

# Measuring CBF from Perfusion MRI by Wavelet Transform

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# Introduction

**Perfusion:** Rate at which nutrient-supplying blood passes through tissue

# **Applications of Perfusion Assessment**

- **Stroke**
- **Alzheimer's Disease**
- **Assessment of Prognosis**
- **Tumor Characterization**
- **Monitoring of Cancer Therapy**

# Medical Imaging Modalities used in Perfusion Assessment

- **PET** (Positron Emission Tomography)
- **SPECT** (Single Photon Emission Computed Tomography)
- **MRI** (Magnetic Resonance Imaging)

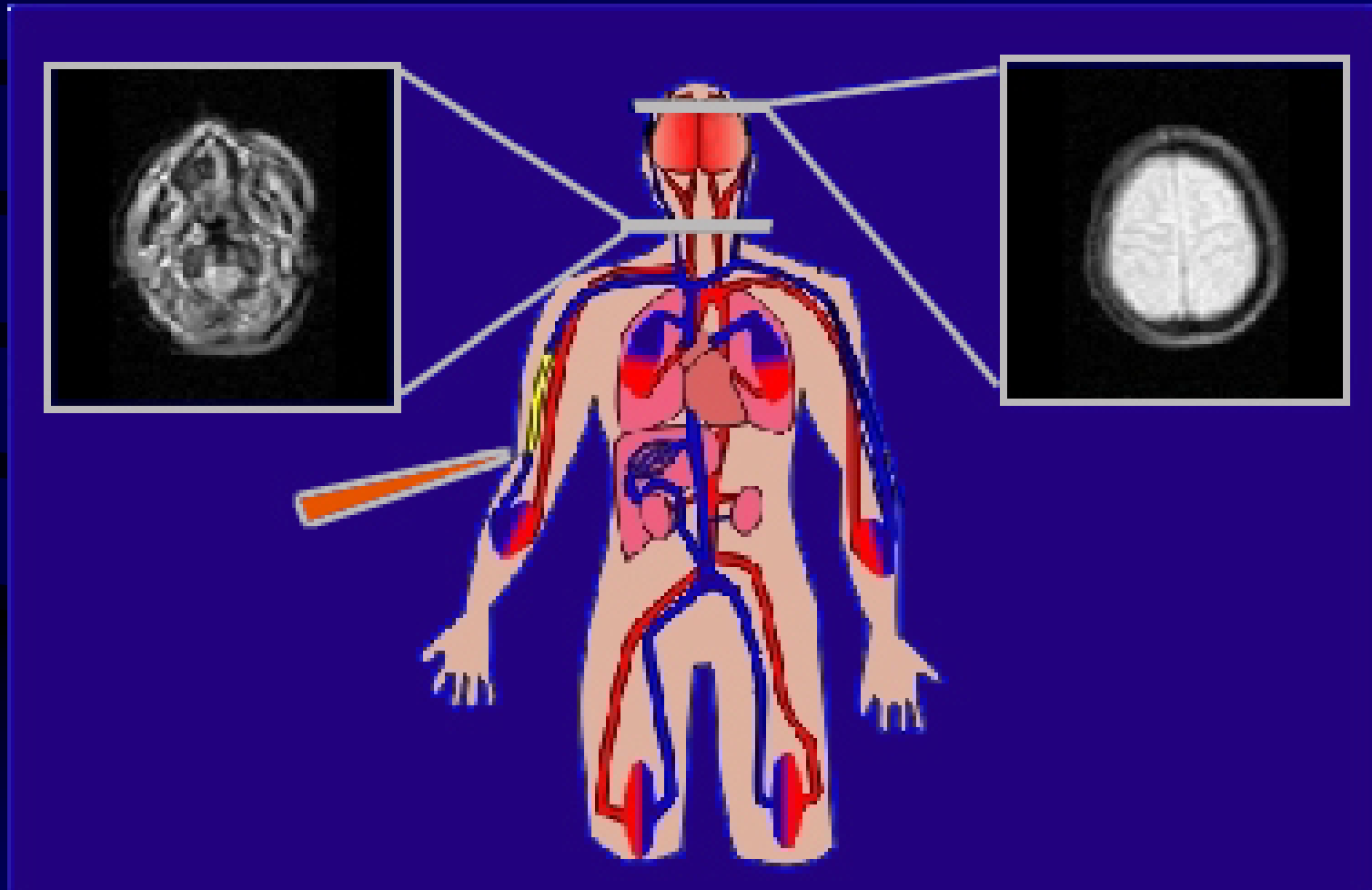
# **Perfusion MRI**

**Observation of the passage of  
a contrast agent, e.g. Gd-DTPA,  
by Rapid MR Imaging Methods,  
e.g. Echo Planar Imaging (EPI)**

