Asian Forum Ⅱ: Perfusion MRI

SY24-1

Perfusion Physics

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Perfusion is referred as the blood supply to micro capillary in tissue. Perfusion parameter such as blood flow, blood volume is a good biomarker to understand blood supply to tissue, viability, and angiogenesis. By definition, perfusion is biological or physiological phenomenon, however, many engineering technologies and basic physics are involved in the MR perfusion acquisition pulse sequence, perfusion analysis model and image processing. There are several approaches to measure perfusion using MRI. Arterial Spin Labeling is a non-invasive perfusion measurement method. Spin inversion induced by RF pulse irradiation is used to “label” the in-flowing blood. The perfused blood signal causes signal intensity change so that perfusion can be measured. Dynamic Susceptibility Contrast MRI measures dynamics of the injected contrast agent and then visualize tissue perfusion parameters from MR signal change. Gradient or Spin Echo EPI is used to measure signal change associated with contrast passage in the tissue. Dynamic Contrast Enhanced (DCE) MRI is another perfusion measurement method based on contrast injection. DCE is used to measure tissue permeability and contrast leakage, thus it has been commonly used for tumor imaging. In this talk, physics and technical background of MR perfusion acquisition pulse sequences, quantitative analysis models and image processing methods will be discussed. We will also discuss the advantages and challenges for each method to understand current status of MR perfusion imaging methods.

Keywords : MR Perfusion, ASL, DSC, DCE

Asian Forum Ⅱ: Perfusion MRI

SY24-3

DCE-MRI in Breast Cancer

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Breast dynamic contrast-enhanced (DCE)-MRI refers to MR imaging techniques with temporal resolution of 2 minutes or less to assess the changes of contrast uptake and washout in tumors. Semi-quantitative analysis of temporal changes of signal intensity includes the slope of curve, the time to peak, the maximum peak enhancement, signal enhancement ratio (SER), or kinetic pattern including washout, plateau, and persistent type. Rapid enhancement and washout pattern usually indicates higher vascular permeability found in fast-growing, malignant tumors and persistent enhancement indicates slowly growing, benign tumors. Semi-quantitative analysis has been widely used to differentiate benign from malignant tumors, to characterize tumors, and to predict response to neoadjuvant chemotherapy in the clinical breast imaging, as it is reproducible and easy to obtain.

Refined quantification of exchange of contrast agent between vascular space and interstitial space is expected to provide more sophisticated hemodynamic information than the semi-quantitative analysis. However, the quantitative analysis requires simplified assumptions between vascular space and interstitial space, tissue T1 values, estimation of arterial input function, post-processing software and high temporal resolution (<10sec) technique. One of most commonly used pharmacokinetic models is two-compartment model by Tofts. It is described by three parameters: the transfer constant (Ktrans; the rate constant of contrast agent transfer from the plasma space into the extracellular extravascular space, units: min-1), the extracellular extravascular space (Ve; units: %), and the rate constant (Kep; the rate constant of contrast agent escape from the extracellular extravascular space back into the plasma compartment= Ktrans / Ve, units: min-1). Measurement of these parameters is more complicated, because breast MR image with very high temporal resolution leading to poor spatial resolution, which is more important in clinical breast imaging. Recent technologic advances such as parallel imaging, non-rectalinier K-space sampling, or key-hole technique enables both very high temporal resolution (<5sec) and relatively high spatial resolution (1x1x1mm) image such as ultrasfast breast DCE-MRI.

In this lecture, advantages and disadvantages of semi-quantitative and quantitative breast DCE-MRI and their applications in the clinical and research fields will be presented. In addition, potentials of ultrafast breast DCE-MRI will be discussed.

