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Contrast Uptake Analysis In Dynamic Susceptibility Contrast MRI Perfusion

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***Abstract*—Magnetic resonance imaging is a well-established medical imaging technique used in radiology to visualize internal structures of the body in detail and also for the detection of pathologies such as brain tumors. But conventional MR techniques continue to have limitations like inability to reliably distinguish high-grade from low-grade tumors. In order to overcome these limitations DSC MRI i.e. Dynamic Susceptibility Contrast MRI perfusion is used. This paper briefly describes an overview of contrast MRI technique and Gamma Variate Fitting (GVF) algorithm for contrast uptake analysis in case of Dynamic Susceptibility Contrast MRI perfusion. GVF approach is proposed for estimation of vital cerebral parameters like Cerebral Blood Volume (CBV), Cerebral Blood Flow (CBF), Mean Transit Time (MTT) and Time To Peak (TTP) which will assist detection of various pathological structures.**

***IndexTerms*—DSC MRI, Gamma Variate Fitting, cerebral parameters, MR perfusion.**

INTRODUCTION

Magnetic Resonance Imaging (MRI) or nuclear magnetic resonance imaging (NMRI) is a medical imaging technique used in radiology to visualize internal structures of the body in detail. MRI makes use of the property of nuclear magnetic resonance (NMR) to image nuclei of atoms inside the body. This radiographic technique is similar to a computerized topography (CT) scanner in that it produces cross-sectional images of the body. The advantage of MRI over CT is, it does not use X-rays. Instead, it uses a strong magnetic field and radio waves to produce very clear and detailed computerized images of internal structures of the body.

MRI is commonly used to scan brain, spine, joints, abdomen, and pelvis. A special kind of MRI, called magnetic resonance angiography [1] (MRA) helps in examining the blood vessels.. It can also be used to further evaluate an abnormality seen on a CT scan.

A MRI scanner is a device in which the patient is made to lie within a large, powerful magnet where the magnetic field is used to align the magnetization of some atomic nuclei in the body, and radio frequency magnetic fields are applied to systematically alter the alignment of this magnetization.

DYNAMIC SUSCEPTIBILITY CONTRAST MRI

Dynamic Susceptibility Contrast (DSC) MRI is an imaging technique used for measuring perfusion of the brain [2]. The perfusion of the brain is essential to maintain brain function. Stroke is an example of a decrease in blood flow and reduced perfusion. During ischemic stroke the blood flow to tissue is hampered due to a clot inside a vessel. To investigate the recovery of stroke patients, follow up studies are necessary. MRI is the preferred imaging modality for follow up because of the absence of radiation dose concerns, contrary to CT.

Dynamic susceptibility contrast (DSC) MRI offers unique information about cerebral hemodynamics both at rest and in response to brain activation. The technique requires intravenous contrast delivered through an automated power injector attached to an IV. The scanner creates an image showing multiple cerebral perfusion parameters including cerebral blood flow, mean time to enhance, and negative enhancement integral or cerebral blood volume. These techniques are most beneficial to patients with vascularstenosis, stroke, and pathologies like brain tumors. DSC perfusion gives the most thorough evaluation of cerebral blood flow. In addition to flow, the technique gives other parameters such as blood volume and transit time that allow the neuro-radiologist to more accurately depict the true state of the brain perfusion. These additional parameters have been thoroughly studied with regard to stroke and tumor[3] evaluation.

The perfusion parameters can show brain tissue at risk of stroke before the stroke has occurred. The best example of this is a patient with a transient ischemic attack [4] or TIA. These patients have brief stroke like symptoms and but may have a normal MRI. DSC perfusion can reveal subtle perfusion changes that could allow possible therapeutic interventions to prevent a future stroke. Cerebral blood volume correlates with the tumor grade or how malignant the tumor is. Brain tumors are frequently heterogeneous when looked at under the microscope.

Perfusion [5] can help guide the neurosurgeon to obtain the most accurate biopsy sample of the tumor to optimize therapy after surgery. It can also help distinguish a brain metastasis, primary brain tumors, and an infectious process prior to surgery. DSC perfusion alone takes approximately 2 minutes of scanner time. While the contrast is
being injected, the scanner is dynamically acquiring images through the brain.

Contrast agents

Contrast agents are used in various techniques of MRI like Dynamic Susceptibility Contrast(DSC) MRI and Dynamic Contrast Enhanced(DCE) MRI.

The Contrast agent must hold propertieslike:

UseParamagnetic

Low molecular weight

Factors defining the behavior of contrast:

Characteristics of bolus delivery and vascular delivery.
Blood perfusion
Transport agents across the vessel wall.
Diffusion of contrast agent in interstitial space.

Contrast agents alter the relaxation time of atoms after oral or intravenous administration. They actually improvise the visibility of internal organs [6].

In DSC MRI technique the contrast used is Gadolinium which will decrease the MR signal intensity. Techniques like dynamic contrast enhanced MRI increase the signal intensity. DCE-MRI is used to characterize various structures and detect malignant tissues. Some advanced features in DCE include Contrast Enhanced Magnetic Angiography and double contrast administration.

