SREE CHITRA TIRUNAL INSTITUTE FOR MEDICAL SCIENCES AND TECHNOLOGY, TRIVANDRUM, INDIA

LOG BOOK

SUBMITTED IN FULFILLMENT FOR THE COURSE OF

(DAMIT)

DIPLOMA IN ADVANCED MEDICAL IMAGING TECHNOLOGY

PERIOD: JAN 2015 – DEC 2016

TINTU THOMAS

SREE CHITRA TIRUNAL INSTITUTE FOR MEDICAL SCIENCES AND TECHNOLOGY, TRIVANDRUM.

CERTIFICATE

This is to certify that **TINTU THOMAS** has participated in Interventional cases and Imaging Cases during the period Jan 2015 to Dec 2016 while working as a Technologist student in the Department of Imaging Sciences and Interventional Radiology, Sree Chitra Tirunal Institute for Medical Sciences and Technology, Trivandrum, Kerala (India).

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Professor& Head,
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PREFACE

This work book, I have done as part of my training in the dept of radiology for diploma in Advanced Medical Imaging Technology (DAMIT) course includes brief details of the equipment used in the Dept, basic physics and working involved with the equipments, the routine protocols and the procedures followed in our different labs, number of cases which I have individually done in X-RAY, CT, MRI &3D WORKSTATION, and the cases which I have assisted in Neuro and Cardiac Cath Lab, I also have included the seminars and projects I have done.

DAMIT is a two years full time residential program in advanced medical imaging technology for qualified radiographers to excel and learn the newer techniques in medical imaging. Selection is done by a national level entrance examination. At present institute offers 3 seats.

The students are posted in the department of radiology equipped with all modern medical imaging facilities-State of art and top of the line-MRI system, Spiral CT system, DSA suit, Color Doppler ultra sound scanner and a radiology network with a central workstation with added 3D software and the division of Interventional Radiology make it a distinguished Radiology Dept .The course schedule contains theory classes, practical training, seminar presentations & projects. Diploma is awarded after successful completion of 2 Year term based on a written examination with viva-voce and internal assessment.

The Sree Chitra Tirunal Institute for Medical Sciences &Technology (SCTIMST), Thiruvananthapuram is an Institute of National Importance established by an Act of the Indian Parliament. It is an autonomous Institute under the administrative control of the Department of Science and Technology, Government of India.

The Institute signifies the convergence of medical sciences and technology and its mission is to enable the indigenous growth of biomedical technology, besides demonstrating high standards of patient care in medical specialties and evolving postgraduate training programs in advanced medical specialties, biomedical engineering and technology, as well as in public health

It has a 250-bedded hospital for tertiary care of cardiovascular and neurological diseases, a biomedical technology wing with facilities for developing medical devices from a conceptual stage to commercialization, and a center of excellence for training and research in public health.

The Institute has the status of a University and offers postdoctoral, doctoral and postgraduate courses in medical specialties, public health, nursing, basic sciences and health care technology. It is a member of the Association of Indian Universities and the Association of Commonwealth Universities

ACKNOWLEDGEMENT

First and fore most, I would like to thank my Head of the Department Prof. Dr. Kapilamoorthy , Prof. Dr C Kesavadas, Prof. Dr. Bejoy Thomas Asso Pro Dr..Jayadevan ER Asso Pro Dr. Santhosh K, and all other faculty members who had guided me through the different phases of my studies encouraged and helped me on all aspects of my training.

I thank the Director of the institute Dr Asha Kishore, Dean Dr Kalyana krishnan and the Registrar Dr. A.V George, for their advices and kind attention towards me.

I extent my heartful thanks to all the Radiographers, other staffs of radiology, staff members of different departments, for their help during my stay in the institute. I am thankful to the patients who were the core medium of study.

At last, I would like to acknowledge my sincere thanks to PG residents, senior and junior **DAMITS** for their co-operation at work place and in studies.

COURSE CURRICULUM

POSTING	NUMBER OF MONTHS
DSA	7
MRI	8
CT	8
CARDIOLOGY AND BME	15 DAYS

1. Every Thursday - 8:00 AM to 9:00 AM – Seminar

PRACTICAL DATA SHEET

A) Cases done in OPD X-Ray.
Equipment : SIEMENS Heliophos 4M 500mA.-+
No of Cases : More than 1700 (Chest, Spines, Pelvis, and Extrimities.)

B) Portable X-Ray.
Equipment : SIEMENS Simox D 40mA.GE genius 60mA0
No of cases : About 2500 including chest, abdomen, skull and CV Jn.

C) CT Scan.
Equipment : Brilliace iCT 256 slice/ Ge light speed dual
No of Cases : Head - 3000
Chest - 500
Abdomen - 300
CT Angios - 1100
Cardiac CT - 56

D) CT Interventional Procedures.
CT Guided Biopsies : 30
Bone Biopsies : 25
Stereotactic Studies : 45
Laser Ablations : 5

F) Magnetic Resonance Imaging.
Equipment:
Magnetom Avanto Tim 76 x 18 1.5T / GE Discovery 750w 3T
No of Cases Done :
Brain - 1900
Cervical Thoracic, & Lumbar Spines - 1300
Stereotactic MRI (Pallidotomy & Biopsy's) - 23
Musculo Skeletal System
(Pelvis, Hip joint, Knee, Shoulder joint Etc.) - 60

Cardiac imaging	-	100
Abdomen and Chest	-	30
MR Angiograms	-	290

H) D S A Lab.

Equipment : **GE innova 3131**. BiPlane System

No of Cases Assisted:

4Vessel Angios	**:**	450
Aortograms	:	50
IVDSA	:	3
Peripheral Angios	:	30
Spinal Angios	:	60
Coronary angio	:	6
Bronchograms	:	5
PTBD	:	45
WADA Test	:	25
BOT	:	4
Ba Studies	:	17

Interventional Procedures:

Angioplasty	:	140
PTCA	:	5
PDA Coiling	:	6
Embolization (Onyx,Glue& Particle)	:	120
GDC Embolization	:	60
Chemo. Embolization	:	26
Thrombolysis	:	12
Stenting	:	60
Tracheal Stenting	:	1
PLDD	:	6
Vertibroplasty	:	1
TESI	:	20
TGN laser ablation	:	9
Flow diverter	:	4
TEVAR	:	7
EVAR	:	3

SEMINARS PRESENTED

- CR & DR
- MRI Safety
- CT Angiographic Technique
- Interventional Procedures in DSA
- Contrast Media used CT,MRI & DSA
- Gradient echo pulse sequences & Clinical applications
- MR Angiography
- Flow and Haemo Dynamics & clinical application
- K space & parallel imaging
- Hybrid Imaging
- SWI & clinical application

INDEX

Magnetic Resonance Imaging

System Specification

1. SIEMENS Magneto Avanto Tim 76x18 1.5T

- Offering full iPAT functionality.
- Utilizes highest SNR.
- Q-engine (33 mT/m)
- SQ-engine (45 mT/m) with 50 cm FoV.

Magnet specifications

- Length - 150 cm
- Magnet bore diameter - 90 cm
- Total system length - 160 cm
- Magnet weight - 3,550 kg (approx)
- Super conductor - Ni-Ti
- No of field generating coils - 7

Gradient specifications

- Max Gradient amplitude - 40 mT/m (X & Y)
- Min rise time - 200μS
- Max slew rate - 200T/m/s

RF system

- RF transmit coil – Body coil
- Peak power of Transmitter amp – 15 kW
- Receiver band width – 500 Hz- 1MHz

Syngo platform

- *syngo* is the common software for siemens modalities.
- Panoramic Recon Image Processor, reconstructing up to 3226 images per second
- Host Computer - Pentium 4 based, 3 GHz and 2 GB RAM capacity.
- Spectro processing card.

2. GE DISCOVERY 750w 3T

- Offering parallel functionality & multidrive RF TRANSMIT Technology.
- Utilizes highest SNR.

Magnet specifications

- Magnet bore diameter - 70 cm
- Total system length - 130 cm
- Magnet weight - 3,550 kg (approx)
- Super conductor - Ni-Ti
- No of field generating coils - 7

Gradient specifications

- Max Gradient amplitude - 44 mT/m
- Min rise time - 220μS
- Max slew rate - 200T/m/s

RF system

- RF transmit coil – Body coil , Head coil & Extremity coil
- Peak power of Transmitter amp – 15 kW/channel[30kW total] for body & 4.5kW for head
- Receiver band width – ±250kHz

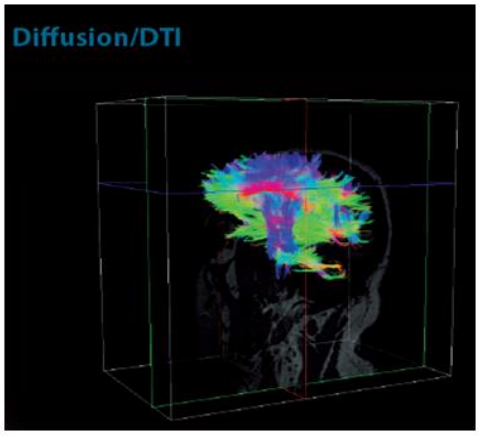
NEW POST PROCESSING SOFTWARE

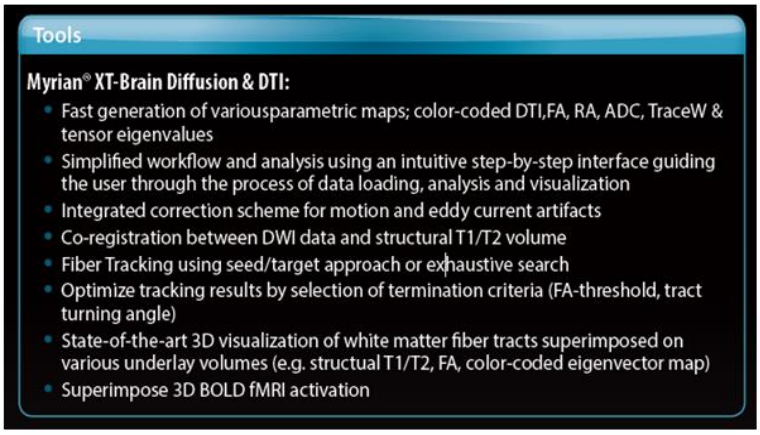
MYRIAN – INTRASENSE

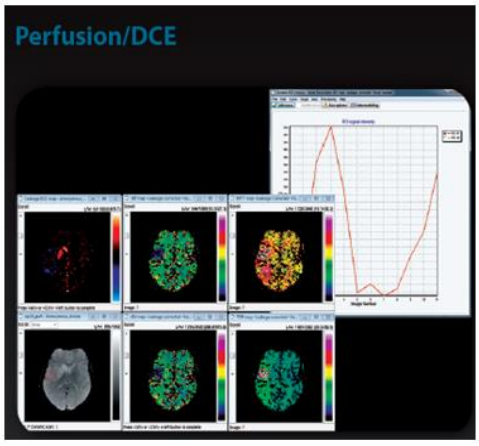
- Module based solution for Diffusion/DTI , Perfusion/DCE imaging
- Windows based software
- Vendor – neutral application , process image from any modality manufacture

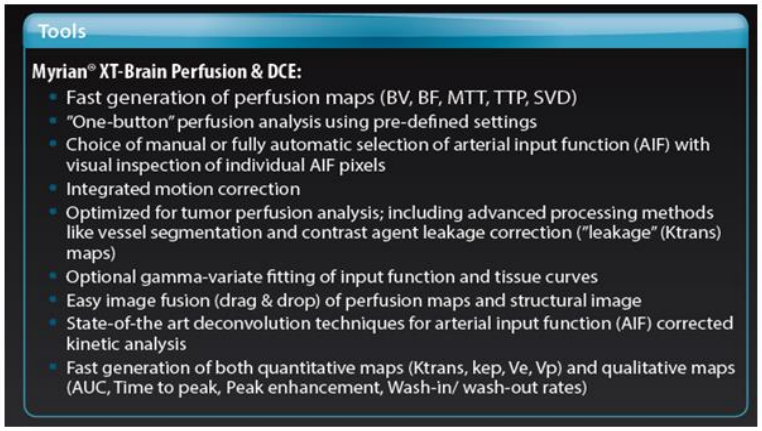
XT- BRAIN nordic ICE

Provide flexibility for research oriented work





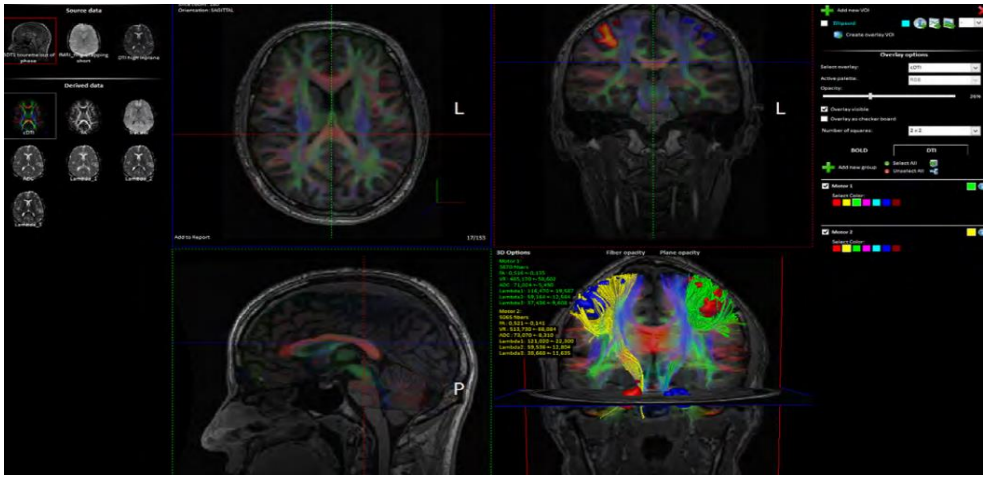




Nordic Brain EX :