## **Advantages of Perfusion MRI (pMRI)**

- **Higher spatial resolution**
- **No patient exposure to ionizing radiation**

# Experiment of Perfusion MRI :

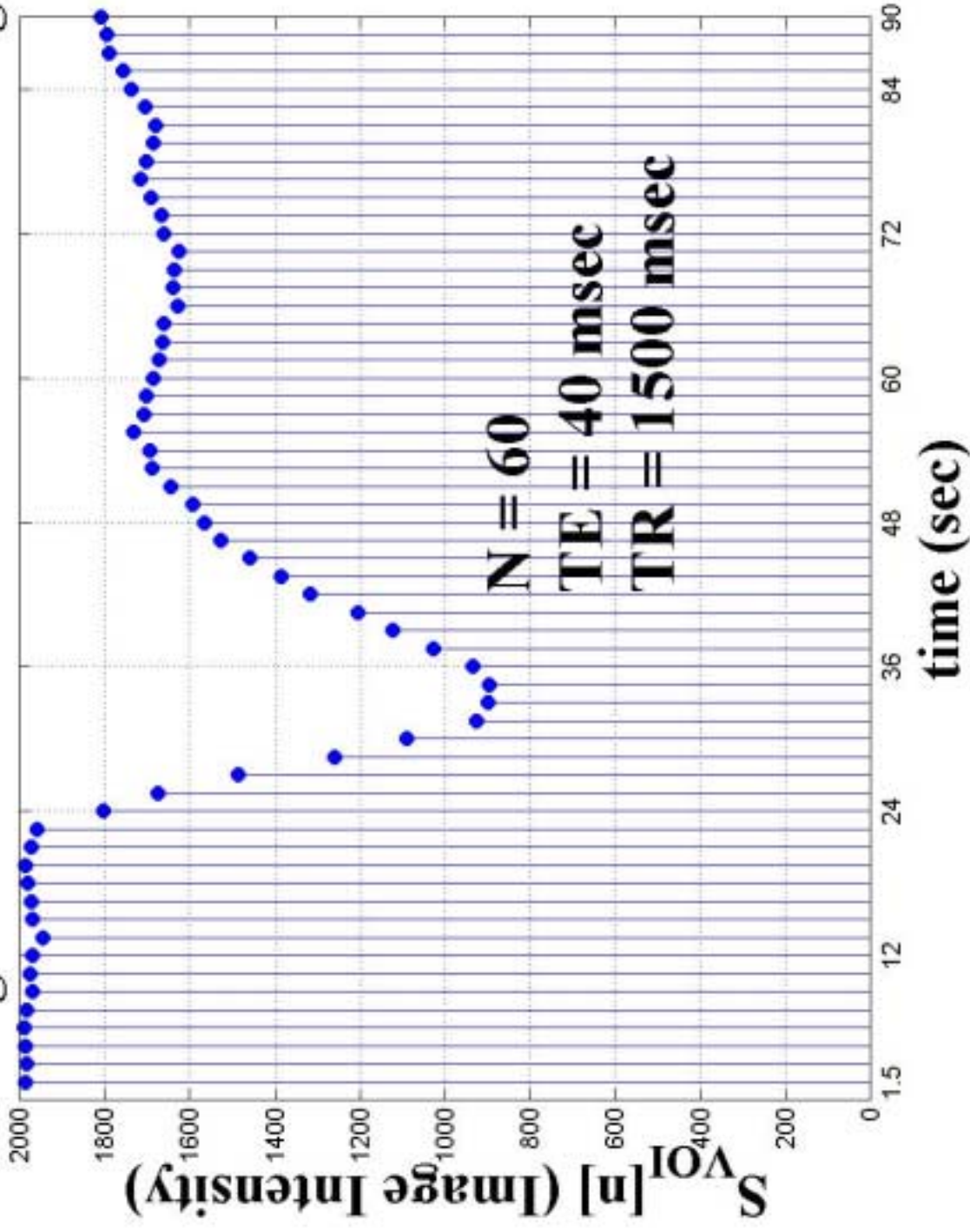


# Theory

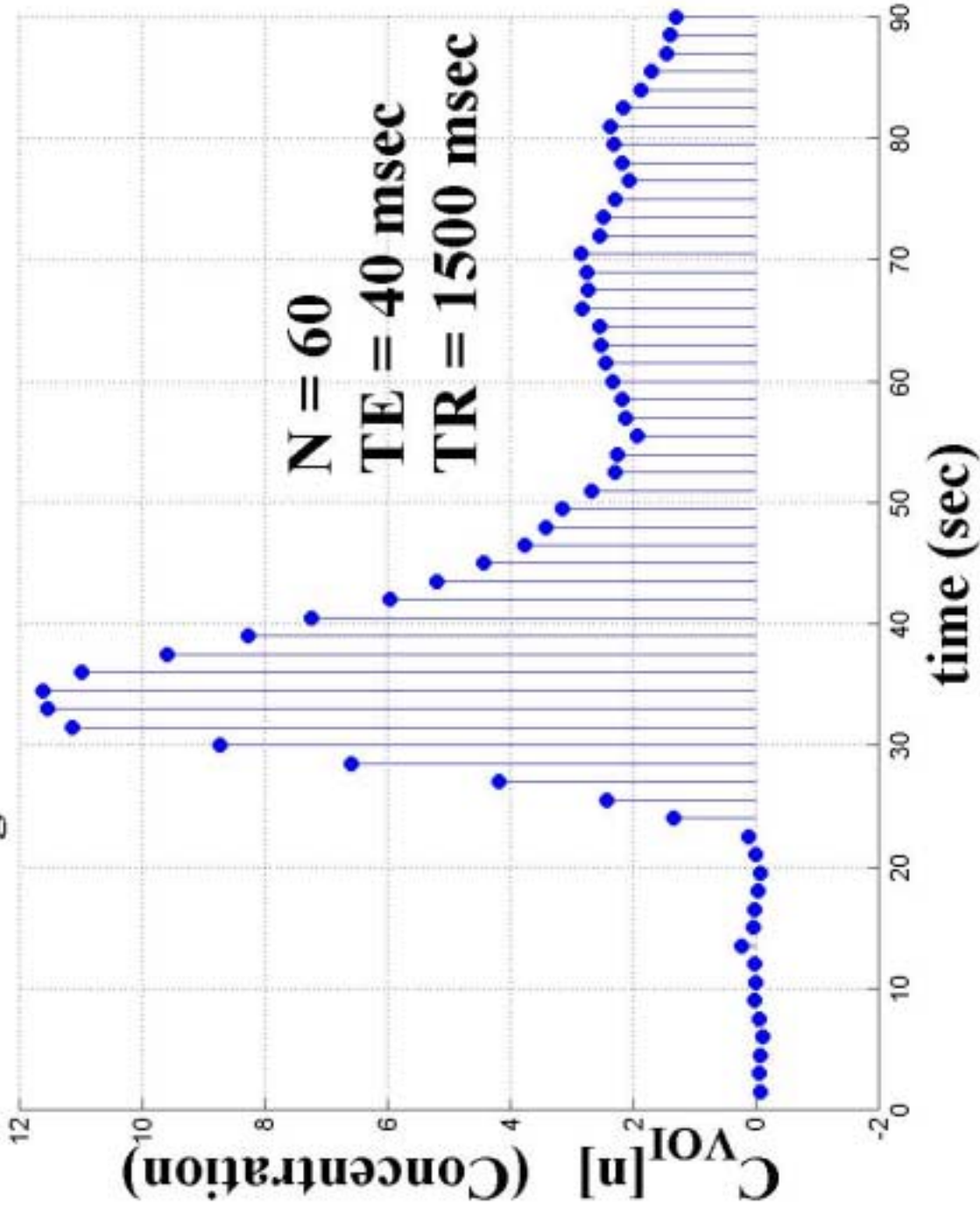
## Changes in Transverse Relaxation Rate