As soon as the contrast is injected a time series of fast T_2^* weighted images is acquired. Figure 1 and figure 2 proves the use of contrast agent in improving the appearance of image after MR scan. Various structures of brain are clearly visible after contrast injection. The series of image acquisitions before and after contrast injection are applied with post image processing techniques like applying threshold and filtering, sharpening and segmenting.

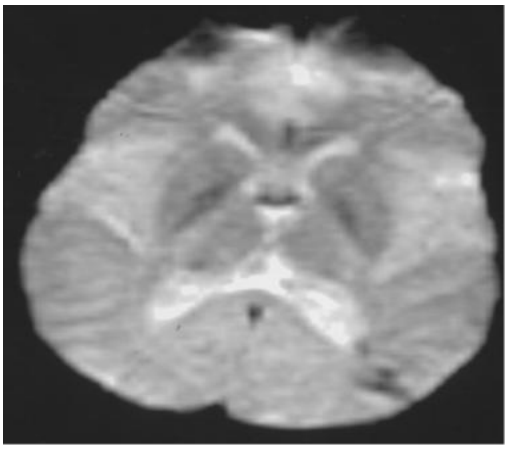

Fig 1: Image before contrast

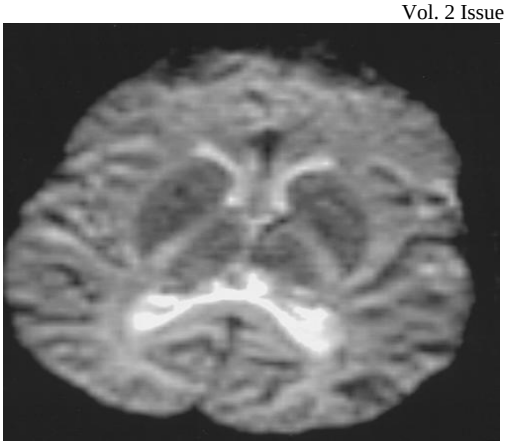

Fig 2:Image after contrast

Since the contrast agent is paramagnetic in nature, its susceptibility effect leads to loss of signal intensity.

Functional model

Loss of signal intensity due to change in relaxation time of tissues is mathematically converted to concentration change with respect to time according to the principles of indicator dilution theory[7].

According to the theory, change in concentration is represented as,

$$C(t) = K\,(t-AT)^{\alpha}\, e^{-(t-AT)/\beta} \qquad (1)$$

Where, t is time after contrast injection
C(t) is concentration at time, t
K is constant scale factor
AT is Appearance time of contrast
α , β are arbitrary parameters.

The coefficients are correlated and responsible for maintaining shape and size of the curve. According to literature raise and fall of curve is controlled by these parameters [8]. Appearance time is the time at which the contrast reaches tissue and alters the signal intensity. With respect to appearance time the concentration change is measured. Changing the coefficients in the curve will not only modify the shape and size of curve but also changes magnitude of peak [8].

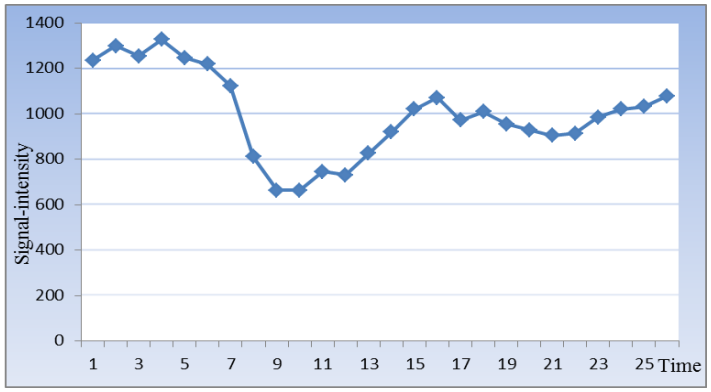

Fig 3: Gamma variate curve

Function is modelled carefully so that recirculation curve is not misinterpreted as bolus curve. In Figure 3, which represents a gamma variate curve, the first depression is the first pass of contrast bolus, where the contrast arrives and then departs causing intensity change. The second pass is usually considered as recirculation curve.

METHODOLOGY

Cerebral perfusion refers to delivery of blood to tissues inside brain. Hemodynamic perfusion imaging is done for a series of clinical application such as tumor characterization, diagnosis of stroke and other disorders.

Signal intensity –time curve and gamma variate curve

Perfusion imaging in brain is performed using first pass of contrast bolus. A fast series of T_2^* weighted MR images are acquired and monitored for contrast bolus. As soon as the contrast reaches the tissues, it alters the relaxation time of the same i.e. T_1, T_2, T_2^*. Due to this, there will be a drop in signal intensity. As the contrast arrives, there will be a drop in signal intensity and intensity rises as the contrast washes out. Because the contrast is not fully washed out, a recirculation curve is seen. The profile of signal intensity vs. time can be interpreted as a gamma variate curve as in figure 4. Gamma variate function describes the time points at which contrast appears and disappears after washout. The function is proportional to blood flow in cerebrovascular structures. Modeling the function is typically difficult due to the problems like recirculation, signal noise and also turbulence of blood flow.

