

MEASURING CBV BY THE RECIRCULATION PART OF DYNAMIC SUSCEPTIBILITY CONTRAST MRI ON RAT MODEL

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Introduction

By using the Dynamic Susceptibility Contrast (DSC) method for MR perfusion imaging, relative cerebral blood volume maps are obtained from integrating the first pass area of the local tissue concentration time curve $C_T(t)$. However, because of relatively high heart rate and fast circulation in small animal experiments, C_T peak changes quickly and results in only few data points for quantification. In this work, we investigated the feasibilities of using the recirculation part of C_T for assessing CBV. Relative CBV maps of normal rats' first pass and recirculation of Gd-DTPA bolus were compared. Furthermore, additional rCBV maps by administration of monocrySTALLINE iron oxide nanoparticles (MION), which features high susceptibility effect and long plasma half-life, were also generated as proportional references for relative quantifications.

Materials and Method

According to the principles of DSC perfusion imaging, the area under the first pass curve of the Gd-DTPA C_T function is proportional the CBV times the integral of arterial input function.[1] After first passing, the contrast agent bolus is dispersed by pulmonary and system circulations before re-circulating to tissue, and C_T becomes a stable decreasing function with low concentration. This "recirculation" part of C_T is usually removed when assessing the CBV value. However, by assuming the AIF as a gradually decreasing function, the area of recirculation is proposed as an alternative index for relative CBV quantification in this study. For small animal imaging, the recirculation CBV can be calculated from more data points in longer duration than the first pass CBV map, and therefore supposed to be less affected by the noise and insufficient sampling rate of applied MRI sequences.

In this study, three normal male Sprague-Dawley rats (mean weight of $314.3 \pm 38.9g$) were anesthetized with 1.5% Isoflurane and scanned in a 4.7T animal MRI scanner (Bruker Biospec 47/40). For DSC imaging, 150 consecutive multi-slice gradient echo EPI scans were applied with TE/TR as 25/500 ms, FOV as 32mm, and matrix size as 64×64 . 0.3 ml of Gd-DTPA (Magnevist) was manually injected at the 10th second and flushed with 0.5 ml of saline. Relative C_T were then generated by calculating the $\Delta R2^*$ from the scans before contrast agent arriving. The integration of the C_T curve from contrast agent arriving to the time the value dropping to half maximum was regarded as first pass CBV, while the integration of last 80 data points (i.e. 40 seconds) was utilized for recirculation CBV. Four pre-MION and four post-MION gradient echo EPI (TE/TE as 25/2500ms) were then scanned with a Fe dosage of 20mg/kg. The $\Delta R2^*$ maps by the susceptibility of steady state MION were also considered as MION CBV maps and utilized as references for comparison.[2]

Results

Fig. 1 showed one example of the scatter plot of the first pass CBV and recirculation CBV of one slice of our experiments. The results display considerably positive correlation between the first pass and recirculation CBV map. R squares were found to be 0.8958 ± 0.0448 , which are consistent with our hypothesis. However, an intercept of regression line was also showed in Fig. 1, which implies the deviation from proportionality within at least one of the methods. Therefore, we applied MION CBV map as a reference to compare with first pass and recirculation CBV maps, and r squares were found to be 0.62193 ± 0.15744 , 0.69407 ± 0.1515 , respectively (Table 1). For intercept per slope values were found to be 0.072326 ± 0.044215 and 0.033261 ± 0.041996 , respectively as well, which represent the normalize offset of the first pass and recirculation CBV maps. The higher r square and lower normalized offset between recirculation CBV and MION CBV once more support the feasibility of recirculation CBV map, since MION CBV map is taken to be as an ideal CBV.

Discussion and Conclusion

The recirculation CBV map is highly relative to first pass CBV map. Besides, the superior regression curves with MION CBV map guarantee the advantage of using the recirculation CBV for small animal imaging. The errors of first pass CBV may come from the fast changing peak value, relative low scanning speed of MRI, and even the nonlinearity between $\Delta R2^*$ and contrast agent concentration around peak value. On the contrary, the recirculation CBV seems more reliable by recruiting more data points for calculation, since the extravasation supposed to be minor in the short duration of DSC imaging. In conclusion, we confirmed the feasibility of using the recirculation part of C_T for relative CBV measurement. One may also consider integrating the total area under the C_T curve including both the first pass and recirculation parts, to further enrich the data points and to enhance the reliability.

Reference

1. Axel L, Radiology 137, 679-86. (1980).
2. Mandeville JB et al., MRM 39, 615-24 (1998).

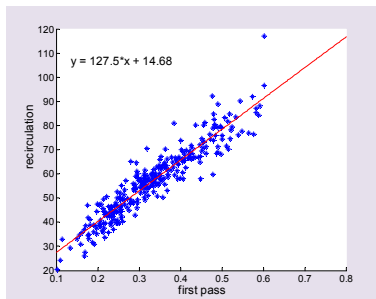


Fig1. The scatter distribution between first pass and recirculation in rat brain. Note the high correlation between first pass CBV (x axis) and recirculation CBV (y axis).

Data	Linear regression: $y = \text{slope} * x + \text{intercept}$, x: MION CBV, y: first pass or recirculation CBV			
	r square		Normalized offset(intercept/slope)	
	mion & first pass	mion & recirculation	mion & first pass	mion & recirculation
1	0.6431	0.772	-0.06647102	-0.033662877
2	0.4956	0.529	-0.081634446	0.001484687
3	0.5561	0.6271	-0.128644804	-0.113779681
4	0.4624	0.551	-0.001047136	-0.001177692
5	0.8947	0.9212	-0.103918613	-0.033403742
6	0.6797	0.7641	-0.052239674	-0.016057231
mean	0.62193 ± 0.15744	0.69407 ± 0.1515	0.072326 ± 0.044215	0.033261 ± 0.041996

Table 1. comparison of parameters between MION&first pass CBV maps and MION&recirculation CBV maps. Note the higher r square and lower offset between recirculation CBV and MION CBV.