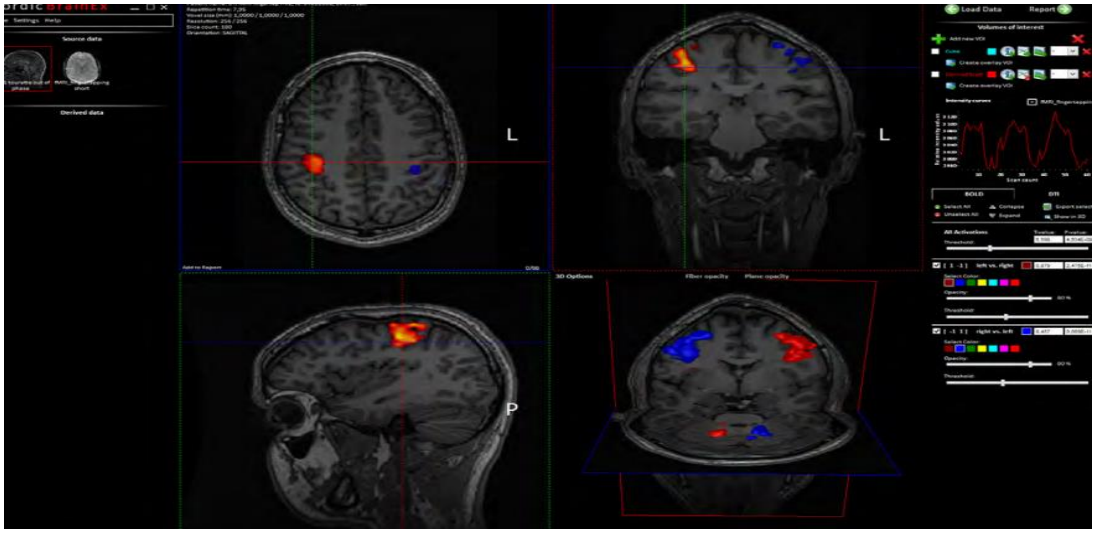
Clinical tool that focus on ease of use and efficiency in clinical setting

- DTI Fiber tracking Module

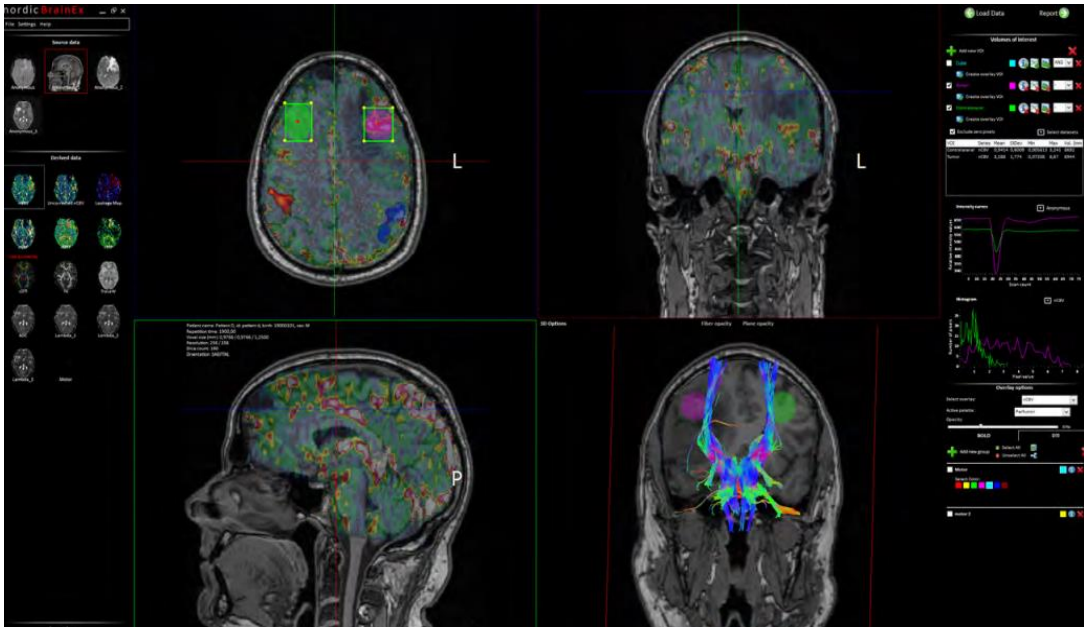


Preprocessing - Motion Correction, Eddy current correction, Smooth, Average, Adjust noise level
Fiber tracking – multiple VOI, AND OR & NOT option

- BOLD fMRI module



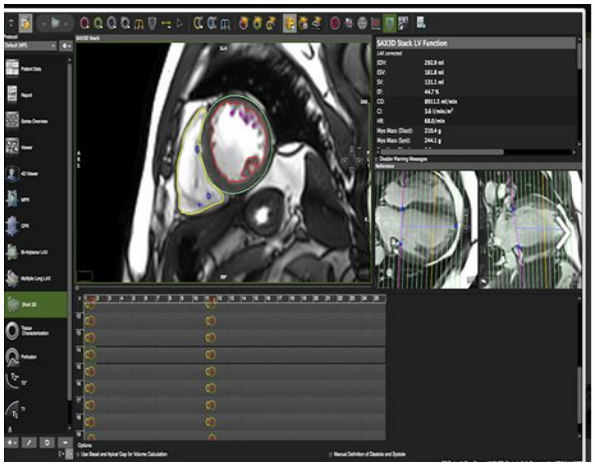
➢ Perfusion/DSC module

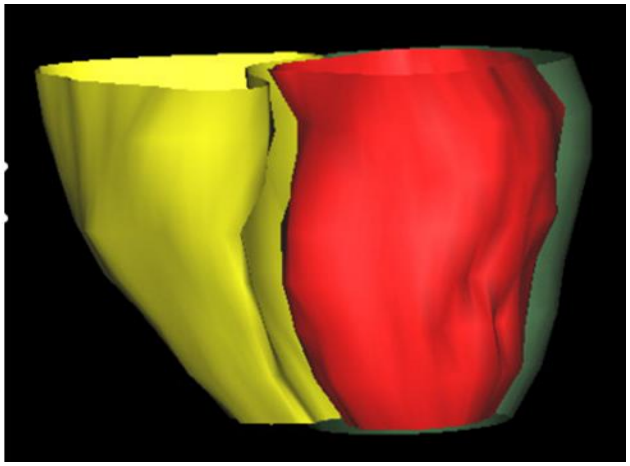


➢ Possible to combine the results from BOLD , DSC PERFUSION and DTI

CIRCLE CARDIO VASCULAR IMAGING

➢ LV/RV FUNCTION





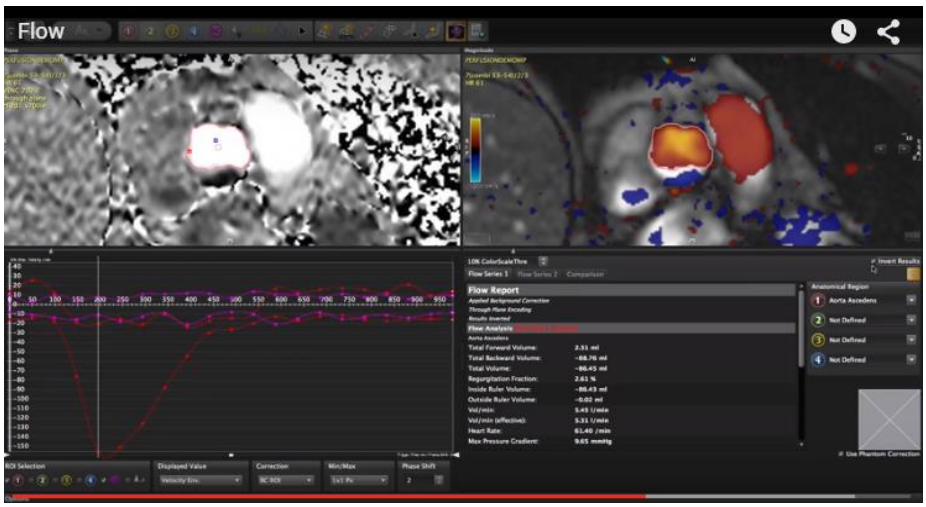
➢ Left and right atrial volumetric [disk area summation & area length method]

➢ Polar maps offering customizable segmentation including AHA segmentation model

➢ Semi-automatic mitral & tricuspid valve correction

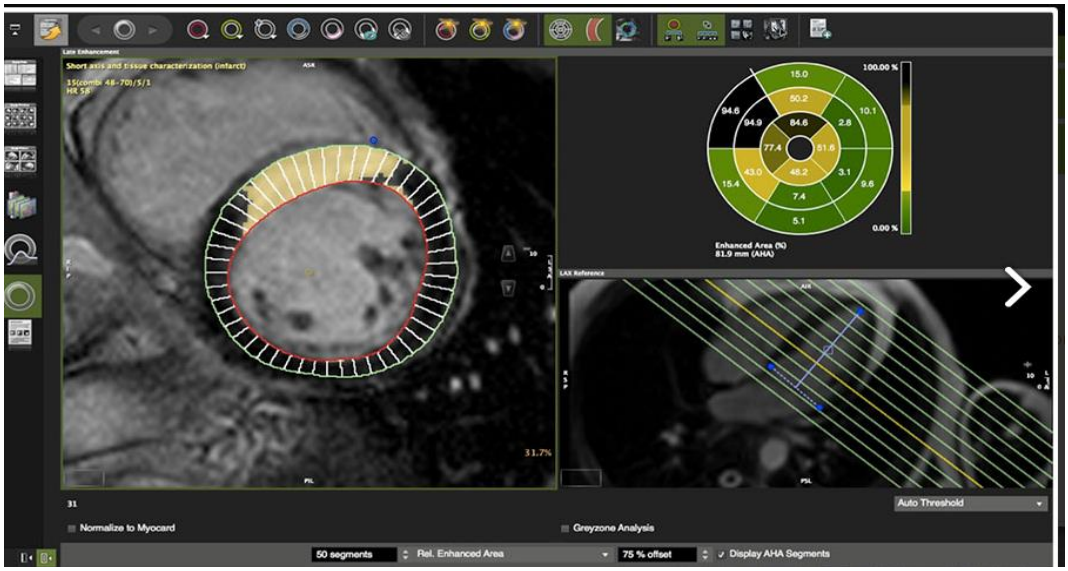
- Optional in- or exclusion of trabeculae and papillary muscles in/from myocardial mass
- Unique threshold based edge detection allows for quick and precise delineation of trabecular structures and/or papillary muscles
- 4D model of left and right ventricle (mesh or solid surface)

➢ FLOW



- Color coded flow velocities with adjustable color scale
- Automatic border detection, forwarding and registration
- Automatic synchronization of phase and magnitude images
- Flow and velocity analysis of up to four regions of interest in one series
- Flow analysis of two different series and calculation of flow difference, sum and ratio, etc. (to assess shunt volumin A and more)
- Display of flow velocity curves in an interactive diagram
- Background and phantom correction options
- Option of post–hoc flow direction inversion
- Wide range of calculated values including regurgitant volume and fraction, cardiac output, min/max and mean pressure gradients, as well as net positive and net negative volumes

TISSUE CHARACTERIZATION



Late Enhancement and T2 weighted imaging

- Qualitative and quantitative assessment of scar and edema
- Infarct core and "grey zone" quantification
- MVO assessment
- Calculation of myocardial salvage
- Existing contours can be derived from other sequences
- Various threshold settings, including an auto-threshold mode (Otsu) and Full-Width-Half-Max
- Polar maps of enhanced area and transmurality
- Color–coded 4D mesh model display of tissue characteristics