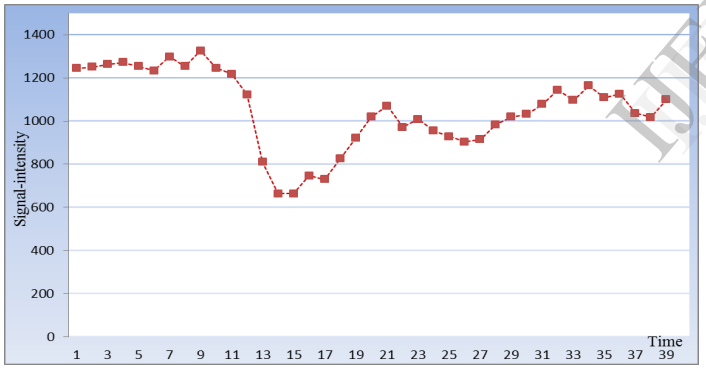

Fig 4: Signal-intensity vs. time graph

Curve fitting

The intensity time curve generated after contrast injection, which is a gamma variate curve, is to be fit for result generation. The crude form of signal is filtered using image processing filtering technique to remove noise. Thus input to the fitting algorithm is a filtered signal intensity curve.

Intensity-time curve is then mathematically converted to a profile of concentration – time curve. Fitting technique used is based on linear least square approximation, which finds the best fit curve for the original curve. In Figure 5, red color curve is the original gamma variate signal and blue color curve is fit curve. The final approximated curve is then integrated to yield coefficients. These coefficients are directly proportional to various cerebral perfusion parameters like cerebral blood volume, cerebral blood flow, mean transit time and time to peak.

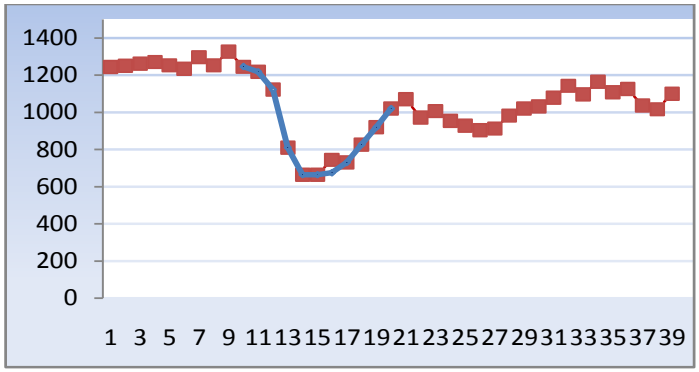

Fig 5: Approximated gamma variate curve

The sequence of steps for the calculation of perfusion parameters is shown in fig 6. The input required is MRI signal after contrast injection.

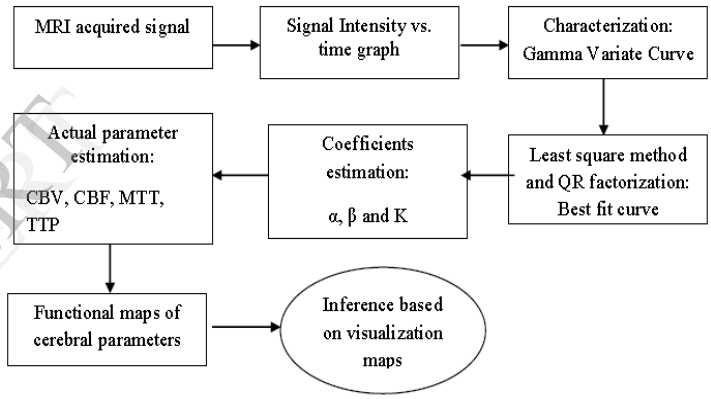

Fig 6: Sequential steps for parameter estimation

After the contrast bolus passage, MR signal is acquired and intensity vs. time profile is obtained. The characterized curve is approximated to a best fit curve. The parameters computed from the curve help physicians in detecting diseases.

I. CONCLUSION

Magnetic resonance imaging has now become the primary technique in the routine diagnosis of many disease, sometimes replacing computed tomography (CT). MRI has advantages such as, it is non-invasive, uses non-ionizing radiation, has high soft-tissue resolution and discrimination in any imaging plane. It may also provide both morphological and functional information. DSC MRI is a very promising technique for studying *invivo* perfusion in human organs, both in physiologic and in pathologic conditions. The method of gamma variate fitting is an efficient way to estimate perfusion parameters thus

providing an informative and accurate description of the pathology. This method of MR imaging can be useful in distinguishing high and low grade tumors.

If the initial signal is made much noise free, providing good input to the implementation algorithms, accurate values of perfusion parameters can be obtained. Thus, MR imaging technique is a boon in the field of diagnosis and medicine.

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