MRI based Quantification of Global Cerebral Metabolism in Neonates with Congenital Heart Defect

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Introduction: Periventricular leukomalacia (PVL), a type of hypoxic ischemic injury, is the most common cerebral pathology observed in neonates with congenital heart defects (CHD) [1]. While the exact reason for this type of white matter injury is unclear, hemodynamic and metabolic dysregulation is thought to play a role [2]. We utilized a previously described non-invasive magnetic resonance (MR) method that can measure global bi-hemispheric cerebral venous oxygen saturation (SvO2) and cerebral blood flow (CBF) simultaneously [3, 4]. The two measurements can be combined using Fick’s law to yield global cerebral oxygen metabolism (CMRO2) in absolute physiological units. The goal of this work was to illustrate the feasibility of MR susceptometry based oximetry to quantify SvO2, CBF and CMRO2 in absolute physiological units at rest and in response to hypercapnia in neonates with CHD. The latter was evaluated to assess the dynamic range of the method and cross-validate MR based hemodynamic measurements with more clinically widespread optical methods. Additionally, pre-operative hemodynamic parameters were correlated with the incidence of PVL postoperatively.

Results and Conclusion: In line with the known vasodilatory effect of hypercapnia, an increase in CBF and SvO2 was observed (Figure 1). A summary of various hemodynamic parameters measured at baseline and in response to hypercapnia is shown in Table 1. A significant correlation between MR and optical measurements was associated with worse PVL injury post-operatively (p = 0.033) (Figure 3). In conclusion, we demonstrated the feasibility of conducting MR based hemodynamic measurements in neonates with complex CHD. Measured CBF and CMRO2 values were substantially lower than in adults [2,3]; however in good agreement with those observed in preterm infants who also have a high incidence of PVL [6]. The measurements demonstrated a significant correlation with optical methods and agreed well with expected physiological changes in response to hypercapnia. Additionally, our results illustrate the potential utility of preoperative hemodynamic measurements as predictors of postoperative injury. These results highlight that MRI based measurements of cerebral hemodynamics can serve as a valuable adjunctive tool to evaluate and manage critically ill infants with CHD.

Methods: 35 full term infants with a diagnosis of complex CHD were recruited. The study was performed under general anesthesia on the morning of the patient’s scheduled cardiac surgery. After a 30-minute baseline period of ventilation with FiO2 of 0.21, CO2 was added to the air mixture to achieve an FICO2 of 0.03. MRI and optical measurements were acquired simultaneously before and at the end of the hypercapnic period. All scans were conducted on a 1.5 T Avanto MRI located next to the operating room and intensive care unit. An interleaved GRE sequence consisting of four interleaves was used for simultaneous measurement of SVO2 in the superior sagittal sinus (SSS) using MR-susceptometry based oximetry and CBF using PC MR [4]. Scan parameters: FOV =112×112×5 mm3, voxel size = 0.8×0.8×5 mm3, flip angle = 25°, TR=35ms, VENC = 10cm/s (normocapnia) and 20 cm/s (hypercapnia), NEX=3, total scan time ~ 1 minute. Additional T1, T2 and diffusion weighted images were acquired and a clinical neurologist reviewed all images for the presence of PVL. An average neonatal brain mass of 300g was assumed and normalized to the volume drained by SSS (~60%) to express CBF and CMRO2 in conventional units. For optical measurements, diffuse correlation and near infrared spectroscopies were used to evaluate tissue blood flow and oxygenation levels, respectively [5].

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In conclusion, we demonstrated the feasibility of conducting MR based hemodynamic measurements in neonates with complex CHD. Measured CBF and CMRO2 values were substantially lower than in adults [2,3]; however in good agreement with those observed in preterm infants who also have a high incidence of PVL [6]. The measurements demonstrated a significant correlation with optical methods and agreed well with expected physiological changes in response to hypercapnia. Additionally, our results illustrate the potential utility of preoperative hemodynamic measurements as predictors of postoperative injury. These results highlight that MRI based measurements of cerebral hemodynamics can serve as a valuable adjunctive tool to evaluate and manage critically ill infants with CHD.