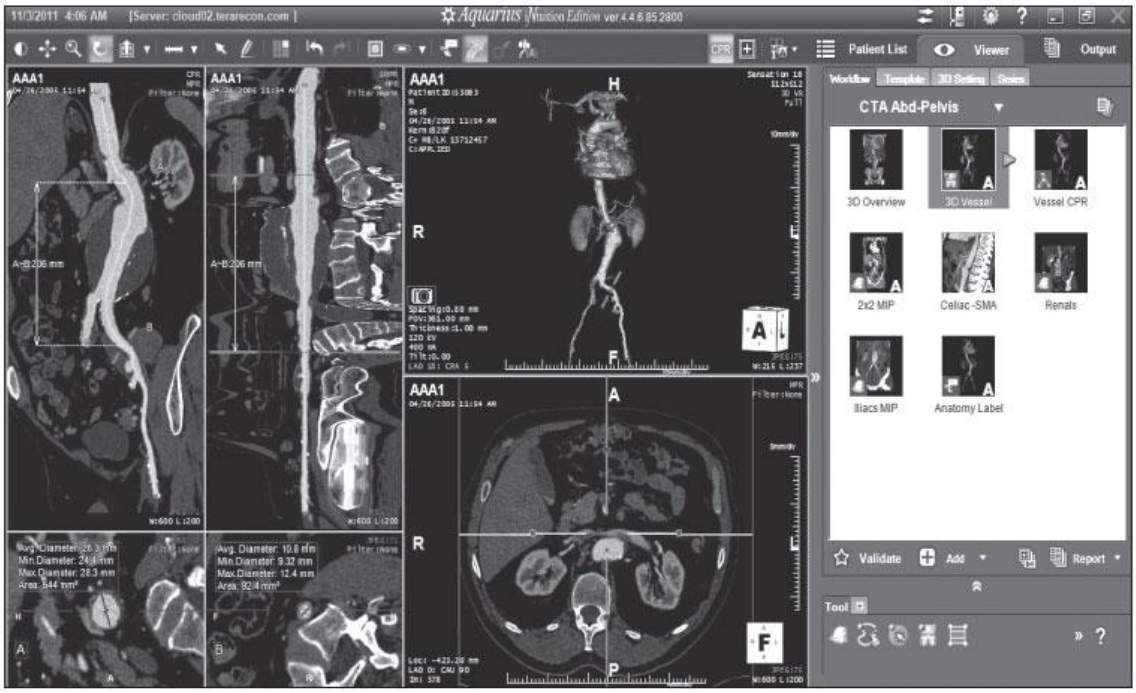
Early Gadolinium Enhancement

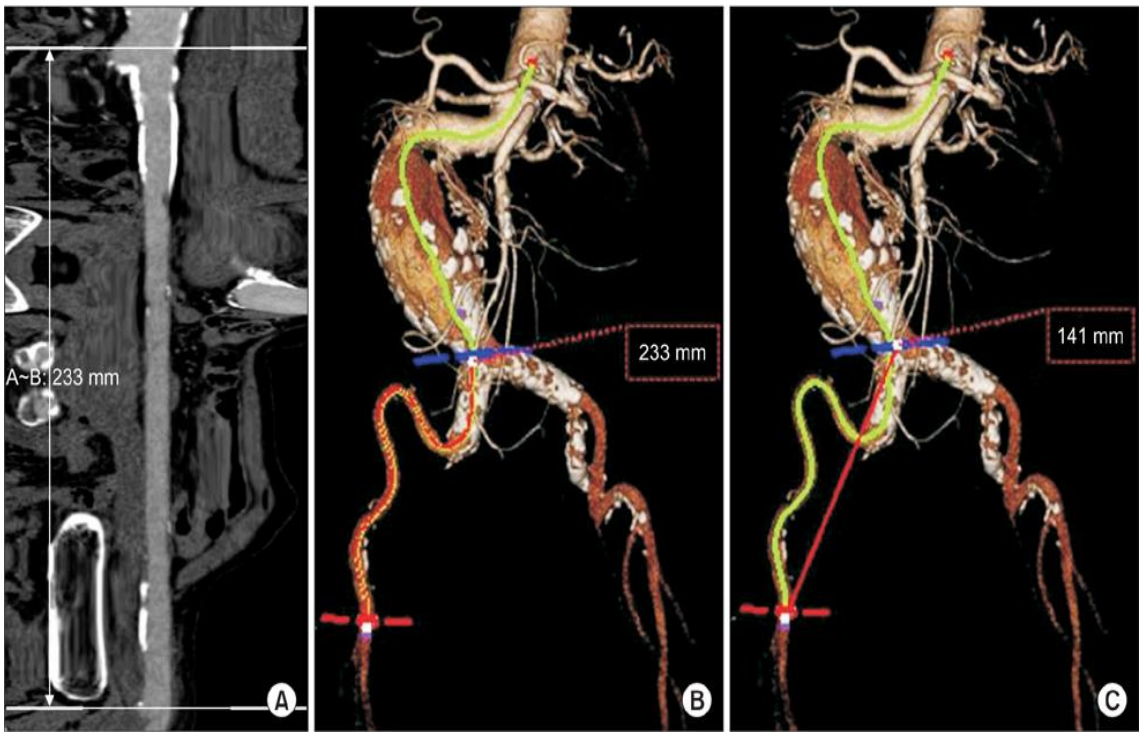
- Assessment of inflammation properties and/or MVO
- Contours are automatically forwarded to the corresponding baseline/post–contrast image
- Calculation and auto–display of myocardial early enhancement and T2 signal intensity ratio (quantitative Lake Louise Criteria for myocarditis)
- Color map of T2 signal intensity ratio

- **PERFUSION, T_1 MAPPING. T_2/ T_2^* MAPPING , 4D VIEWER**

TERARECON – iNtution

- ✓ Volume rendering applications
- ✓ Perfusion
- ✓ Image fusion .etc





Advances in MRI

- Advanced sequences for MRA
- Perfusion weighted imaging
- Diffusion Tensor imaging
- Susceptibility weighted imaging
- Functional MRI
- Silent MRI and Silent MRA

ADVANCES IN MRA

1. TRICKS / TWIST / KEYHOLE
2. INHANCE/NATIVE/Delta flow

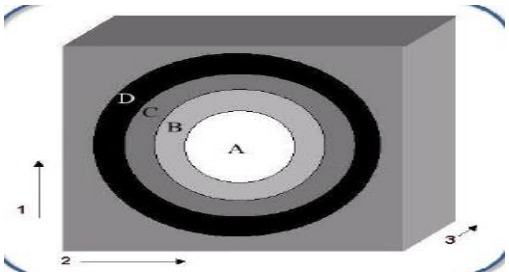
TRICKS / TWIST

. This can be used in combination with contrast injection to provide dynamic clinical information, including the evaluation of abnormal vascular anatomy as well as vascular hemodynamics, and perfusion measurements. The technique is possible because of the advances in the parallel imaging technique and advances in the k- space coverage scheme because of the higher performance gradients

TRICKS is a CE MRA multi-phase, single station, acquisition technique to visualize dynamic processes, such as the passage of blood with contrast agent through the peripheral vascular system. It eliminates the need for a timed or automatic triggering of contrast.

Background:

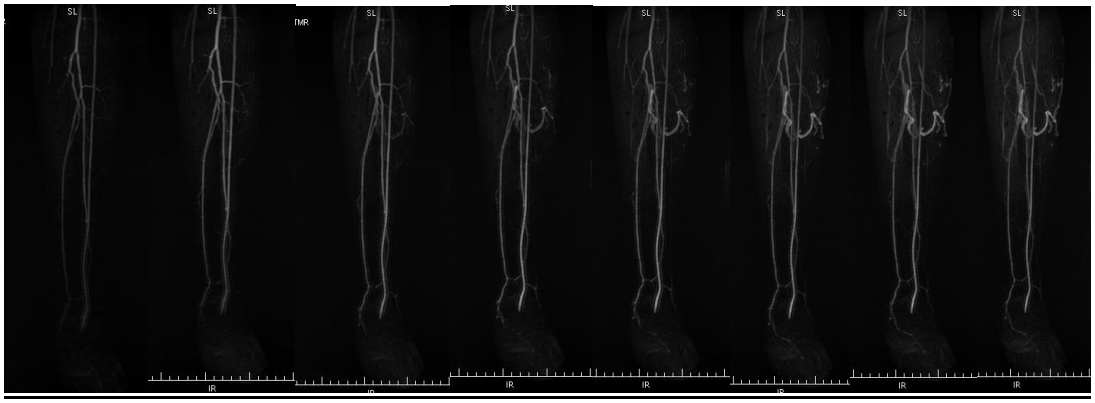
Elliptic Centric-TRICKS is a modified 3D Fast GRE pulse sequence that produces. CE MRA high spatial and temporal resolution images. A mask acquisition used to produce automatically subtracted source images. Collapsed images from each temporal output phase. TRICKS high temporal resolution is achieved by dividing the 3D k-space into a number of segments from the center of k-space out (A to D). Views are acquired in elliptic centric order and the rate of sampling is varied such that the center of k space is sampled more often than the outer regions. When the center of k space is sampled more frequently than other regions, the time period from one phase to the next is shortened. The end result is that the contrast kinetics/flow is subdivided into more phases with TRICKS than with other PSDs and, therefore, the temporal resolution is shorter than other PSDs.



K – SPACE SCHEME

Basic idea of contrast-enhanced dynamic MRA. a) Conventional measurements with relatively poor temporal resolution. b) TRICKS

reduces the time between subsequent 3D data sets to better distinguish between the arterial and venous phase.



TRICKS image of RT Leg

Clinical Applications

There are many benefits of using dynamic TRICKS for clinical applications. These include:

- Better detection of vascular diseases such as in arterio venous malformations (AVM) or shunts by providing the dynamic information.
- Better assessment of vascular diseases such as in peripheral obstructive artery disease (POAD) or steal phenomenon by visualizing the hemodynamics.
- Smaller amounts of contrast agent required for the contrast enhancement study.
- Complete elimination of venous contamination even in abnormal hemodynamic states.

INHANCE / NATIVE - NON CONTRAST ANGIOGRAPHY

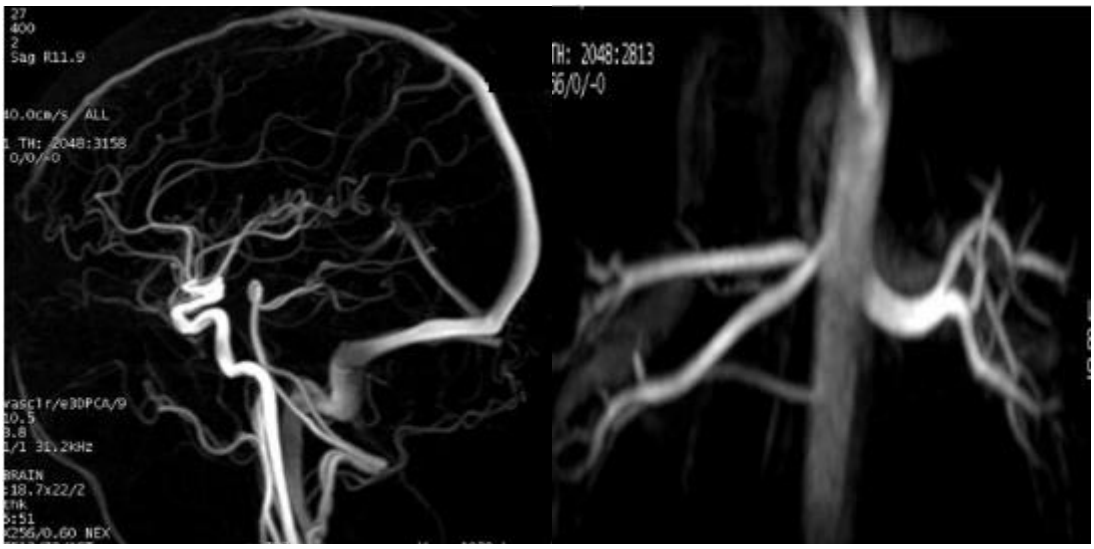
Advances in MRI is help full to provide non contrast MRA in abdominal and peripheral application. The early techniques of NON CONTRAST MRA include 2D &3D TOF IMAGING , GATED 2D TOF , PHASE CONTRAST ANGIOGRAPY

INHANCE include newer non contrast angiography technique for imaging patient's without contrast medium

INHANCE 3D VELOCITY:

Inhance 3D Velocity is a modified 3D Phase Contrast PSD. It is designed to acquire contrast-free angiography images with excellent background suppression at a shorter scan time in comparison to 3D PC.

- Shortened scan times through the use of partial k-space filling technique, ASSET compatibility, and dB/dt optimization and RF pulse modifications for shorter TR and TE times.
- A spoiled gradient technique improves SNR and improves background suppression.
- T1-weighted magnitude images can be generated.
- Respiratory trigger compatibility increases 3D PC applications to include abdominal angiography, in particular renal artery visualization.

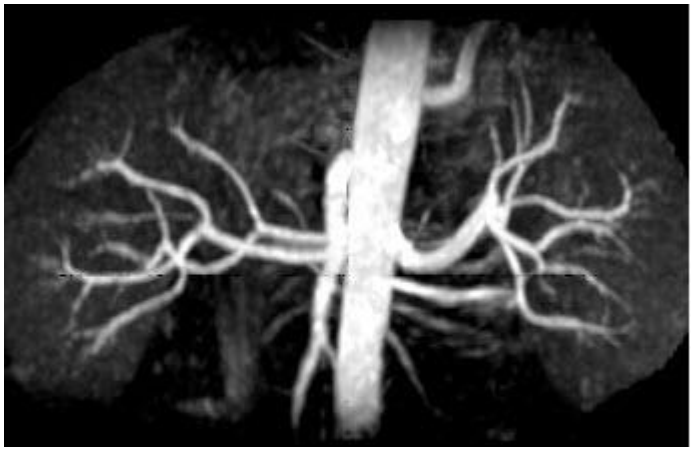


INHANCE INFLOW IR [NATIVE TRUEFISP]

Inhance 3D Inflow IR1 is a contrast-free angiographic (non-CEMRA) method based on the inherent in-flow effects of blood. This sequence is based on 3D FIESTA, which improves SNR and produces bright blood images. Selective inversion pulses are applied over the region of interest to invert arterial, venous, and static tissue. At the null point of the background tissue, an excitation pulse is applied to generate signal. The

net result is an angiographic image with excellent background suppression and free of venous contamination. Inhance Inflow IR can also be used to image venous vasculature. This can be achieved by setting inversion recovery pulses to suppress upstream arterial flow. Respiratory trigger is used to reduce motion artifacts and **SPECIAL** (a chemical saturation technique) is implemented to produce good fat saturation.

The underlying limiting factor in this method is the volume of blood entering the inverted target region within an inversion time. The maximum inversion time which can be used is limited by the recovery of the magnetization of the targeted area – in practice this means a maximum TI of around 1400 ms can be used without in tolerable loss of contrast. The use of this technique has been successfully applied in renal angiography as well as in the assessment of transplanted kidneys to rule out anastomotic stenosis.



INHANCE 3D DELTA FLOW [NATIVE SPACE]

Inhance Deltaflow is a non-contrast agent MRA1 method that is typically used to image peripheral arteries in a run-off exam. Inhanc Deltaflow acquires two 3D slabs: one during systolic phase and one during diastolic phase.
A multi-phase SSFSE scan is acquired to determine the diastolic trigger delay for the Inhance Deltaflow acquisition.

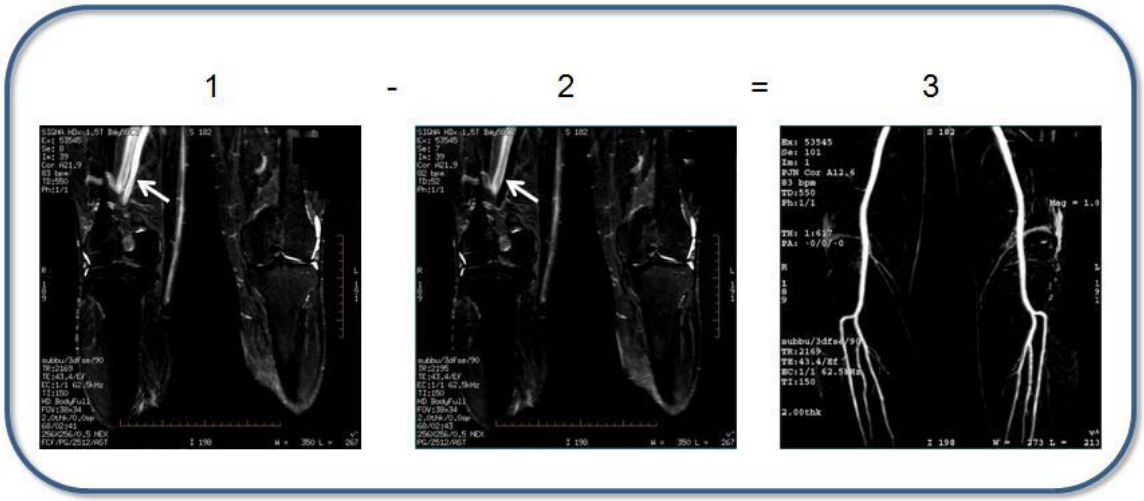
Background:

The signal produced from arterial flow is sensitive to the cardiac cycle. During systolic phase, arterial flow is fast resulting in a dark signal. During diastolic phase, arterial flow is significantly slower resulting in a

bright signal. Unlike arterial flow, venous and background signal are relatively insensitive to the cardiac cycle.

