Cerebral Cine PC-MRI to Investigate Brain Hemodynamic Of Neonates With Transposition Of The Great Arteries Before And After Cardiopulmonary Bypass Surgery.

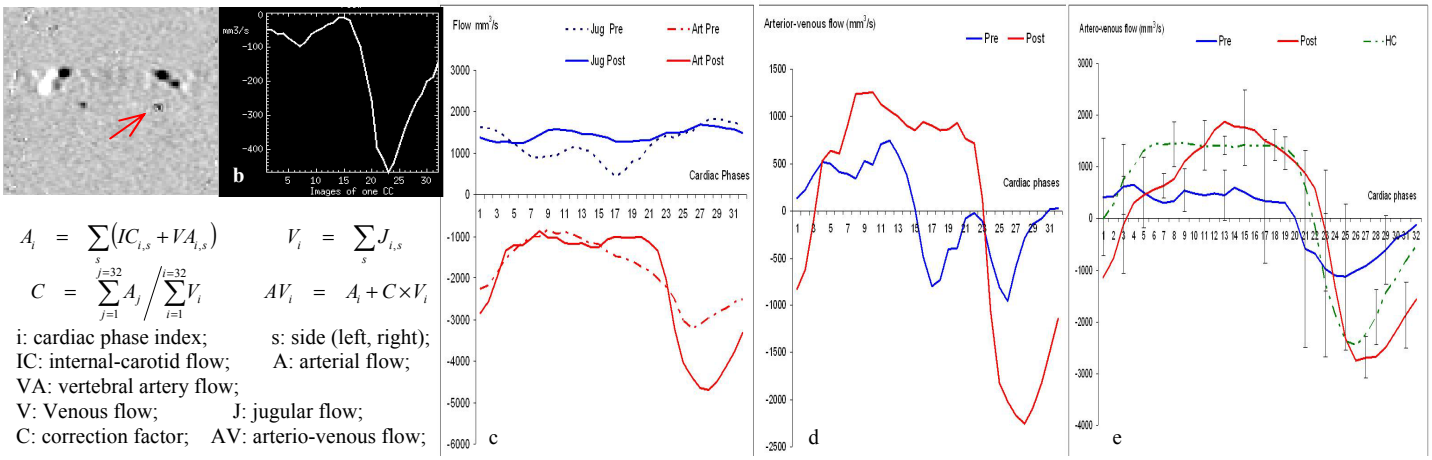
Malek I Makki[1], Olivier Baledent[2], Hitendu Dave[3], Walter Knirsch[4], Bea Latal[5], Ianina Scheer[6], and Cornelia Hagmann[7]

[1]*MRI Research Center, University Chidlren Hospital, Zurich, Switzerland,* [2]*Imagerie Medicale, CHU Nord Amiens, France,* [3]*Congenital Cardiovascular Surgery, University Children Hospital Zurich,* [4]*Cardiology, University Children Hospital Zurich,* [5]*Child Development, University Children Hospital Zurich,* [6]*Diagnostic Imaging, University Children Hospital - Zurich,* [7]*Neonatalogy, University Hospital Zurich*

Introduction: Neonates with transposition of the great arteries (TGA) require balloon atrioseptostomy and prostaglandine infusion to compensate severe cyanosis and require cardiopulmonary bypass (CPB) surgery within the first weeks of life. Cerebral lesions in these patients occur during foetal life, after birth before, during and after CPB. About half of all children undergoing open-heart surgery during the neonatal period have white matter injury such as periventricular leukomalacia, cerebral infarctions, haemorrhages or decreased grey matter volume [1-3]. To date no study investigated the brain hemodynamic of neonates undergoing CPB. Cine PC–MRI is well known for its ability to measure blood flow in both the cardiac and brain arteries during the cardiac cycle. The aim of this study was of two folds: ***1)*** compare the brain hemodynamic of neonates with TGA before and after CPB surgery, and ***2)*** compare these results to age matched healthy controls.