$$\begin{aligned} C(t) &= k \cdot \Delta R_2 \\ &= -\frac{k}{TE} \ln \left[ \frac{S(t)}{S_0} \right] \end{aligned}$$

# MR Signal Extracted from Real Clinical Images



# Concentration Signal Extracted from Real Clinical Images



# Essential Equation

$$C_{VOI}(t) = \frac{\rho}{k_H} F \int_0^t C_{AIF}(\tau) R(t - \tau) d\tau$$

**$k$**  : Correction Factor

**$p$**  : Density of Brain Tissue

**$F$**  : Cerebral Blood Flow (CBF)

**$C(t)$**  : Concentration of Contrast-Agent

**$R(t)$**  : Residue Function

# Discretization

$$\begin{aligned}C_{VOI}(t_n) &= \frac{\rho}{k_H} F \int_0^{t_n} C_{AIF}(\tau) \cdot R(t_n - \tau) d\tau \\&= \frac{\rho}{k_H} F \cdot \left[ \sum_{m=0}^n C_{AIF}(t_m) \cdot R(t_n - t_m) \right] \cdot \Delta t \\&= \frac{\rho}{k_H} F \cdot \left[ \sum_{m=0}^n C_{AIF}(m \cdot \Delta t) \cdot R((n - m) \cdot \Delta t) \right] \cdot \Delta t \\&= \frac{\rho}{k_H} F \cdot \Delta t \cdot \left[ \sum_{m=0}^n C_{AIF}[m] \cdot R[n - m] \right]\end{aligned}$$