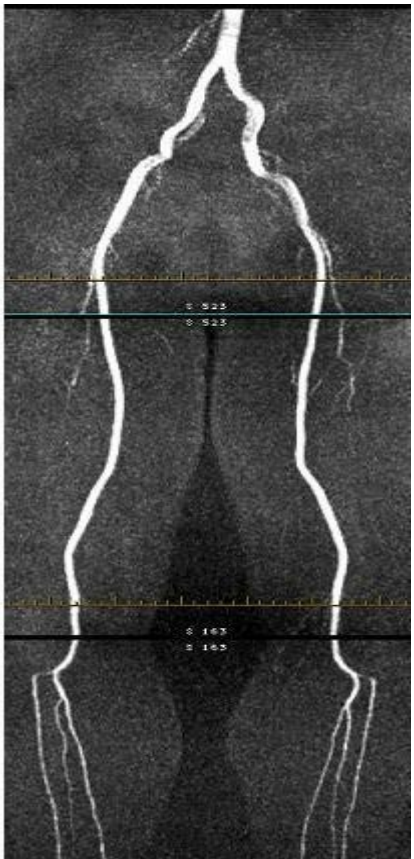
Subtraction of the systolic slab from the diastolic slab results in the visualization of the arteries with good background suppression. A STIR pulse can be applied to both the systolic and diastolic acquisition for additional fat suppression.

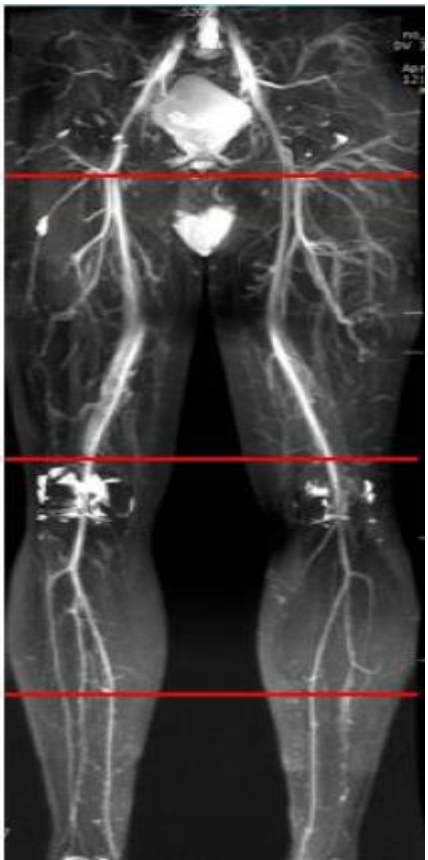
Inhance Deltaflow image results when the diastolic slab is subtracted from the systolic slab



Multi-phase SSFSE

Multiphase SSFSE acquires multiple phase images with increasing delay between each phase. An automatic subtraction of the first phase (corresponding to systolic) from other phase images provide arterial images, which can used to estimate the delay that corresponds to the optimum arterial visualization (diastolic start time)





MR-Echo

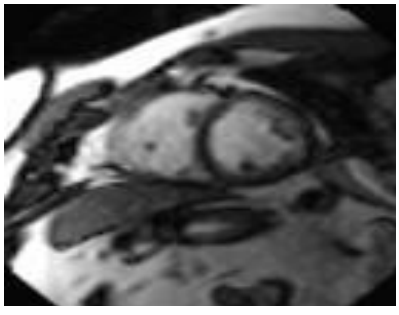
The ***MR-Echo*** application is for cardiac real-time prescription and acquisition. Real time acquisition is particularly useful in patients with irregular heartbeats and with patients who cannot perform a breathhold
Acquisition. Using real-time images as localizers, the following batch scans can be efficiently performed using MR-Echo Scan and save:

- Function scans, which are typically acquired for wall motion studies
- Time Course scans, which are typically used to evaluate the heart, using a single cardiac phase acquired at multiple locations that are continually repeated over a breath hold
- Myocardial Evaluation scans, which are typically used to evaluate cardiac viability

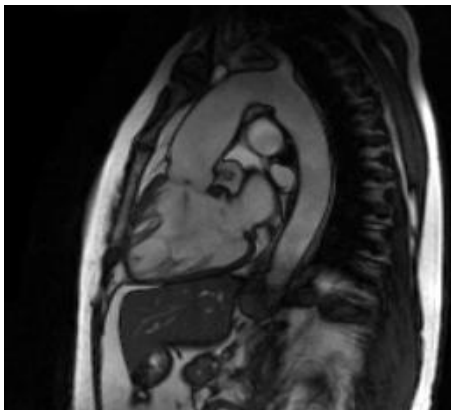
Background

The **MR-Echo desktop** has four protocol tabs, each with a unique PSD1 for different applications:

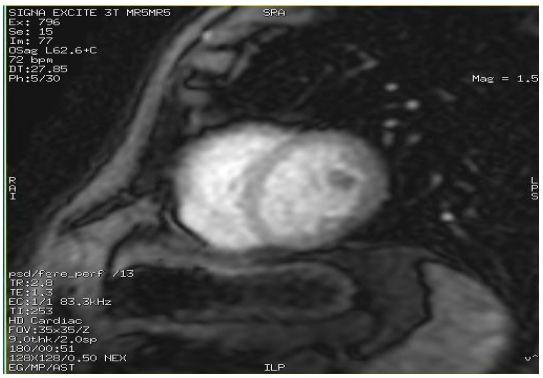
Real-time uses a non-gated 2DFIESTA PSD for acquiring real-time images of the heart using a FIESTA (bright blood) pulse sequence. The PSD acquires images at a high-frame rate for localization and qualitative ventricular function assessment.



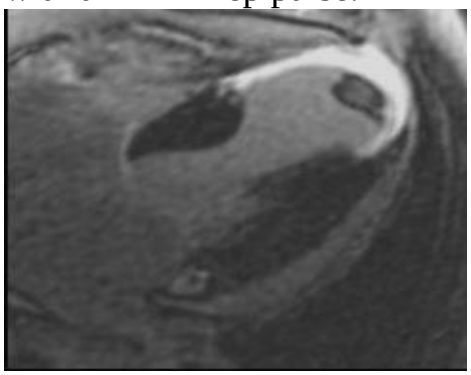
Function uses a gated 2D FIESTA PSD. It provides a multi-phase CINE high-frame rate acquisition mode for high-image quality breath-hold cardiac images that are added to the image database. This mode functions with both ECG2 or peripheral gating.



Time Course uses a cardiac-triggered 2D Fast GRE or FIESTA PSD with a saturation component. The
PSD can be selected when setting up the scan.



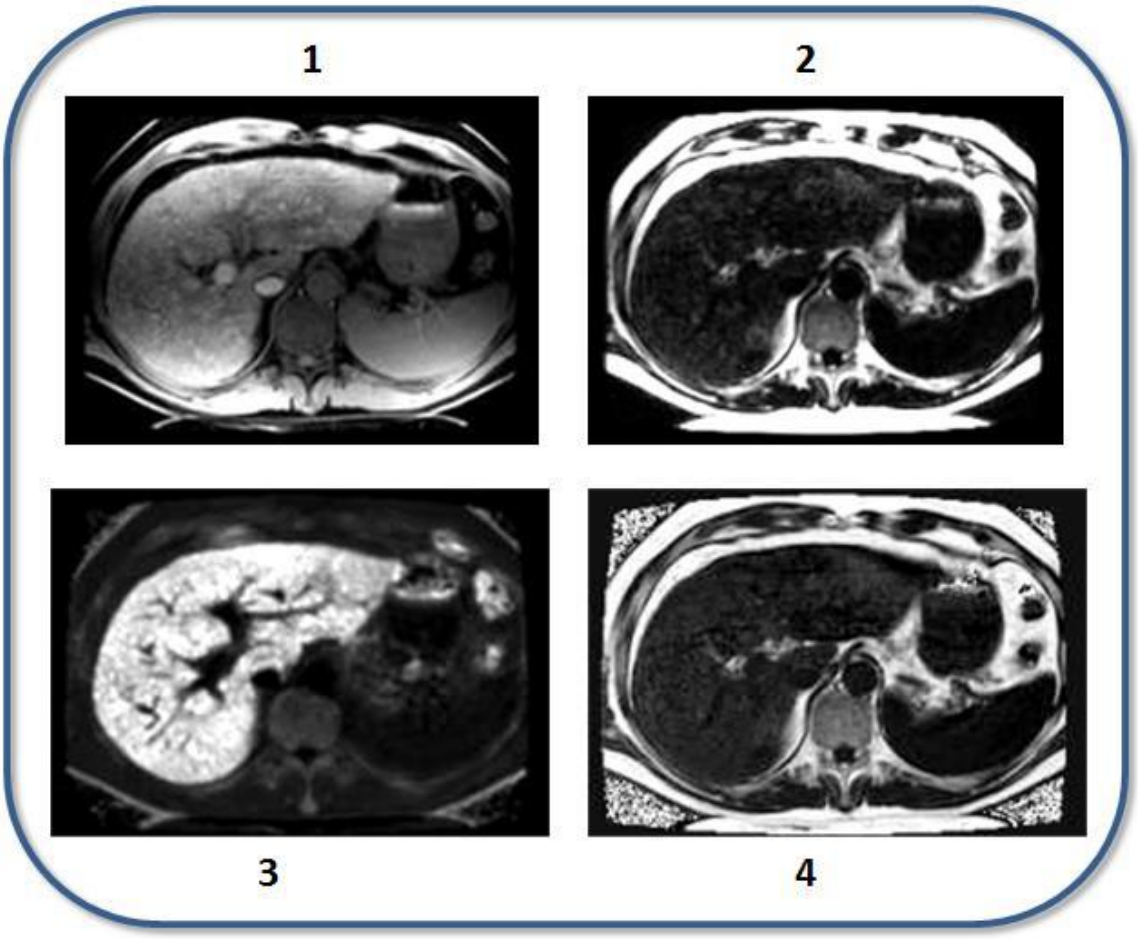
Myocardial Evaluation uses a single-phase, cardiac-triggered Fast GRE with an IR1-Prep pulse.



IDEAL IQ

IDEAL1 IQ is a one-click application that expands on the **IDEAL** technique to produce triglyceride fat fraction images and R2* maps in addition to water and triglyceride fat images from the collected multi-echo images of an IDEAL IQ acquisition. R2* is the inverse of the T2* relaxation rate

The combination of the R2* map with the triglyceride fat-signal fraction map enables IDEAL IQ to improve the accuracy of tissue characterization parameters (R2* or triglyceride fat) by removing contamination from multiple chemical components.
IDEAL IQ uses ARC, which allows for acceleration in both phase and slice directions for supported coils

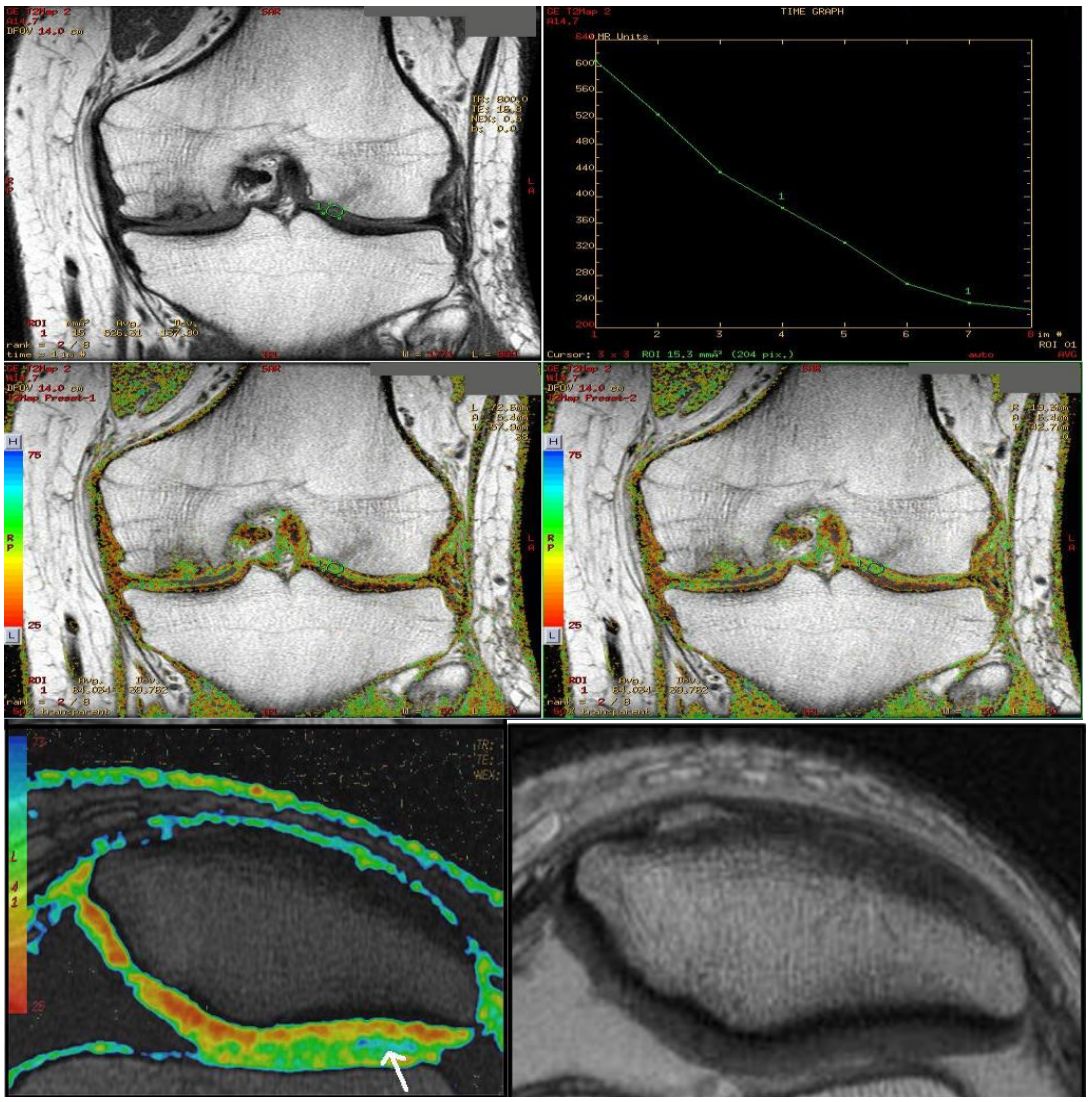


1= T2* corrected water IDEAL IQ image 2 T2* corrected triglyceride fat IDEAL IQ image 3 R2* map IDEAL IQ image, 4 Triglyceride fat-fraction IDEAL IQ image

T2 Map (Cartigram)

T2 MAP is used to noninvasively detect changes in the collagen component of the extracellular matrix of cartilage. T2 MAP acquires multiple scans at each location; each set of scans has a unique TE resulting in a set of gray scale images that represent different T2 weighting.

