Evaluation of the Longitudinal Relaxation Rate of Blood in Neonates.

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Introduction

Critical illness in newborns may affect cerebral blood flow (CBF) through impaired autoregulation. This makes accurate perfusion quantification from utmost importance when evaluating brain perfusion in clinical studies. In an Arterial Spin Labeling (ASL) experiment the longitudinal relaxation rate of blood (T_{1b}) determines how fast the tracer decays and as such should be obtained to accurately quantify CBF. Previously, techniques to measure the T_{1b} in the neonatal population have been established[1,2]. In this study the T_2 Prepared Blood Relaxation Imaging with Inversion Recovery (T2-TRIR)[2] sequence was used to measure the T_{1b} in a large cohort of neonates. The purpose of this research was to investigate the influence of the T_{1b} on perfusion quantification and to further investigate the relation between hematocrit and T_{1b}.

Materials and methods

MR imaging (3.0T, Philips) was performed in 112 neonates with a mean gestational age at scan of 39 weeks (range: 30-54 weeks). The study was in line with institutional guidelines. Scan parameters of the T2-TRIR sequence were; TR/TE/ΔTI/TI1= 1500/20/150/130 ms, matrix 128x128, FOV 160x160, FA 95°, 2mm slice, SENSE=2.5, eTE=0,40,80 and 160ms and scan time 2:15. In addition, in a subset of the neonates pulsed ASL and 2D-PC-MRA were performed. The inversion recovery of venous blood was measured in the superior sagittal sinus on the T2-TRIR image and the T_{1b} ($T_{1b\text{-fitted}}$) was fitted using the formula; $M_b(TI) = M_{ob}\,[1-(1.0 + e^{-eTE/T2b}.\ IE).e^{-TI/T1b}]^2$. Cerebral blood flow (CBF) was quantified on the ASL images with first T_{1b}=1.6 ($T_{1b\text{-}1.6}$) and second $T_{1b\text{-fitted}}$ (n=16). Both quantification models were compared. Volume flow measurements obtained with 2D-PC-MRA (n=11) were plotted against brain volume to provide perfusion estimates. The relation between ASL CBF (ASL-$T_{1b=1,6}$ and ASL-$T_{1b\text{-fitted}}$) and 2D-PC-MRA CBF was investigated. In 13 neonates hematocrit was measured on a capillary blood sample (Htc_c) and in 8 neonates Htc was measured on an arterial blood sample (Htc_a) within 24 hours of the MR examinations. The relation between Htc and the longitudinal relaxation rate constant of blood ($R_{1b}=1/T_{1b\text{-fitted}}$) was investigated.

Results

In 77 neonates (69%) T_{1b} fitting was successful. An overview of the subject characteristics and corresponding mean T_{1b} values is given in Table 1. A significant difference between ASL-$T_{1b\text{-}1.6}$ CBF and ASL-$T_{1b\text{-fitted}}$ was shown (p=0.007, Wilcoxon signed-rank test). Mean % difference between ASL-$T_{1b\text{-}1.6}$ CBF and ASL-$T_{1b\text{-fitted}}$ CBF was 13% [range -12% to 37%] (Figure 1). Linear regression showed an R^2 of 0.597 when comparing 2D-PC-MRA CBF to ASL-$T_{1b\text{-}1.6}$ CBF (p=0.005), R^2 increased to 0.665 after implementing $T_{1b\text{-fitted}}$ (p=0.002) (Figure 1). The relation between R_{1b} and Htc was found to be; R_{1b} = 0.27.Htc_c + 0.423 (R^2=0.199, p= 0.000) and R_{1b} = 0.577.Htc_a + 0.334 (R^2=0.298, p= 0.083) (Figure 2).

Discussion

A good performance of the T2-TRIR sequence to measure the T_{1b} was shown. Perfusion was shown to be more accurate after implementing the $T_{1b\text{-fitted}}$ in the quantification model. The relation between Htc, arterial sampled, and the longitudinal relaxation constant of blood was similar to the one found by Varela et al; R_{1b} =0.5. Htc + 0.37 [3]. However, the spread in our data was much wider and as such the relation was not significant. Noise in our fitting model may attributed to this. In addition, intrinsic noise in blood sampling might influenced this as well. In our data we did show that the relation between the longitudinal relaxation rate constant of blood and hematocrit was dependent on the sampling technique.