## Discrete-time Equation

$$C_{VOI}[n] = \frac{\rho}{k_H} F \cdot \Delta t \cdot C_{AIF}[n] \otimes R[n]$$

# Model-Independent Methods

Residue Function : Unknown }  
Imaging Speed  $\Rightarrow$  Noisy Data }

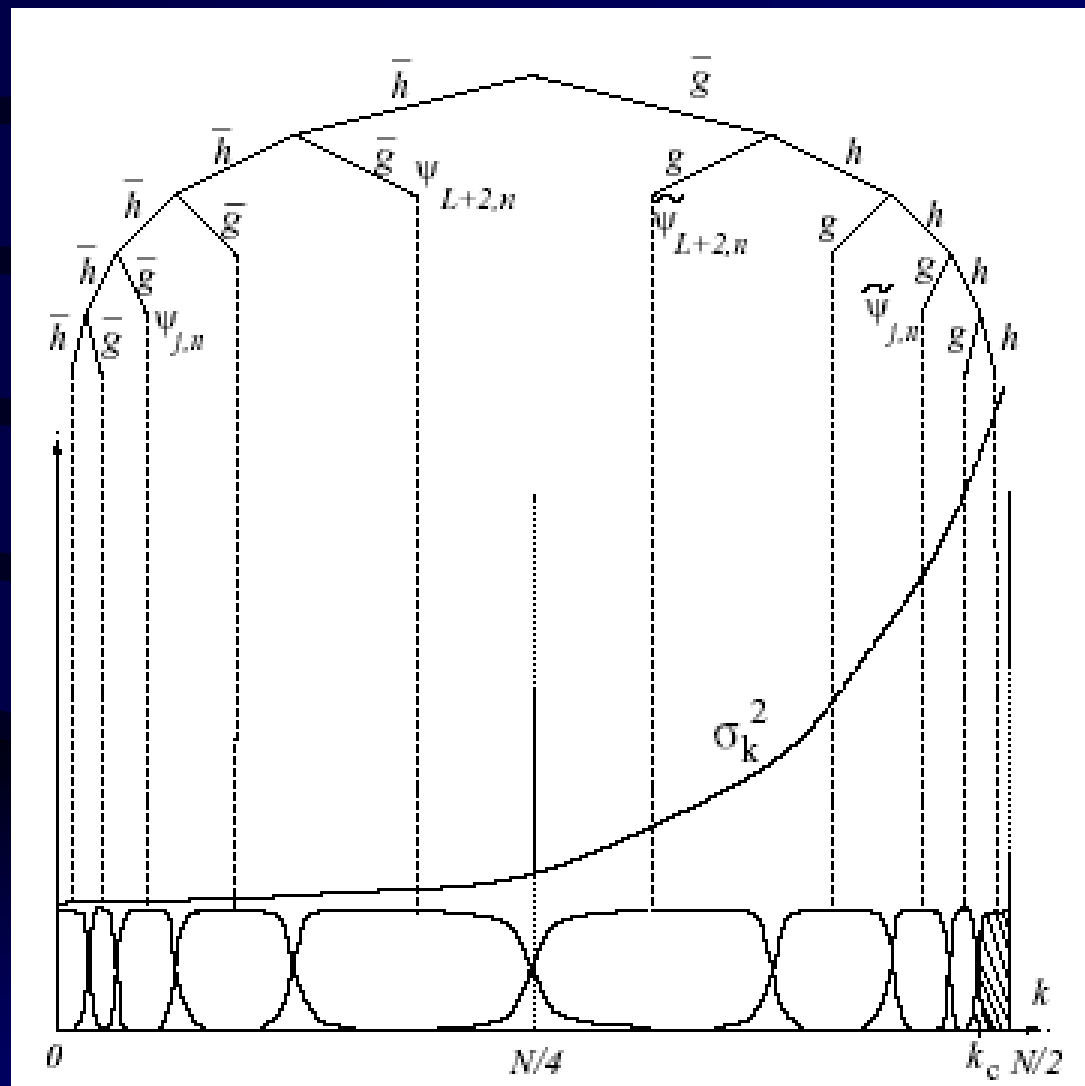
$\Rightarrow$  *Deconvolution* Problem

# Measuring CBF using Wavelet Transform

## Deconvolution in Mirror Wavelet Basis

- Inverse Convolution in presence of noise
- Decomposition in Mirror Wavelet Basis
- Soft-Thresholding of Wavelet coefficients
- Hard-Thresholding of Finest Scale
- Reconstruction in Mirror Wavelet Basis
- Shift-Invariant Algorithm