The acquired data can be processed in FuncTool to produce T2 color maps, which demonstrate more subtle changes in cartilage ultrastructure that are not visible on gray scale MR images. The T2 map and the parametric images produce visible image contrast changes in early stages of cartilage degeneration such as osteoarthritis.



T2 Map

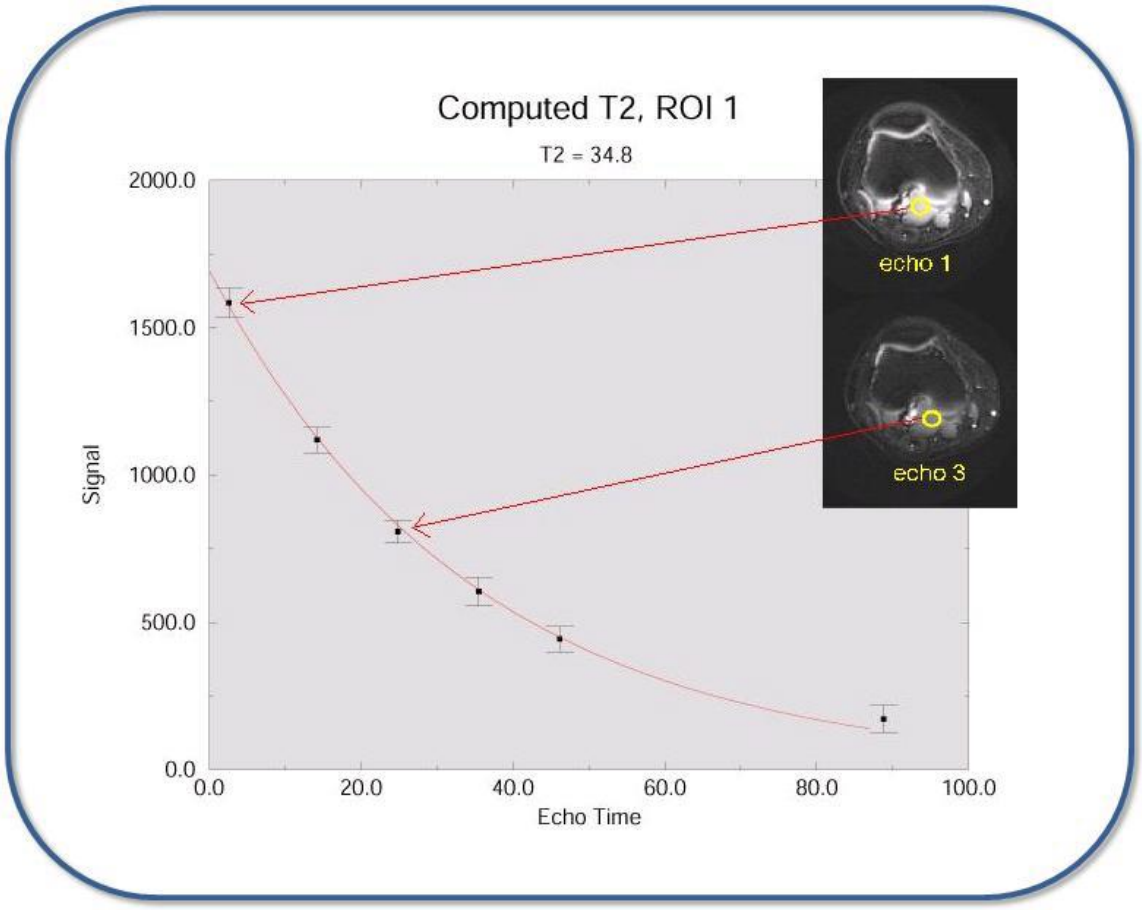
knee (top) and color map (bottom) post-processed in FuncTool. Blue signal intensity indicates high T2 value

Background:

The number of TEs per scan (not selectable) determines the number of images that are acquired at each location. For example, if 10 locations are prescribed and 6 (number of TEs) per scan are prescribed, then there are 10 data sets with 6 images per location. Each image within a data set or location has six unique

T2-weighted images because all lines of k-space are filled with one

(each individual) TE. This differs substantially from the traditional Fast Spin Echo sequence.



Perfusion weighted imaging

Perfusion means the steady state delivery of blood to tissue parenchyma through the capillaries, it derived from the French verb "per fuser" meaning to "pour over or through."

Two type of techniques

- Exogenous contrast
- Endogenous method

Exogenous method

- Dynamic susceptibility Contrast imaging (DSC)
- Dynamic Contrast Enhanced Imaging (DCE)

Endogenous contrast

- ASL

Dynamic susceptibility imaging

Dynamic susceptibility contrast (DSC) MRI, also known as bolus tracking MRI, is a well-established technique to measure perfusion (or cerebral blood flow, CBF) and other related hemodynamic parameters. It involves the sequential acquisition of MR images following an intravenous injection of contrast agent. The passage of contrast agent through the brain induces a measurable drop in the MR signal when a T2- or T2*-weighted sequence is used. This signal–time course is used to compute
Important hemodynamic perfusion parameters, such as rCBF, cerebral blood volume (rCBV) and mean transit time (MTT).

Steps follow the workflow for the acquisition

- The contrast agent
- The acquisition of DSC-MRI data).
- Data pre-processing
- The contrast concentration–time course
- Common perfusion parameters

- Post-processing

The contrast agent

MR contrast agents provide additional image contrast by altering the local relaxation times of the protons. In DSC-MRI, gadolinium (Gd)-chelated contrast agents are commonly used. When the blood–brain barrier (BBB) is intact, the strongly paramagnetic Gd3+ ions remain intravascular, promoting transverse (T2/T2*) relaxation of tissue water protons via the susceptibility effect. Within the intravascular space, longitudinal (T1) relaxation is also significant. However, when a T2- or T2*-weighted sequence is used, and the BBB is intact, the susceptibility effect dominates image contrast. Thus, the passage of Gd-based contrast agent through the capillary bed leads to a transient drop in the MR signal.

The injected volume of contrast should be sufficient to promote a measurable drop in MR signal intensity, but not too large. Typically, the injected dose is between 0.1 mmol/kg (so-called 'single dose') and 0.2 mmol/kg. Bolus injection speeds less than about 4 mL/s have been shown to underestimate perfusion (6). A tolerable and safe injection rate is about 5 mL/s. In order to achieve a well-defined bolus, the contrast should be injected into a vein in the right arm (7) and followed by at least 25 mL of saline injected at the same rate (8), which flushes the catheter and veins.

The acquisition of DSC-MRI data.

The susceptibility contrast generated by the passage of a paramagnetic contrast agent through the microvasculature is imaged using T2- or T2*-weighted sequences (see step 6). Fast acquisition imaging techniques, such as echo planar imaging (EPI), are required to characterize the transient MR signal drop (of approximately 10 s). Single-shot EPI is the most widely available fast imaging sequence on clinical scanners and facilitates whole-brain coverage at reasonable signal-to-noise ratios (SNRs). It has therefore become a popular choice for clinical DSC-MRI.

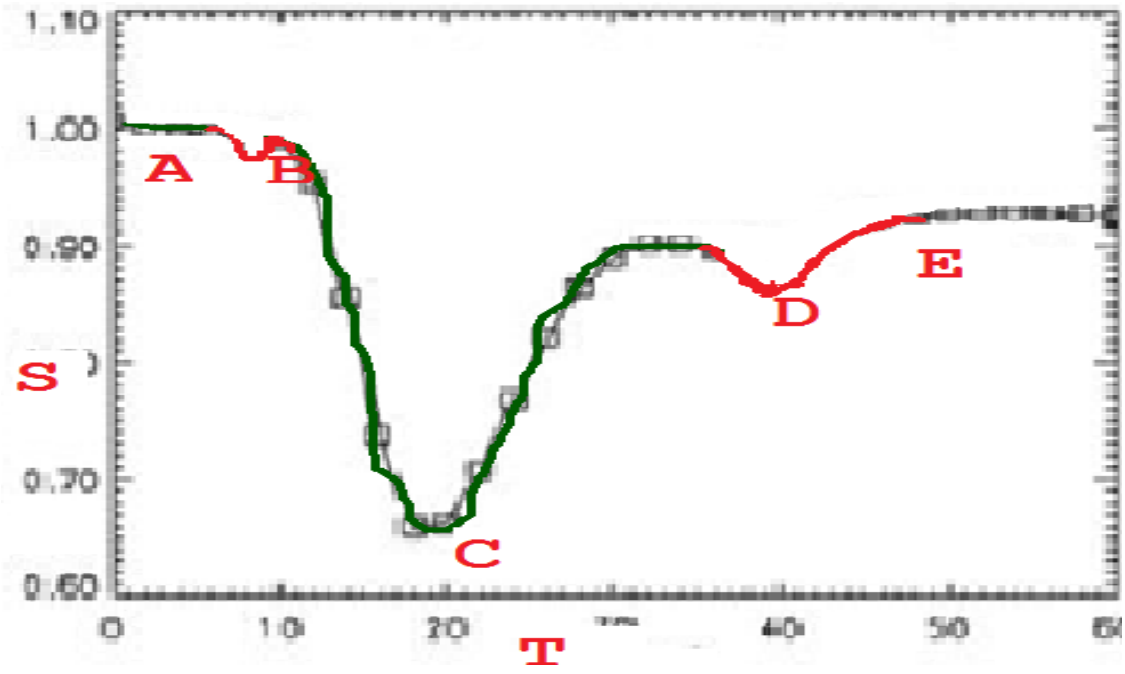
Alternative (less commonly available) acquisition methods have been implemented with a view to reduce EPI artifacts, whilst improving susceptibility contrast, spatial and temporal resolution. Segmented EPI has the advantage of less distortion, but is more sensitive to T1 effects because of shorter TRs. The three-dimensional 'principle of echo shifting with a train of observations' (PRESTO) sequence (10) also reduces distortions and can acquire images at very high temporal resolution, thus

providing a precise characterization of the MR signal–time course data. However, T1 effects can again be a problem.

DSC-MRI can be acquired using either spin echo (SE) or gradient echo (GE) sequences, which provide subtly different contrasts. The SE DSC-MRI signal drop is largest in the vicinity of capillaries, where the phase accumulation across the diffusion distance is greatest. Consequently, SE DSC-MRI images are sensitive to the microvasculature. In contrast, GE acquisitions do not refocus static field in homogeneities and are therefore sensitive to changes in T2*. As a result, the susceptibility-induced signal drop is larger for GE acquisitions than for SE acquisitions across all vessel.

For the more commonly used GE sequence, the optimal signal drop is achieved by setting the MR TE equal to T2* of the tissue, TR should be no longer than 1.5 s in order to achieve a <25% error in grey matter CBF calculated using standard analysis methods. Good CNR data can be acquired using a flip angle of 60–90º at 1.5-T or 60º at 3-T. However, if a short TR is used (<1.5 s), particular care must be exercised to minimize the effects of T1 relaxation on the MR signal–time course.

The Concentration–Time Course



A: Base line
B: Arrival point of contrast agent.
C: Peak signal change
D: Recirculation of bolus.

Common Perfusion Parameters

- Cerebral blood volume (CBV)
- Cerebral blood flow (CBF);
- Mean transit time (MTT);
- Time to maximum (Tmax).

Cerebral blood volume (CBV);

- Cerebral blood volume (CBV) is the fraction of tissue volume occupied by blood vessels
- Units: ml / 100 g brain
- 4ml/100g
- Flow x circulation time=CBV

  CBF X MTT=CBV

Cerebral blood Flow (CBF);

- Cerebral Blood Flow (CBF)
- Delivery of blood to tissue / unit time
- Units: ml / 100g brain / min
- CBV/MTT=CBF
- 50 ml / 100g brain / min

Mean Transit Time (MTT)

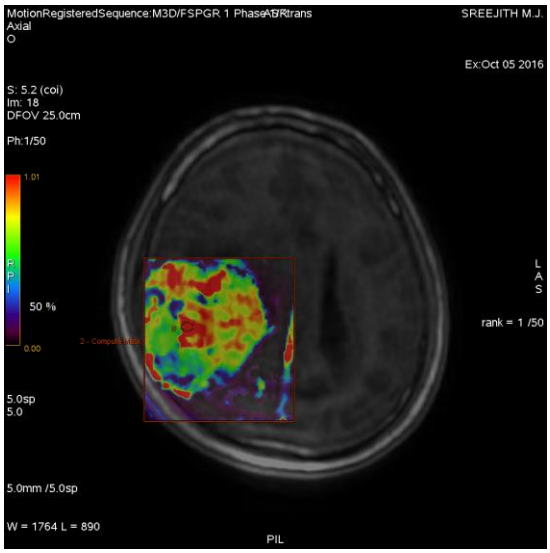
- Mean Transit Time (MTT)
- Average time to flow through capillaries (artery → vein)
- MTT=CBV/CBF
- Units: seconds
- 5 S

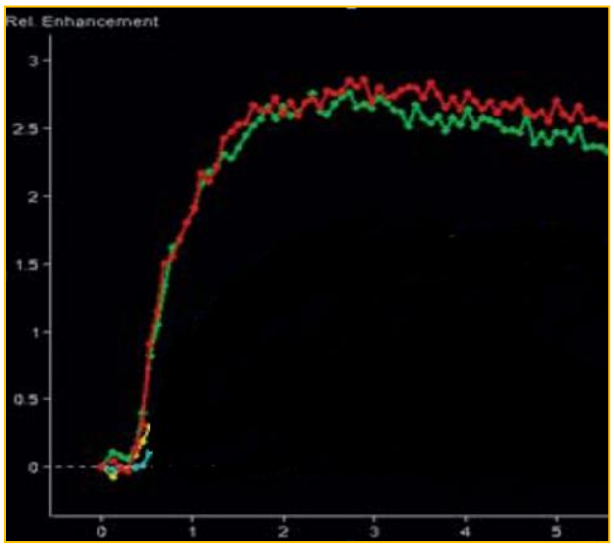
Time to maximum (Tmax)

- Tmax is the arrival delay between AIF and the tissue

DCE Perfusion (T1 perfusion)

DCE-MRI perfusion uses metrics to describe the permeability of the BBB and the relationship to the extracellular extravascular space (EES). The same leakage that confounds the DSC perfusion is measured with DCE using a dynamic T1-weighted sequence. The acquisition time course is often over several minutes for DCE, This time allows for measurement of the wash-in and wash-out of the contrast material in the EES. There are several methods for image interpretation. The simplest method is to examine the signal intensity curves over time for a region of interest. The rate or slope of the wash-in and washout curve for multiple regions of interest can be visually assessed. This type of assessment is valuable for distinguishing tumors (rapid curve rise) from radiation necrosis (slow curve rise). Semi quantitative methods can also be used and parametric maps can be easily created showing the slope of the wash-in and wash-out curves, maximal enhancement, and arrival time. Additional quantitative methods can also be performed by integrating the initial area under the DCE tissue concentration curve (IAUCC). , it also reflects multiple physiologic processes including permeability, volume of the EES, and blood flow processing involves use of T1 maps, a vascular input function (much like the AIF in DSC-MRI), and complex pharmacokinetic models. This later method of post processing provides the metrics ktrans (the transfer coefficient between the plasma and EES that reflects permeability of the BBB), vp or fractional plasma volume, and ve or fractional volume of the EES.





