The Method of Reducing Echo Time in 3D Time-of-flight Angiography

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ABSTRACT
We have designed ramp profile excitation pulse based on the Shinnar-Le Roux (SLR) algorithm. The algorithm provides many advantages to pulse designers. The first advantage is the freedom of deciding the amplitudes, frequencies, and ripple sizes of stopband, passband, and transition band of pulse profile. The second advantage is the freedom of deciding the pulse phase, more specifically, minimum phase, linear phase, maximum phase, and any phase between them. The minimum phase pulse is the best choice in the case of 3D TOF, because it minimizes the echo time, which implies the best image quality in the same MR examination condition.
In addition, the half echo technique is slightly modified in our case. In general, using the half echo technique means that the acquired data size is half and the rest part can be filled with complex conjugate of acquired data. But in our case, the echo center is just shifted to left, which implies the reduction of echo time, and the acquired data size is the same as the one without using the half echo technique. In this case, the increase of right part of data leads to improvement of the resolution and the decrease of left part of data leads to decrease of signal to noise ratio. Since in the case of 3D TOF, the signal to noise ratio is sufficiently high and the resolution is more important than signal to noise ratio, the proposed method appears to be significantly affective and gives rise to the improved high resolution angiograms.

Keywords: 3D TOF, ramp profile, minimum phase, half echo.

1. INTRODUCTION
The 3D time-of-flight (3D TOF) angiography is widely used enhancing vessel contrast in MRI. In general, the image quality of 3D TOF can be improved using many advanced techniques such as Multiple Overlapping Thin Slab Acquisition (MOTSA) technique, ramp profile excitation pulse, Magnetization Transfer Contrast (MTC) pulse, moving presaturation pulse, flow compensation, and half echo technique. In addition the half fourier technique can be used to reduce scan time further. The vessel image quality is closely related to the echo time. In the same imaging condition, the image quality can be improved by shortening the echo time. There are many methods of reducing the echo time. Examples are many such as reducing the excitation pulse duration, increasing the acquisition bandwidth, reducing the data acquisition points, and reducing the timing of flow compensation gradient pulse by using the powerful and precise gradient subsystem. However, these methods are suffering from poor slice selectivity, insufficient signal to noise ratio, or low resolution. This work proposes the two methods of reducing the echo time without such defects. The first is the method of using the minimum phase excitation pulse with a ramp profile. The later is the method of shifting the echo center with reducing the area of dephasing gradient along the readout direction, which is similar to the half echo technique.

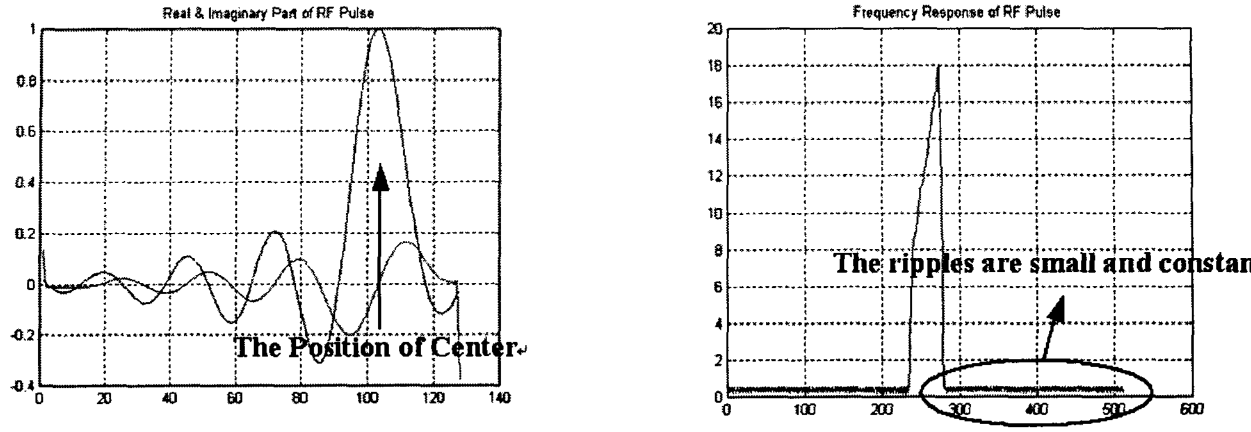
2. MATERIALS AND METHODS
2.1. Minimum Phase Ramp Profile RF Pulse Design based on the SLR (Shinnar-Le Roux) Algorithm
The SLR algorithm is well known method of designing RF Pulses. The algorithm provides the freedom of deciding the amplitudes, frequencies, and ripple sizes of stopband, passband, and transition band in pulse profiles. By using this algorithm, we can take the advantages of not only the good selectivity and freedom of deciding profile, but also the minimum phase of RF pulse, which has an effect on the echo time and vessel image quality. The RF pulse can be also applied to the other pulse sequences. The design example is as following.