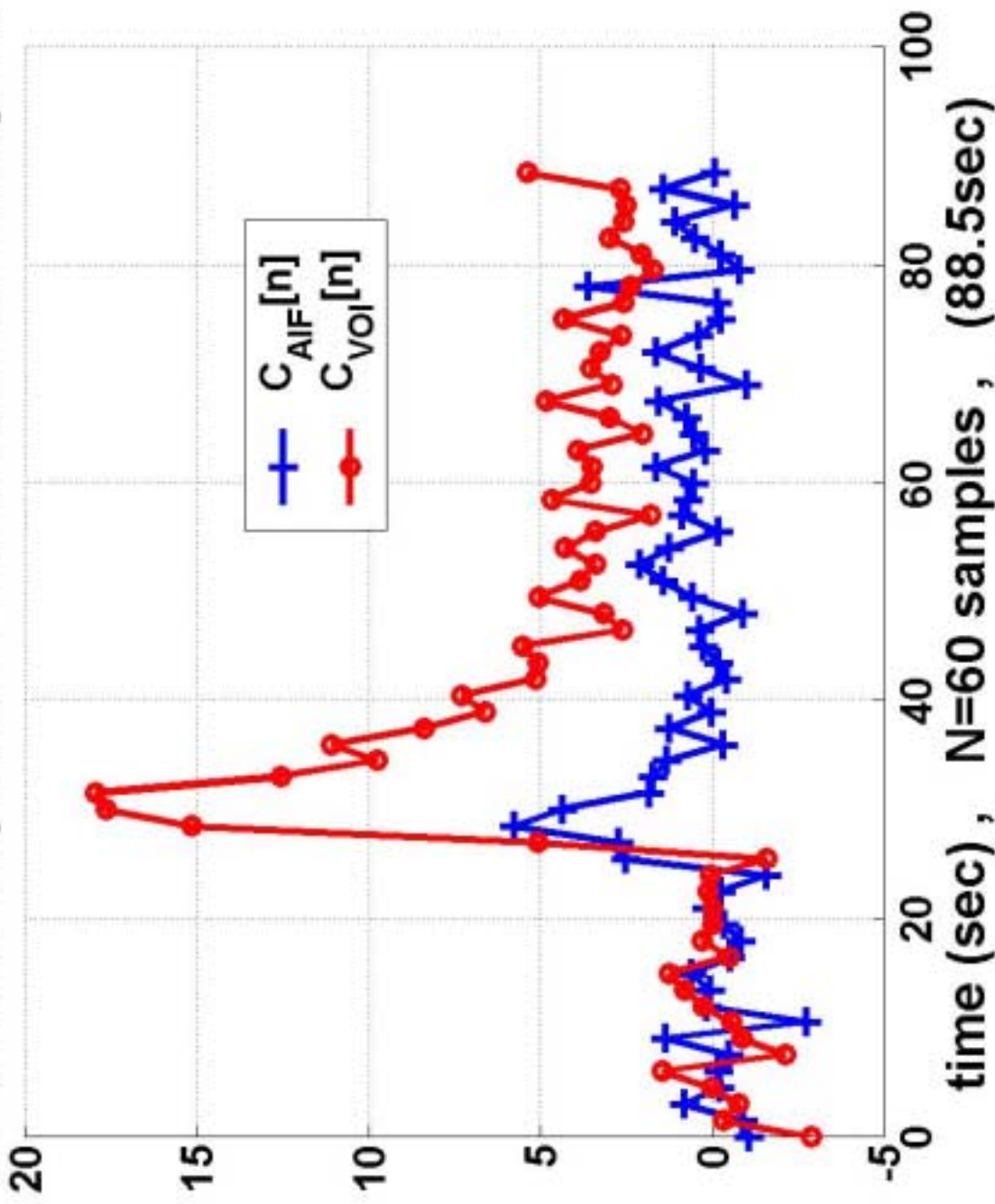
# Mirror Wavelet Basis



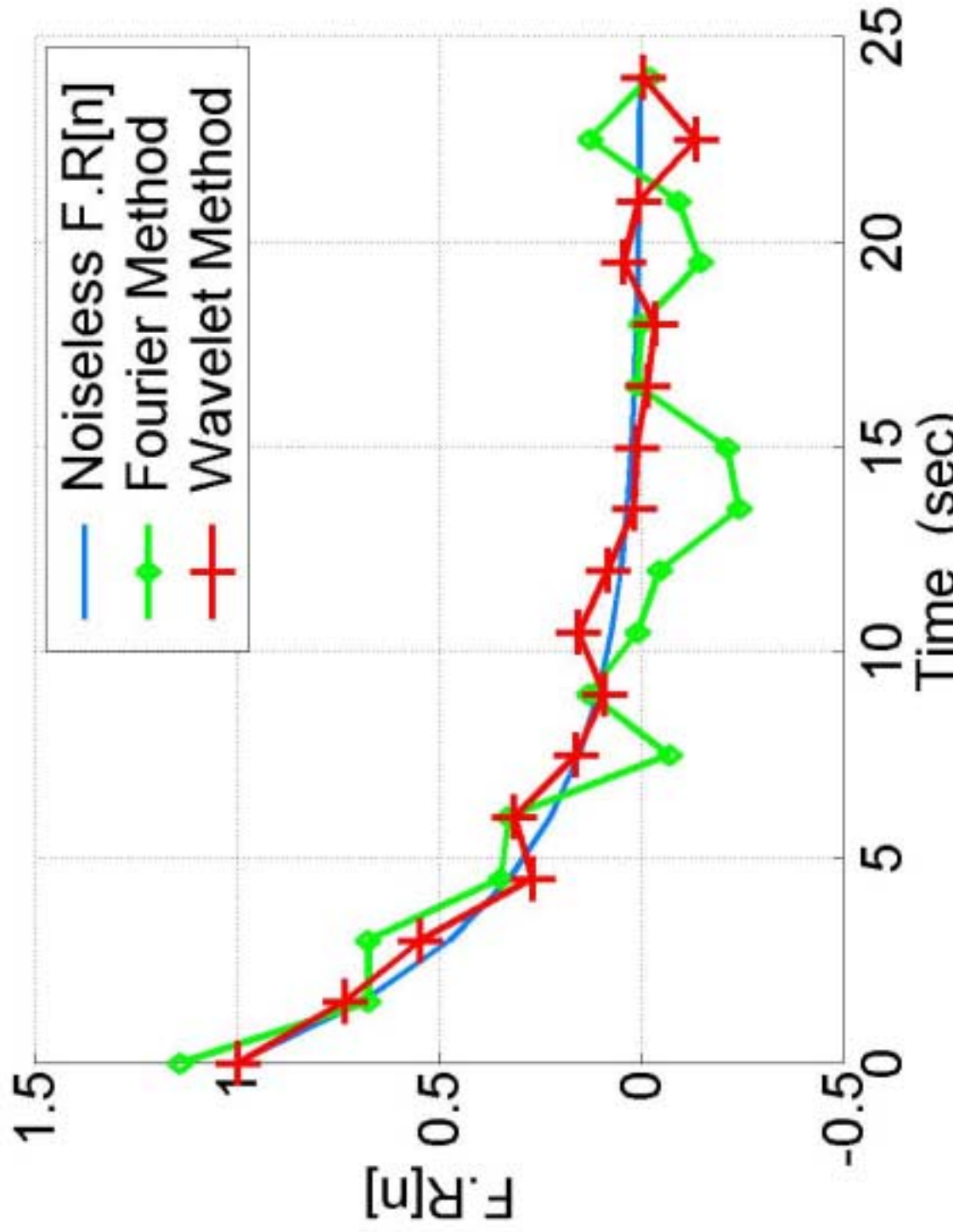
# Simulations

- **Arterial Input Function (AIF):**  
**Gamma-Variate Function**
- **Residue Function:**  
**Exponential Function**
- **Recirculation:**  
**Adding an Exponential to the AIF**
- **Noise:**  
**AGWN to MR signal**

# Simulated Noisy AIF and VOI Concentration Signals



# Results



# Conclusion

- **The Mean Square Error is improved compared to the Fourier Method.**
- **The proposed method seems promising. It can be extended to clinical applications by choosing an appropriate thresholding parameter, i.e., the maximum amplitude of mirror wavelet coefficients.**