Methods: Four term neonates with TGA (gestation age = 39 ± 1 week; birth weight = 3238 ± 509 g) had cerebral cine 2D PC-MRI before and after CPB surgery. At time of MRI the postnatal age of the pre-surgical group (Pre) ranged between 3 and 27 days and that of the post-surgical group (Post) ranged between 16 and 41 days. Four healthy neonates (HC) born at term (gestation age = 38 weeks ± 5 days; birth weight = 3355 g ± 461) were recruited as control subjects. The post-natal age of the controls group ranged between 16 and 32 days. All subjects were scanned in natural sleep and monitored by an anesthesiologist. The imaging parameters were: one slice at the level of C2C3, FOV= 14 cm^2, 4 mm slice thickness, 2 views per segment, 2 repetitions, peripheral gating with 32 cardiac phases, and *Venc*=100 cm/s. Semi-automatic flow measurements were performed using dedicated software (www.tidam.fr) that combines region growing, thresholding of the velocity map and changes in the area of the selected vessels [4]. We bilaterally selected the internal carotid artery, vertebral artery and jugular veins. Jugular blood flow was normalized with cerebral arterial input flows. Following extraction of the arteriovenous flow (AV) difference through the cardiac-cycle we generated the cerebral vascular flow curve. Amplitudes and shapes of this AV flow curve during the cardiac cycle provide information us about the normal behavior during diastole and systole.

Results: Within group analysis (Paired Ttest) revealed no left-right differences neither in the arteries (carotid, vertebra) nor in the jugular flows, thus we combined the 2 hemispheric measures of each vessel in one value. The AV flow curves of the **HC** presented a diastolic period that lasts for 2 third of the cardiac cycle with a maximum positive peak (flush in) of +1467 mm^3/s while the systolic period (one third of the cardiac cycle) displayed a smooth bump with a negative peak (flash out) of -2446 mm^3/s. The AV flow of the **Pre** group had irregular amplitudes and was associated with decreased diastolic peak to 663 mm^3/s and systolic peak flow to -1126 mm^3/s. The **Post** group AV curves were significantly modified and resembled in shape to the HC group. Following surgery the peak flows increased to 1412 mm^3/s in diastole and to -2747 mm^3/s systole.



$$A_i = \sum_s \left(IC_{i,s} + VA_{i,s}\right) \qquad V_i = \sum_s J_{i,s}$$

$$C = \sum_{j=1}^{j=32} A_j \Big/ \sum_{i=1}^{i=32} V_i \qquad AV_i = A_i + C \times V_i$$

i: cardiac phase index; s: side (left, right);
IC: internal-carotid flow; A: arterial flow;
VA: vertebral artery flow;
V: Venous flow; J: jugular flow;
C: correction factor; AV: arterio-venous flow;

Figure 1: Upper left corner is a snapshot of the processing software showing a the phase image with red arrow pointing to the left vertebral artery and (b) the resulting flow curve. (c) is a graph of pre-surgical (Pre) and post-surgical (Post) flows measured in the arteries (Art) and jugular veins (Jug) of a neonate (GA=37 weeks; BW=3003 g). The Pre was acquired 3 days after birth (BPM=115) and the Post was acquired 13 days after birth (BPM=122). (d) is the resulting Pre and Post arterio-venous flows of the same patient. (e) Averaged arterio-venous flows of each group (healthy controls HC, pre-surgery Pre and post-surgery Post). Negative values represent caudo cranial flow and positive values represent cranio-caudal flow.

Discussion: Although challenges to achieve such study are numerous (neonates population, congenital heart diseases, natural sleep scan, small vessel size, peripheral gating, SNR, spatial resolution...) we successfully demonstrated the capability of this sequence to quantify cerebral blood flows in small vessels of neonates with TGA and to evaluate the impact and the severity of the heart malformation in brain hemodynamic. An additional 2 minutes scan provides reliable and reproducible measures of blood flows in main cerebral arteries and veins even at any age. We also showed that PC-MRI could help clinicians and cardiac surgeons to assess the impact of the CPB surgery in the cerebral hemodynamic by investigation of blood redistribution through the brain. In conclusion cine PC-MRI is a repetitive and reproducible in-vivo fast technique showing that neonates with TGA who had altered brain hemodynamic will have a healthy-control like cerebral blood flow following CPB surgery.

References: [1] Mahle WT et al. *Circulation* (2002); [2] Miller SP et al. *N Engl J Med* (2007); [3] Watanabe K et al. *J Thorac Cardiovasc Surg* (2009); [4] Baledent O. et al. *Invest Radiol* (2001)