a. Input Specification

a. RF Pulse Phase = Minimum Phase
b. Passband Ripple Size (delta1) = 0.01
c. Stopband Ripple Size (delta2) = 0.01

d. The Ratio of Passband, Stopband, and Transition Band = 6:91:3
e. The Ratio of the small flip angle and large flip angle = 1:2
f. The Bandwidth of RF Pulse = 1kHz
g. The RF Pulse Duration = 1msec

b. Output result



a. RF Pulse Shape **b. Excitation Profile**

Fig. 1. The Shape and Profile of the RF Pulse designed with SLR Algorithm

The result of pulse shape as shown in Figure 1.a illustrates that the center of RF pulse is shifted, or group delayed to the right side, which implies that we can reduce the echo time with this RF pulse. And the result of excitation profile as shown in Figure 1.b demonstrates that it satisfies the input specification very well and it has no large fluctuation, but just small and constant one which can be negligible.

c. The application of the designed RF pulse

The designed RF pulse should be converted to the file that contains the amplitude and phase value, or real and imaginary value. And it should be changed to the format fit for the system. In general, it is hard to decide the optimal ratio of small flip angle and large flip angle of ramp RF pulse in 3D TOF, because it related to the velocity of the vessel in the region of interest. In case of MOTSA (Multiple Overlapping Thin Slab Acquisition), the continuity of the vessel is bad if the ratio of flip angle is not proper. We decided the input specification of RF pulse very carefully after various experiments.

2.2. The Echo Shifting Method

This method appears to be similar as the half echo method in terms of reducing the area of dephasing gradient along the readout direction. However, it is different in terms of acquiring the full data points. So, there is no need to fill the complex conjugate of data in the case of the echo shifting method.

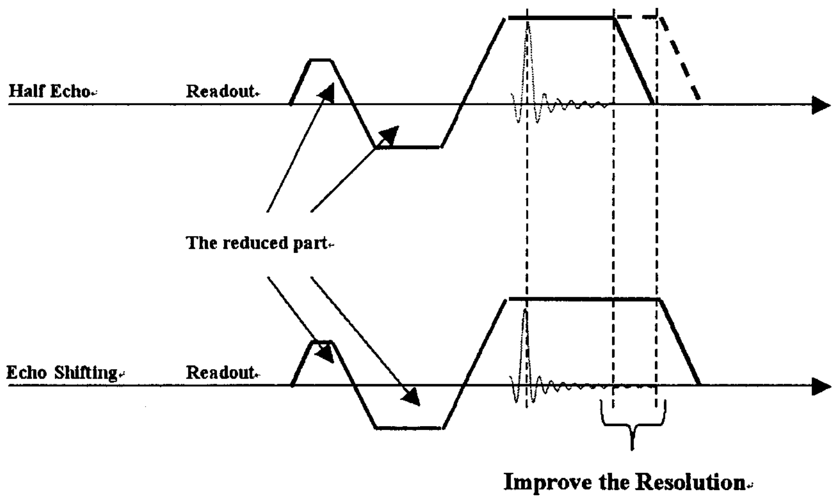


Fig. 2. Comparison of Half Echo and Echo Shifting Methods

From figure 2, one can find the increment of right part of data, which leads to the improvement of high frequency which results in the improvement of spatial resolution. The reduced left part of FID data has two effects. The first is the reduction of the echo time that can improve the vessel images significantly. The later is a slight degradation of signal to noise ratio. However, since the SNR is sufficiently high, such a degradation can be negligible in the case of 3D TOF.

3. CONCLUSION

We have applied the methods to our system and found conspicuous improvement of the vessel images. Improved spatial resolution enables the distinction of small vessels and diseases. Many clinical experiments show that it is very useful method in clinical applications.

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