Conclusion

The longitudinal relaxation rate of blood should be fitted in neonates when quantifying ASL perfusion images. The relation between hematocrit and the longitudinal relaxation rate constant of blood is dependent on the sampling technique.

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Table 1

	N	Postconceptional age (in wks, mean [range])	Corrected postconceptional age (in wks, mean [range])	T1b (in s, mean [sd])
Preterm	13	27 [26-28]	31 [30-31]	1.827 [0.212]
TEA	40	28 [24-33]	41 [40-43]	1,928 [0.173]
3m	3	39 [37-40]	52 [52-53]	1.774 [0.227]
Asphyxia	10	39 [36-42]	40 [37-42]	1.760 [0.190]
Others	11	37 [34-54]	40 [35-54]	1.731 [0.181]

Table 1: Subject characteristics, for subjects with successful T2-TRIR scan, are given. Subjects were categorized; infants scanned at preterm age, infants scanned at term-equivalent age (TEA), infants scanned at 3 months-equivalent age (3m), infants diagnosed with asphyxia (n=10) and others. Postconceptional age is age when born, corrected postconceptional age is age when MR imaging was performed Mean $T_{1b\text{-fitted}}$ and standard deviation for each category are shown.

Figure 1

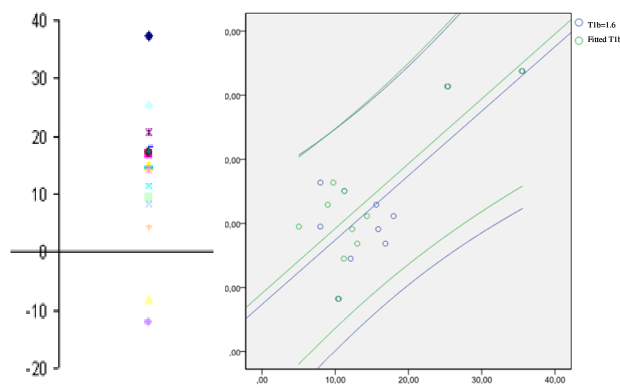

Figure 1. Left: ASL-$T_{1b\text{-}1.6}$ CBF is compared to ASL- $T_{1b\text{-fitted}}$ CBF. The zero line (x-axis) represents ASL-$T_{1b\text{-}1.6}$ CBF. The difference between both quantification models is given in %CBF and is shown for each subject. In most subjects ASL-$T_{1b\text{-}1.6}$ CBF was higher than ASL- $T_{1b\text{-fitted}}$ CBF, visualized here by a positive difference. **Right:** The relation between ASL CBF (x-axis) and 2D-PC-MRA CBF (y-axis) is shown. In blue ASL-$T_{1b\text{-}1.6}$ CBF and in green ASL- $T_{1b\text{-fitted}}$ CBF. The relation improves after fitting the T_{1b}.

Figure 2

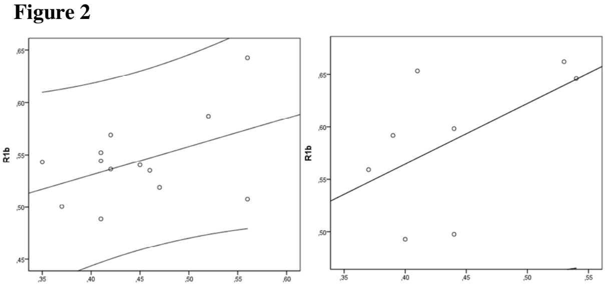

Figure 2. Left. Relation between Htc_c and R_{1b} is shown (R^2=0.199). The trend line is a linear fit between the inverse of $T_{1b\text{-fitted}}$ and Htc_c. **Right.** Relation between Htc_a and R_{1b} is shown (R^2=0.298). The trend line is a linear fit between the inverse of $T_{1b\text{-fitted}}$ and Htc_a.

References

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