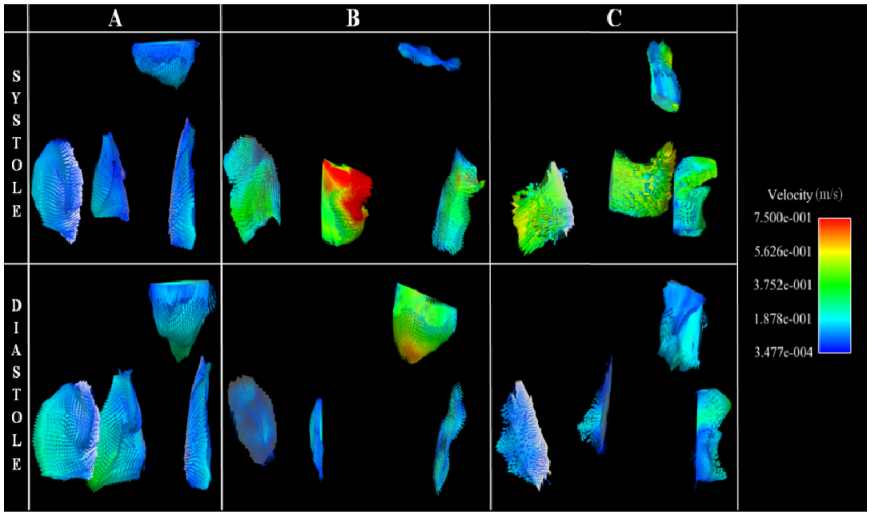

Fig. 2 Time-resolved velocity vector plots (m/s) of patient 1 (A), 2 (B), & 3(C). Orientation of images is the same as seen in Fig. 1 (coronal view dorsal to the thoracic circulation).