T1 Measurement of Flowing Blood on Inversion Recovery GEPI

J-Y. GUO[1], S-E. Kim[1], E. Jeong[1], D. Parker[1], L. Zhang[1], R. Roemer[1]
[1]University of Utah, Salt Lake City, Utah, United States

Abstract:

A novel pulse sequence for the measurement of T_1 of flowing blood has been developed. This pulse sequence employs a nonselective adiabatic inversion pulse followed by a series of multiphase gradient EPI pulse sequences to measure the spin lattice relaxation constant (T_1) of flowing Blood. The new combined method of the fitting method and the nulling point method (CFN) is used to acquire more accurate and consistent T_1. The simulation and experimental results show that this CFN method provides a more reliable measurement of the T_1 of flowing blood.

Introduction:

The blood spin-lattice relaxation time (T_1) is an important parameter for the measurement of perfusion as well as the temperature of the flowing blood. The fitting method was used to measure T1 of flowing blood by Dumoulin, et al [1]. The periodic deviations from the fitted curve caused by the cyclic velocity changes increases the uncertainty of the T1 measurement. The nulling method of T1 measurement of flowing blood was used by Wendland, et al. [2]. The nulling method needs at least six measurements and takes about 3 minutes to acquire data. The CFN method just takes about 10 seconds and provides a precise measurement of the T1 of flowing blood.

Method:

The new pulse sequence which employs a nonselective adiabatic inversion pulse followed by a series of multiphase gradient EPI pulse sequences was used to acquire the data. ECG gating was used so that the images were taken at almost the same cardiac phase to get rid of the periodic deviation due to the pulsatile flow. According to the Bloch equation, a three parameter model (1) was used to fit the data.

$$I(t) = \left| A - B \cdot e^{-t/T_1} \right| \quad (1)$$

Here I(t) is the intensity of signal, A and B are constants, t is time. The results of T1 had the large uncertainty because of the noise from the pulsatile flow even with the ECG gating. To suppress the effect of noise on T1, the CFN method was used. Initially, the data was fitted according to the equation (1) to get T1, A and B. Those parameters were plugged back into the equation (1) to calculate the nulling point of the data. And then the compensation of the nulling point determined from the pulse sequence was added to this time to calculate the real nulling point (Tn). Finally, the T1 value from the CFN method was determined by the equation T1 = Tn/ln(2).

Result:

All the data were acquired on a GE Signa (GE Medical System Inc., Milwaukee,WI) 1.5 T MRI system. The data from the four human volunteers were post-processed according to the fitting method and the CFN method for comparison. Two kinds of result are shown in the table (1). For each volunteer except No.3, there were three regions of interest (ROIs), which were shown in Figure (1). The major ROIs were in the Ascending Aorta, and the other ROI was just for comparison. For the different volunteer, the image plane was required to be perpendicular to the Ascending Aorta, and so the other two regions become smaller or bigger for the different volunteers. Region C was not clearly seen in the third volunteer. The standard deviation of T1 in the different regions was calculated from the multiple T1 values from the same region. The mean value is the average of the T1 values of the different regions. From Table (1), the T1 values of the four volunteer are 1204, 1353, 1360, 1477 ms according to the data from the Ascending Aorta.

Volunteer	Method	A(ms)	B(ms)	C(ms)	Mean(ms)
V.1	I	1285±12	1591±45	1425±37	1434±154
	II	1204±9	1194±4	1226±3	1208±17
V.2	I	1272±20	1146±20	1951±89	1437±433
	II	1353±1	1307±4	1340±11	1334±24
V.3	I	1616±18	1541±17		1579±54
	II	1360±16	1329±7		1345±22
V.4	I	1712±33	1602±43	1540±75	1618±88
	II	1477±1	1435±10	1435±5	1449±25

Table 1. T1 results from the data of 4 volunteers. Here two methods were used. I is the Fitting method, II is the CFN method. A, B, C are the different ROIs shown in Figure (1).

In the above results, the precision of T1 calculated by the CFN method for flowing blood was shown. In an attempt to show the accuracy of the CFN method compared with the fitting method, a simulation was performed. In the simulation, T1 (1200ms) and TR (911 ms) were given. The results from the CFN method and the fitting method were almost equal to the real value (1200ms) of T1 without the noise. The simulation demonstrated that these two methods are theoretically equivalent. An estimate of noise was extracted from each of the three ROIs of volunteer 1 according to equation (2).

$$n(i) = \frac{d(i) - f(i)}{f(i)} \quad (2)$$

where d(i) is the experimental data, f(i) is the fitted data, and n(i) is the relative noise. These three estimates of noise were added to the signal data in the simulation, and then the following results were acquired in the table (2).

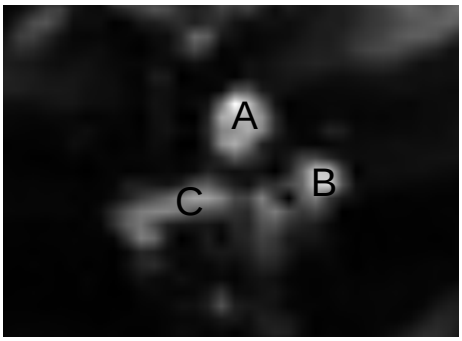

Figure 1. Axial image of Aorta, A for Ascending Aorta, B for Superior Vena Cava , C for left branch of Pulmonary Trunk

Method	Noise A(ms)	Noise B(ms)	Noise C(ms)	Mean(ms)
I	1191	1219	1213	1208±15
II	1203	1210	1205	1206±4

Table 2. The results of simulation with T1=1200ms. The meaning of I, II is the same as that in Table 1.

Conclusion:

From the experimental and simulation results, more accurate and precise T1 values are determined by the CFN method. The T1 values are affected by many factors such as hematocrit, blood oxygenation, and blood temperature.

Reference:

[1] C. L. Dumoulin, M. H. Buonocore, and et al., *Magn. Reson.Med.*, vol. 32, pp. 370–378, 1994.
[2] Michael F. Wendland, Maythem Saeed, and et al., *Magn. Reson.Med.*, vol. 37, pp.448-456, 1997.