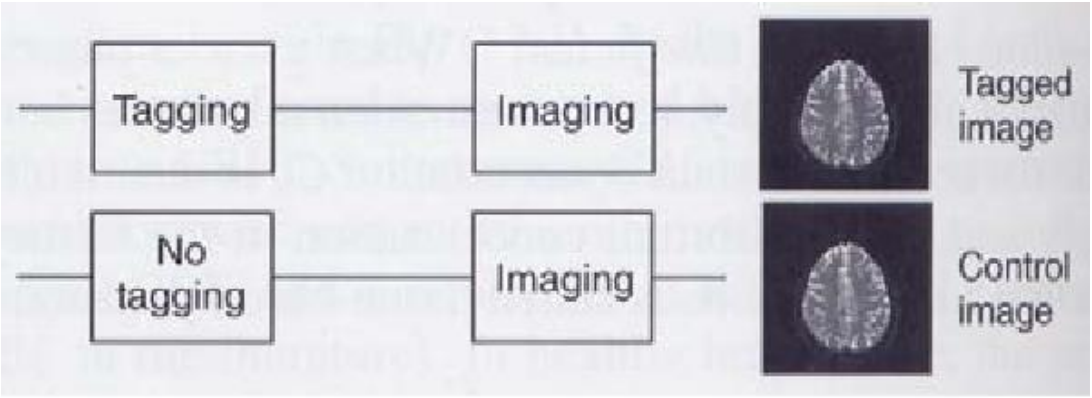
The upslope curve

Clinical application

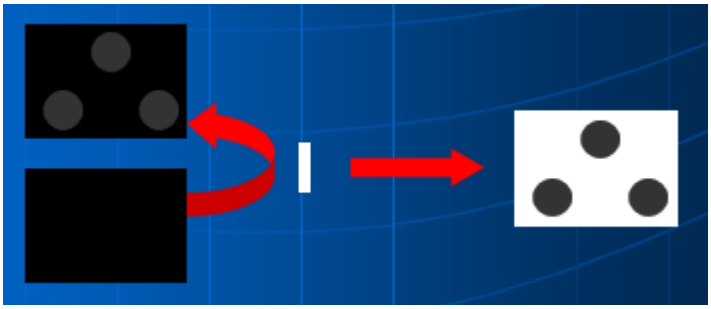
- Evaluation of ischemic penumbra in stroke.
- Classification of brain tumor.
- Grading of brain tumor.
- Cerebral infarction risk assessment
- Selection of patients for extra cranial to intracranial bypass surgery
- Moya Moya evaluation
- Assessing risk of hyper perfusion syndrome
- Balloon test occlusion with CVR
- Selection of patients for medical intervention

ASL

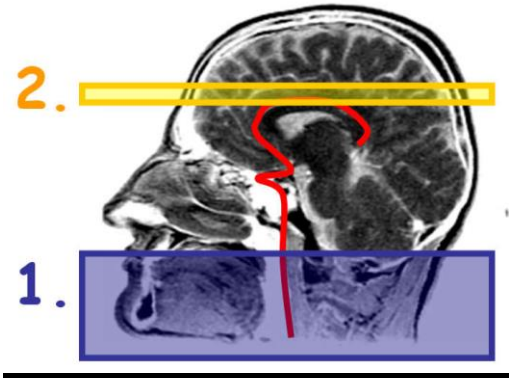
- ASL technique was conceived more than 15yrs ago.
- No exogenous contrast bolus required.
- ASL is based on labeling protons in the blood in supplying vessels outside the imaging plane and waiting for a period called post delay period for reaching the parenchyma.



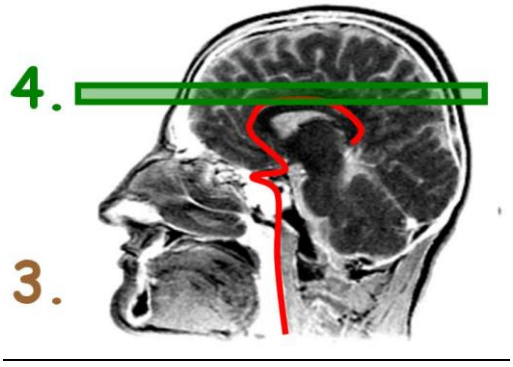
- Images are obtained from the parenchyma in labeled and controlled state.
- Subtracting these two type of images eliminates the static tissue signal will give CBF images.



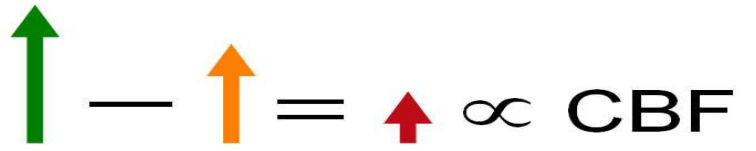
Principle of ASL

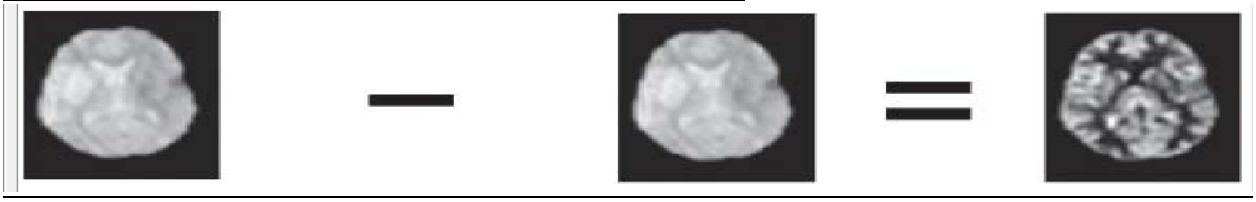


1Tag inflowing arterial blood by magnetic inversion
2. Acquire the **tag image**



3. Repeat experiment without **tag**
4. Acquire the **control image**

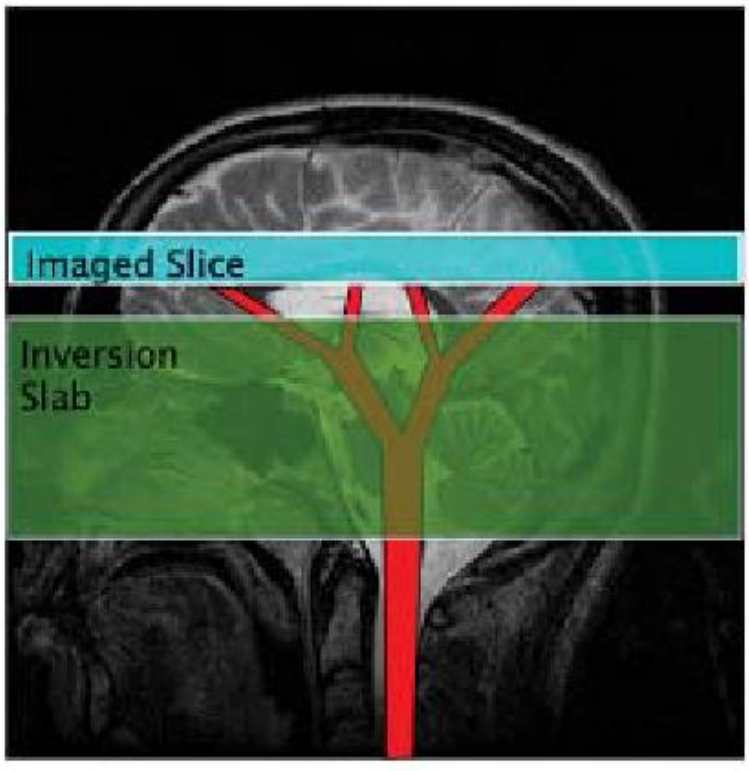




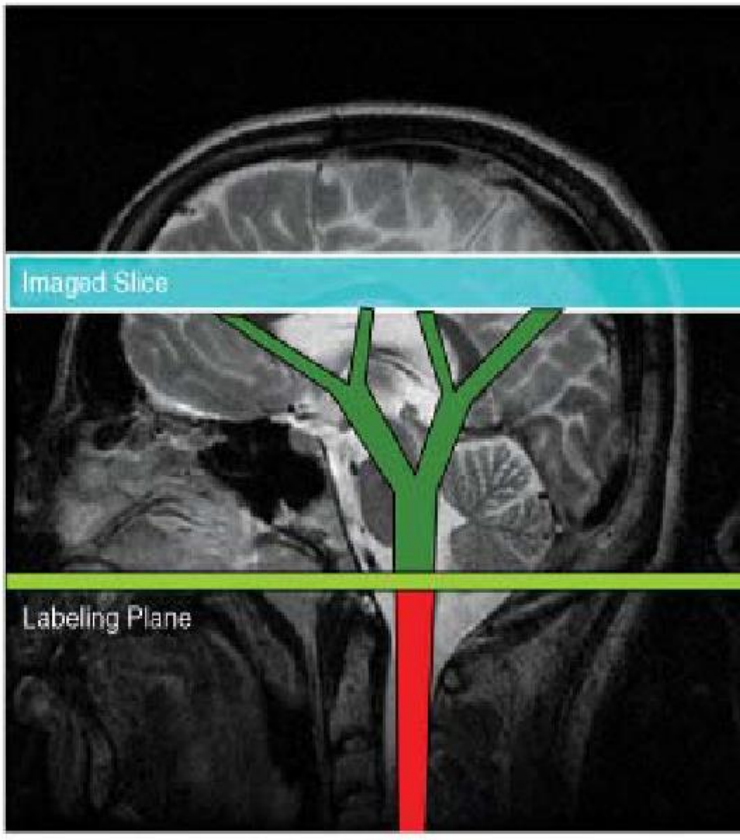
TYPES OF ASL

i. Pulsed ASL
ii. Continuous ASL
iii. Pseudo continuous ASL
iv. Velocity selective ASL

PASL



CASL



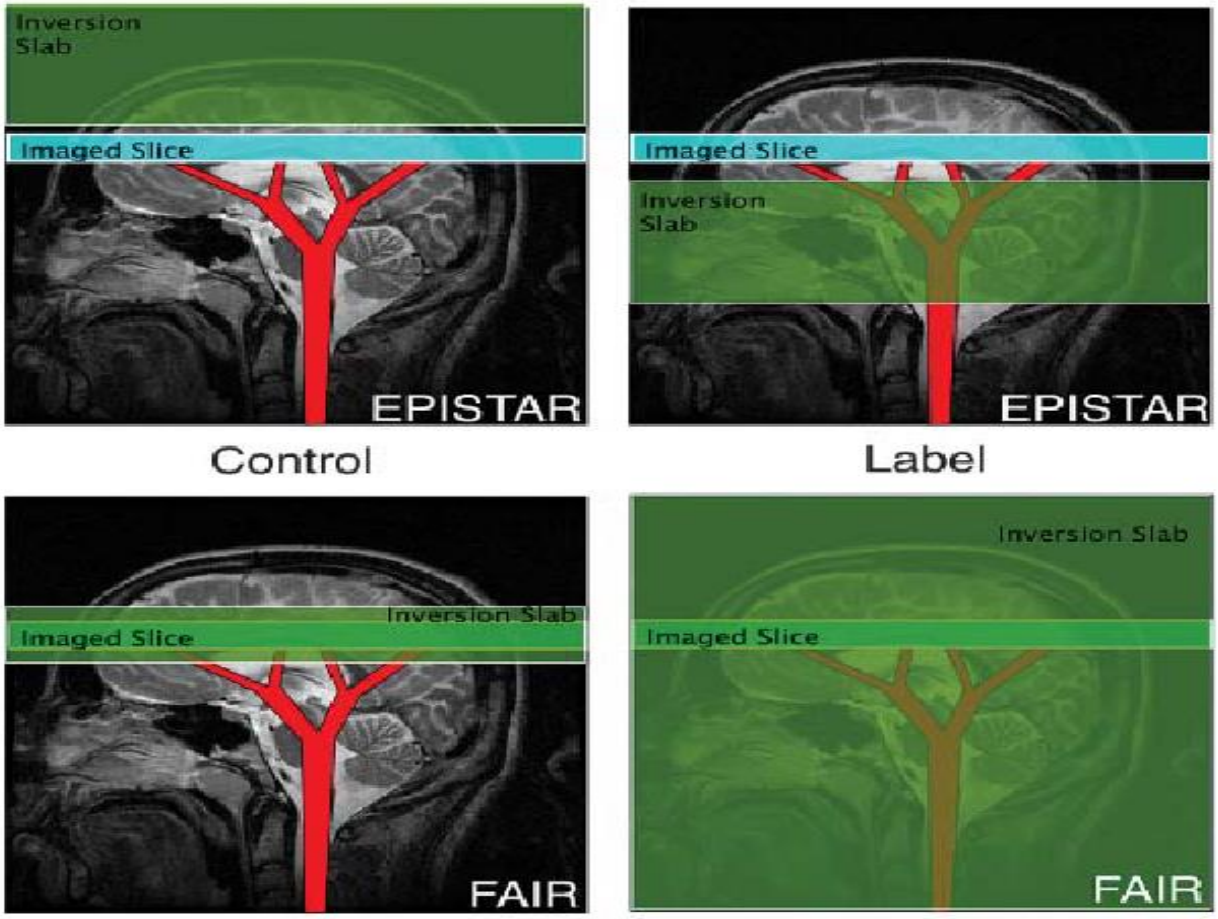
DAMIT

ASL Types	Advantages	Disadvantages
PASL	Higher tagging efficiency Lower SAR	Lower SNR
CASL	Higher SNR than PASL	Lower tagging efficiency Continuous RF transmit hardware required Higher SAR Magnetization Transfer effects
pCASL	Higher SNR than PASL Higher tagging efficiency than CASL	Higher SAR Limited clinical availability.
VS-ASL	Ability to measure low	Lower SNR