Keywords : Breast, Cancer, DCE-MRI

Asian Forum Ⅱ: Perfusion MRI

SY24-4

Introduction to DCE tracer kinetic modelling

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Dynamic Contrast-enhanced (DCE) computed tomography (CT) and DCE magnetic resonance imaging (MRI) can be performed for focal liver lesions. DCE scans differ from clinical dynamic scans and aims to derive quantitative information about the microcirculation. The target lesion, the aorta and the portal veins are repeatedly imaged at high temporal resolution (2 to 12 seconds) in DCE studies. The concentration-time curves of the target, the aorta and the portal vein can be analysed by simple empirical parameters (such as maximum initial slope, peak enhancement, time to peak, and initial area under the curve) or by tracer kinetic modelling. Although empirical curve parameters are simple to measure, they do not correlate directly with properties of the microcirculation. A simulation study has shown that maximum initial slope correlates with blood flow. The other empirical measures do not correlate directly with microcirculatory parameters. The data can also be analysed by tracer kinetic modelling to yield microcirculatory parameters of blood flow, permeability, % intravascular volume and % interstitial volume. Tracer kinetic models are based on a schematic capillary and injection of a microbolus into the arteriole of the schema. Mathematical calculations are based on the kinetics of the tracer as it traverses the schematic capillary, leak into the interstitium, and subsequently leak back into the capillary and flow away. The arterial bolus in a clinical scan is approximated as a series of microboluses separated by short intervals of time by a mathematical technique known as convolution. With this known arterial input observed from the patient, the behaviour of the modelled voxel is fitted with different values of blood flow, permeability, and other microcirculatory parameters to match the observed lesion voxel. The computer performs this curve fitting and the best match is taken to reflect the truth state. Different types of models are compared and explained. Simpler models (such as generalized kinetic model with Ktrans and ve) have more assumptions and simplifications and is not as physiological as complicated models such as a distributed parameter model. The assumptions of the generalized kinetic model, which is commonly used, is explained. However, complicated models require attention to technique and fast data acquisition to show realise better results.

Keywords : DCE tracer kinetic modelling, Ktrans, Distributed parameter model

Asian Forum Ⅱ: Perfusion MRI

SY24-5

DCE (Dynamic contrast enhancement) scan of bone sarcoma (osteosarcoma)

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Variable imaging modalities have been applied for detection of musculoskeletal tumors, such as bone sarcoma. X ray is the choice for diagnosis and differential diagnosis. CT scan provides more information about tumor details and lung metastasis. Bone scan and PET CT may screen metastasis. MR imaging is the most important advanced imaging modality for tumor staging and post operative follow up.

Nowadays pre-surgical chemotherapy plays an essential role in treatment and prognosis of bone sarcoma, especially osteosarcoma. Osteosarcoma (OGS) is the most common malignant bone tumors in children and adolescents. The chemotherapy response is determined by degrees (percentage) of pathological necrosis.

Recently, quantitative MR imaging has been proved to be feasible for assessment of musculoskeletal tumors. Quantitative imaging can provide vascularization and cellularity of bone tissue. Dynamic contrast enhanced (DCE) imaging had been used in evaluation of tumor response of OGS post chemotherapy.

In conventional DCE imaging the time intensity curve (TIC) pattern and slope is available for analysis. New pharmacokinetic model has made assessment of tissue microcirculation with regard to the endothelial integrity possible. In two compartment model parameters can be calculated and quantified as Ktrans (volume transfer constant), Ve (extravascular extracellular space distribute volume per unit tissue volume), Vp (plasma volume per unit volume of tissue), and Kep (microvascular permeability reflux constant). These powerful quantitative data have great potential in assessment of tumor microcirculation and necrosis.

Consequently, imaging of bone sarcoma or OGS is still challenging. Variations of imaging patterns of OGS make diagnosis difficult. Advanced quantitative MRI is feasible to establish valuable imaging information for OGS and to predict patient's outcome.

Keywords : Dynamic contrast enhancement, MR, Bone, Sarcoma

Asian Forum ll: Perfusion MRI

SY24-6

Arterial Spin Labeling in transient ischemic attack and acute stroke: evaluation of collateral status and prognostication

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Arterial spin labeling (ASL) magnetic resonance perfusion has an advantage of being non-invasive, as it does not require intravenous injection of an exogenous tracer. ASL uses electromagnetic labeling of the naturally occurring water in the blood to acquire images sensitive to flow. The endogenous perfusion contrast in the images gathered by this technique comes from the subtraction of two successively acquired images: one with and the other without proximal labeling of arterial water spins after a small Post-Labeling Delay (PLD) time.

The recent introduction of pseudo-continuous arterial spin labeling (pCASL) technique into clinical practice (1) has opened up a new arena for assessment of cerebral perfusion in stroke and transient ischemic attack (TIA). It applies a long labeling pulse (100 times larger than normal pulsatile ASL) to get a better label and has the same good labeling as continuous ASL but does not have SAR problem.

pCASL source images could be interpreted visually without additional post-processing to obtain cerebral blood flow, which is fast and straightforward in clinical practice (2).

Presence of Arterial Transit Artifacts (ATA) is a practical issue when interpreting the ASL source images. When the transit time is prolonged due to pathological changes, or the PLD given is not long enough, any late-arriving spins remains in the vessels would show linear/serpiginous high signals, known as ATA. A simple collateral score (CS) system based on the appearances of ATA has been proposed and applied to estimate the extent of collateral development in Moya-Moya disease. This talk aims to discuss our experience in using ATA to assess collateral flow in acute stroke/TIA.

References

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Keywords : Arterial Spin Labeling, Transient ischemic attack, Acute stroke, Collateral status, Prognostication