Sequence for ASL

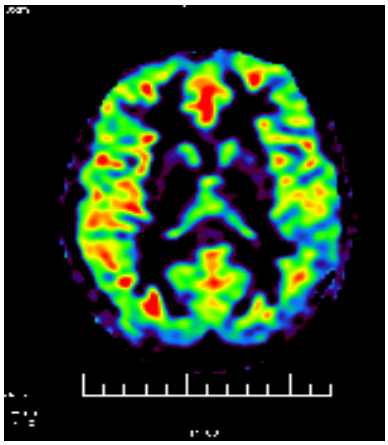
- EPISTAR-Echo planar imaging and signal targeting with all radiofrequency.
- PICORE-proximal imaging with a control for off resonance effect.
- TILT-transfer insensitive labeling technique.
- FAIR-flow sensitive alternating inversion recovery.
- FAIRER-FAIR with extra radiofrequency pulse.

BASE-basis image with selective inversion



Clinical application

- ASL perfusion maps frequently are used to evaluate an intra- or extra-axial neoplastic process.
- Infectious Etiologies.
- Physiologic Quantification.
- Posterior reversible encephalopathy syndrome



Diffusion Tensor imaging

Diffusion

Random transnational molecular motions driven by internal kinetic energy.

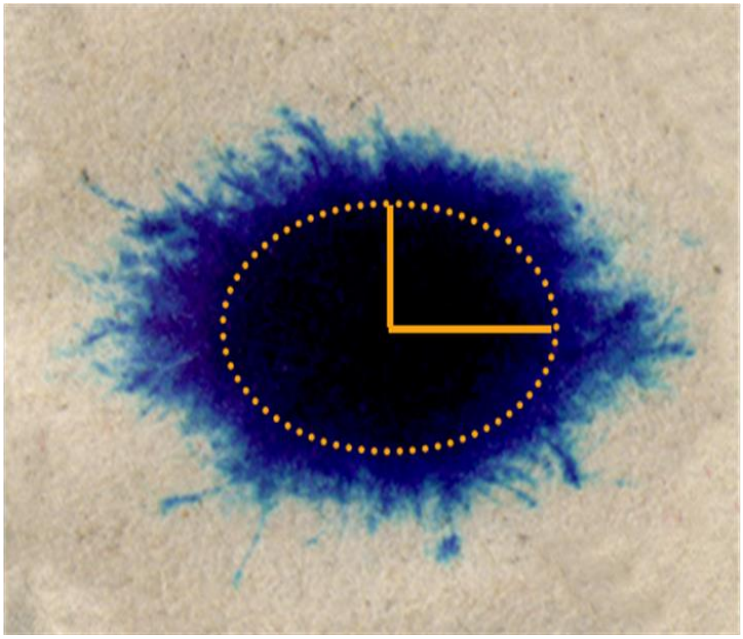
Observed in 1827, by Robert brown.

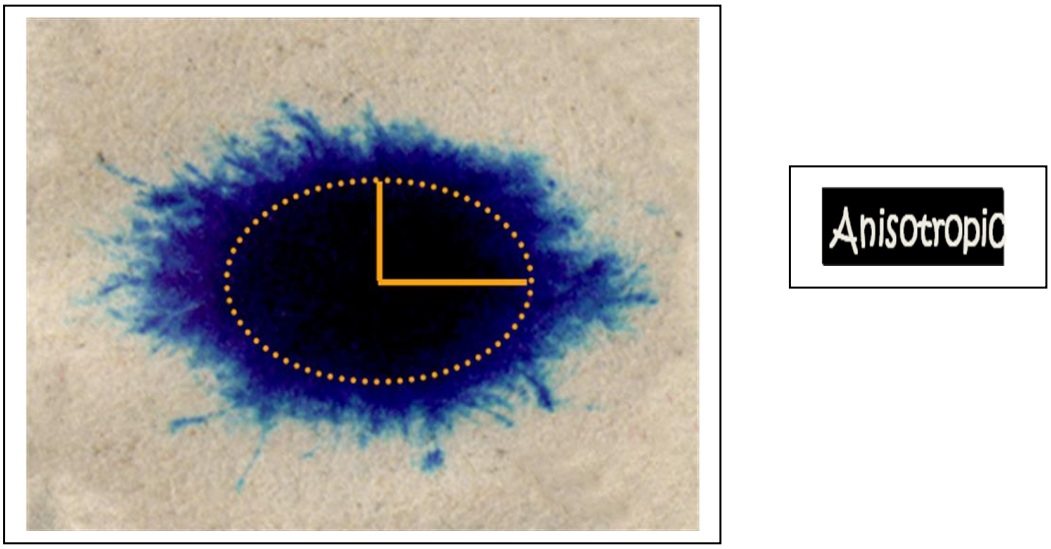
Diffusion refers to the transport of gas or liquid molecules through thermal agitation randomly, that is, it is a function of temperature above 0 K. In pure water, collisions between molecules cause a random movement without a preferred direction, called Brownian motion. This movement can be modeled as a "random walk," and its measurement reflects the effective displacement of the molecules allowed to move in a determined period. The random walk is quantified by an Einstein equation: the variance of distance is proportional to 6Dt, where t is time and D is the proportionality constant called the diffusion coefficient, expressed in SI units of m2/s.

Isotropy and anisotropy

Isotropy means uniformity in all directions. A drop of ink placed in the middle of a sphere filled with water spreads over the entire volume, with no directional preference. If the same experiment is repeated in a sphere filled with uniform gel the restriction is increased as compared with free water, but is still isotropic, as the restriction is the same in all directions.

Anisotropy implies that the property changes with the direction. If a bundle of wheat straw with the fibers parallel to each other is placed inside a glass of water, the ink will face severe restriction in the direction perpendicular to the fibers and facilitated along the fibers. This bundle is highly anisotropic.





Diffusion-Weighted Imaging

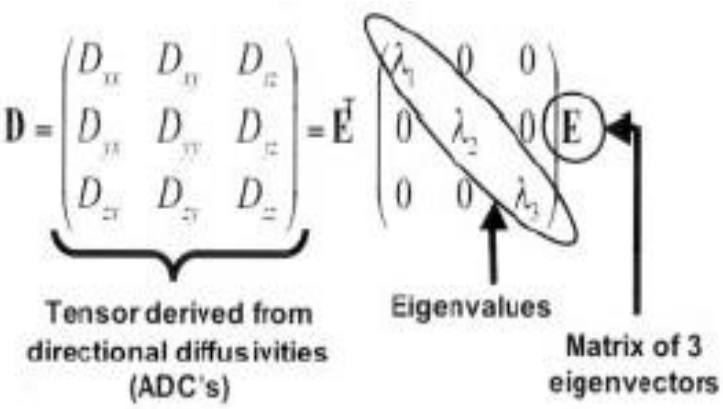
MR image contrast is based on intrinsic tissue properties and the use of specific pulse sequences and parameter adjustments. The image contrast is based on a combination of tissue properties and is denominated "weighted," as the contribution of different tissue properties are present, but one of them is more expressive than the others.

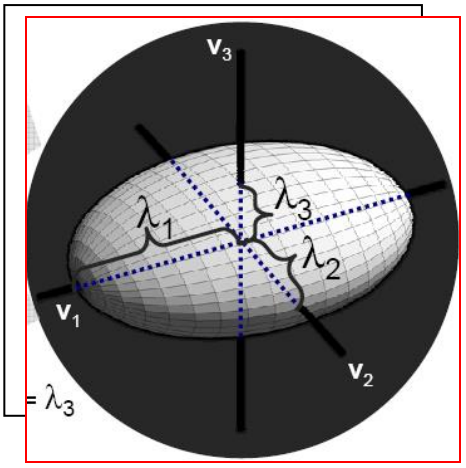
Routine acquisitions have some degree of diffusion influence that is actually quite small. Some strategies have been developed to make diffusion the major contrast contributor, and dedicated diffusion-weighted imaging (DWI) sequences are available nowadays on commercial

scanners, as well as several others as investigational sequences that may or not be available in clinical practice.

Diffusion tensor

A mathematical model representing the directional anisotropy of diffusion.
Represented by a 3 x 3 matrix- 6 directional movement
The eigenvalue of the diffusion tensor are the diffusion diffusivity, and the three principal directions of diffusivity, and the eigenvector corresponding to the largest eigenvalue is the main diffusivity direction in the medium





Diffusion-weighting factors

Trace

- The most clinically measure is Trace.
- This is the sum of the the eigen values of the diffusion tensor. ie D*xx*+D*yy*+D*zz*
- Trace / 3 can be thought as mean diffusivity**.**

b- Value

- The b-value provides diffusion weighting
- For DWI images as TE provides T2 weighting for T2 images.
- The higher the b-value, the more diffusion weighted
- The image will be at the cost of signal to-noise ratio (SNR).

ADC maps

- Diffusion always obtain at least 2 diff. B value measurements to characterize ADC

FA

- Degree of anisotropy

Protocol		**1.5 T**	**3T**
TR	:	3500 m sec.	/8000 ms
TE	:	105 m sec.	/120 ms
THICKNESS	:	5 mm.	/3 mm
DIRECTIONS	:	30.	/30
b VALUE	:	0 &1000	/0 & 1000

Clinical application

- Early detection of stroke
- Evaluate Prognosis of stroke.
- Tumor classification
- Grading of tumor
- Oncologic applications of DW imaging take advantage of restricted diffusion shown by most tumors.
- As a Tool for Surgical Planning.

SWI / SWAN

Susceptibility-weighted imaging (SWI) is a novel magnetic resonance (MR) technique that exploits the magnetic susceptibility differences of various tissues, such as blood, iron and calcification [1]. It consists of using both magnitude and phase images from a high-resolution, three-dimensional (3D) fully velocity-compensated gradient echo sequence.

Phase mask is created from the MR phase images, and multiplying these with the magnitude images increases the conspicuity of the smaller veins

and other sources of susceptibility effects, which is depicted using minimal intensity projection (minIP).

it has also been referred to as high-resolution (HR) blood oxygen level dependent (BOLD) venography. However, in this text, we use SWI to refer to the use of magnitude or phase images, or a combination of both, obtained with a 3D, fully velocity-compensated, gradient echo sequence. This 3D SWI can be used to visualize smaller veins and other sources of susceptibility effects, such as hemosiderin, ferritin and calcium.

Imaging acquisition and image processing

Imaging was performed using a 12-channel phased array head coil on a 1.5 T clinical scanner. The SWI sequence parameters were: TR (repetition time), 48 ms; TE (echo time), 40 ms; Flip angle, 20°; bandwidth, 80 kHz; slice thickness, 2 mm, with 56 slices in a single slab; matrix size, 512×256. A TE of 40 ms was chosen to avoid phase aliasing, and a flip angle of 20° was used to avoid nulling of the signal from pail veins located within the cerebral spinal fluid (CSF) The acquisition time was 2.58 min with the use
of iPAT factor-2.

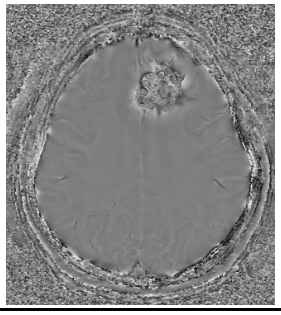
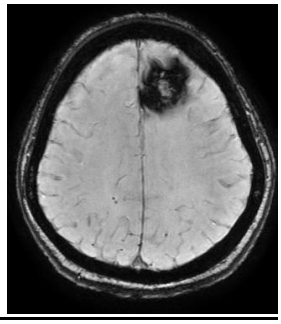
Usefulness of SWI phase imaging

Calcification can be differentiated from hemorrhage based on differences in susceptibility effects – calcium is diamagnetic and blood products show largely paramagnetic susceptibility this makes MR comparable to computed tomography (CT) in calcium imaging.

Blood oxygen level-dependent MR Venography / small vessel imaging

Susceptibility-weighted imaging uses the paramagnetic deoxy-Hb as an intrinsic contrast agent. Deoxy hemoglobin causes a reduction in T2* as well as a phase difference between the vessel and its surrounding parenchyma. The T1 and T2 properties of blood are dependent on the oxygen saturation of the blood, hematocrit and the state of the red blood cells (RBCs) At 1.5 T, arterial blood has a T2* of approximately 200 ms, while 70%saturated venous blood has T2* of 100ms. Hence, Long TEs will help in differentiating arteries from veins [15]. When the phase mask

is multiplied with the magnitude images, the venous data is enhanced; when veins are not present, there is no change in the signal. The resultant images are displayed using the minimum intensity projection, highlighting the signal from veins and minimizing the signal of adjacent brain tissues.

Phase image	mIP image
	

Clinical applications

- detection of hemorrhagic lesions
- Calcification can be differentiated from hemorrhage Iron quantification.
- evaluation of stroke, trauma, vacuities and epilepsy
- characterization of brain tumors

Functional MRI

Over the last decade, functional MR (fMR) imaging has progressed from a research tool for noninvasively studying brain function to an established technique for evaluating a variety of clinical disorders through the use of motor, sensory, and cognitive activation paradigms.

fMR imaging uses blood-oxygen-level-dependent (BOLD) effects to localize regional cerebral blood flow changes temporally and spatially coupled with changes in neuronal activity. When groups of neurons are active, the blood flow to the active neurons increases in excess of what is needed to provide the additional oxygen consumed metabolically. The net result of increased

Neuronal activity is a decrease in paramagnetic deoxygenated hemoglobin in the veins and capillaries within the vicinity of the active neurons. The amount of change depends on many factors including the nature of the task and the region of brain affected. The decrease in deoxy hemoglobin produces a small change in signal intensity, which is typically less than 5% in T2*-weighted images acquired at 1.5 Tesla.

These slight changes in signal intensity (‘‘activation’’) are detected by post-processing statistical analysis techniques that identify the task-related hemodynamic responses.

One clinical application of fMR imaging is the mapping of brain functions in relationship to intracranial tumors, seizure foci, or vascular malformations before surgical excision. The goal of functional mapping procedures is to maximize resection of pathological tissue, spare eloquent cortices, and reduce surgical risk.

- Blood Oxygen Level Dependent (BOLD) is the MRI contrast for de oxy hemoglobin.

- First discovered in 1990 by Seiji Ogawa at at & T Lab, USA.

Hemodynamic response

- A local increase of neuronal activity immediately leads to an increased oxygen extraction rate in the capillary bed.

- The response of the vascular system to the increased energy demand is called the hemodynamic response.

It thus seems likely that the hemodynamic response primarily reflects the input and local processing of neuronal information rather than the output signals (Logothetis and Wandell 2004)

- Consists of increased local cerebral blood flow (CBF), as well as increased cerebral blood volume (CBV) and CMRO2.

- The hemodynamic response not only compensates quickly for the slightly increased oxygen extraction rate but it is so strong that it results in a substantial local *oversupply* of oxygenated hemoglobin.

- About 70% of the BOLD signal arises from larger vessels in a 1.5 tesla scanner, about 70% arises from smaller vessels in a 7 tesla scanner.

- Furthermore, the size of the BOLD signal increases roughly as the square of the magnetic field strength.

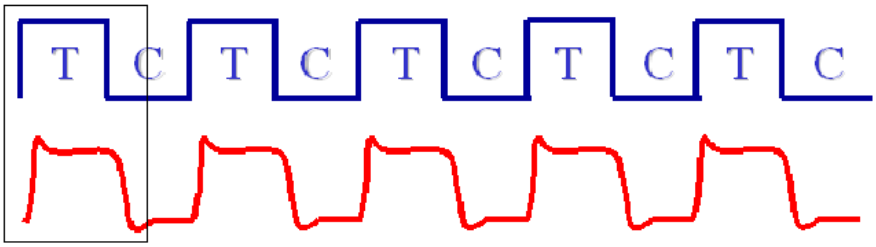
Hence there has been a push for larger field scanners to both improve localization and increase the signal

Types of f MRI

- Depending upon the method of study the f MRI experiments can be categorized in to two :
  - » Block designs
  - » Event related.
  - » Mixed.

Block designs

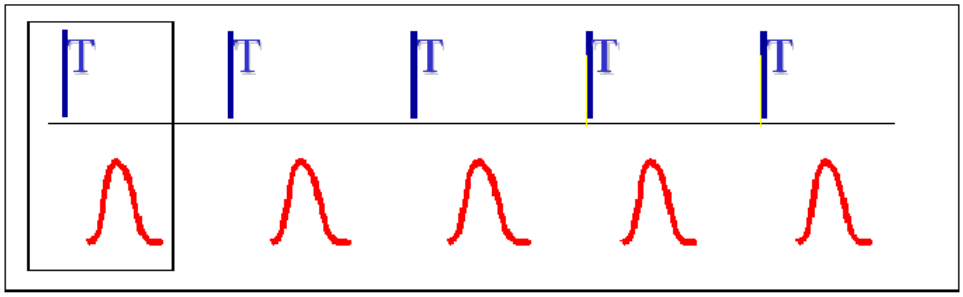
- First used in f MRI and still and the most useful in prevalent neurosurgery.
- It involves subject performs a task, alternated for a similar time with one or multiple control tasks.



Event related f MRI

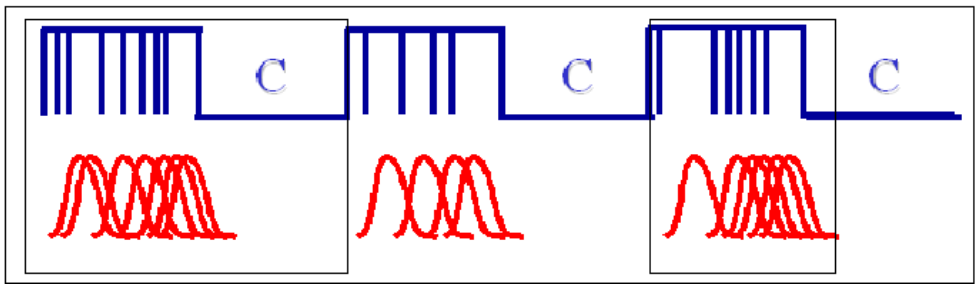
- The individual trials are randomized.

Responses to trials belonging to the same condition are selectively averaged and the calculated mean responses are statistically compared with each other.



Mixed designs

- A combined attempt gives information about maintained versus transient neural activity.
- This technique is an interesting mixture of the characteristic block design measurement of repetitive sets of stimuli and the transient responses detected by event-related designs.



Echo planar imaging

- EPI represents the fastest available scanning method.
- Fulfills most of the requirements demands by the f MRI.

Clinical paradigms

- Certain tasks which are in an arranged fashion for the objectives to map the activity.
- A wide variety of paradigms are developed by the continuous experiments in the field of f MRI.

Different types

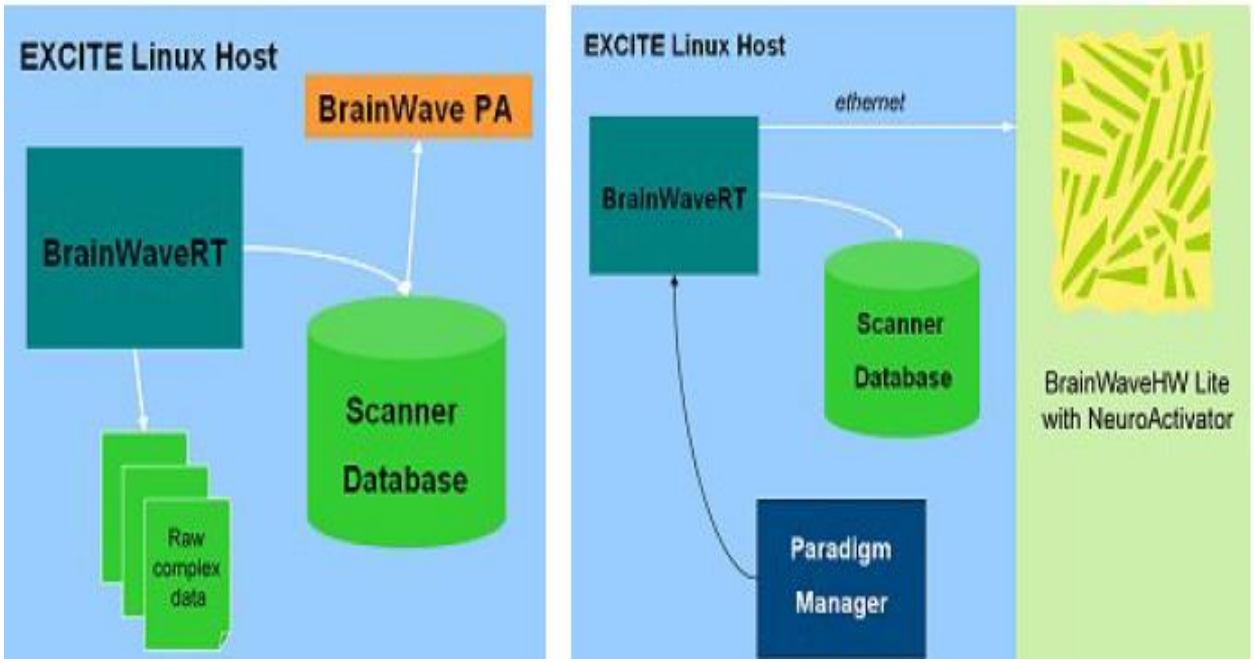
1. Motor paradigms
2. Bilateral finger tapping Vs Rest
3. Lip Pouting vs rest
4. Bilateral leg motor vs Rest
5. Language paradigms
6. Verb generation
7. Word pair
8. Syntax
9. Sematics

Clinical application

- Epilepsy
- Surgical planning

BrainWave- Application for fMRI processing in 3T

BrainWave consists of three basic tools to acquire, analyze and generate fMRI data. **BrainWaveRT** is the primary tool. It is protocol-driven, but has an additional paradigm setup step performed by either a small utility tool called the **Paradigm Manager** or by clicking ***fMRI*** on the Details area of an fMRI Protocol. BrainWaveRT is the main interface to use to collect high-quality EPI images during a functional experiment. If you also have the optional
BrainWavePA is the processing and analysis package that is used to analyze the EPI data set acquired with BrainWaveRT. BrainWavePA determines activation, fuses this activation in color onto a 3D anatomical data

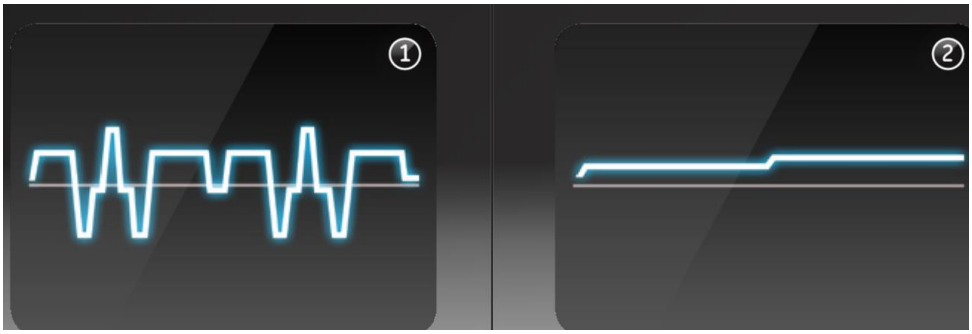


BrainWaveHW Lite comprises equipment used to create custom audio, visual, language and motor paradigms and play them out into the patient environment when used with BrainWaveRT. This equipment consists of a stimulus computer mounted in a rack in the MR equipment room. Paradigm Studio software on the stimulus computer is used to create custom audio and visual paradigms. **Paradigm Studio** software is carried to the patient bore using third party equipment (EPRIME)

SILENT MRI

Silent scan is a novel data acquisition method in which the gradients are used continuously, but are not rapidly switched on or off. Since the gradients are no longer switched on and off, mechanical vibration is eliminated and no noise is generated during the acquisition. The Silenz technology acquires three-dimensional MR data, resulting in isotropic resolution. Further, Silenz has the unique advantage of a very short echo time improving image quality and signal from all tissues of interest.

1 Conventional MR gradient sequence
2 Silent gradient sequence



1. High Fidelity Power Electronics Our High Fidelity Power Electronics platform helps maintain the extremely stable gradients and radio frequency (RF) required to avoid generating image artifacts during reconstruction.
2. Ultra-fast RF switching capabilities Since Silent Scan technology avoids switching gradients rapidly, it's crucial that the RF coil system be capable of switching from transmit to receive mode within microseconds to maximize signal-to-noise ratios within the images

COMPUTED TOMOGRAPHY

CT has been called one of the most important advances in radiology since Roentgen invented X-ray. The past decade has witnessed a constant progression of innovations in the modality, leading up to the introduction of multislice CT.High resolution images, ultra-fast scanning speed, a broad range of clinical applications, and sophisticated image postprocessing tools, unimaginable just a few years ago, have placed multislice CT into the radiology spotlight. These advances have led to important medical insights and opened up dramatic new horizons in the research, diagnosis, and treatment of disease.

Since its introduction in 1972, CT has been an important imaging modality. Recent technological advances have made CT one of the primary diagnostic imaging tools for a wide range of imaging applications. Yet many small hospital radiology departments rely on dated, single-slice scanners or do not provide CT services at all.
As the costs of CT scanners decline rapidly, making the move to multislice CT is easier than ever before.

Today, an advanced multislice unit is priced less than a single-slice CT was several years ago. Moreover, with the accelerated exam throughput and a growing repertoire of procedures, many small hospitals have found that a multislice CT can pay for itself in a short time and go on to turn a significant profit, while enhancing the quality of care in the community.. Most radiologists are familiar with the broad-based clinical benefits enabled by new multidetector technologies, from faster and higher quality exams to sophisticated 3D image processing. No longer constrained by a patient's limited breath-hold time, multislice CT has also significantly broadened the clinical applications, allowing advanced techniques such as imaging of the heart and peripheral vessels.

System specification

Brilliance iCT

The Brilliance iCT enable clinical excellence through the optimal combination of speed, power, coverage and dose utility. It sets a benchmark in full coverage whole body scanning while simultaneously setting new standard for advanced cardiovascular imaging.

X-ray tube

X-ray Tube

Feature	Specification
Focal Spot – Smart Focal Spot	X & Z deflection
Focal spot (IEC)	Large: 1.1 x 1.2 Small: 0.6 x 0.7
Anode Diameter	200mm
Anode Rotation Speed	10,800rpm
Spiral Groove Bearing	Double supported, direct cooling
Target Angle	8°, Segmented

Detectors

Detector

Feature	Specification
Slices	256 x 0.625
Material	Solid-State GOS with 86,016 elements
Slip Ring	5.3 Gbps transfer rate
Data Sampling Rate	Up to 4,800 views/revolution/element
Collimations Available (Channels x mm)	2 - 128 rows x 0.625 - 1.25mm; fused combinations for axial
Slice Thickness (Spiral mode)	0.625 - 10mm variable
Slice Thickness (Axial mode)	0.625 - 10mm variable
Scan Angles	240°, 360°, 420°

Collimators

Collimator

Feature	Specification
Wedge Filters	Small, Medium, Large
IntelliBeam Filters	2
Eclipse DoseRight collimator	Reduces dose up to 30% during helical scans.

Image Quality

Image Quality

Feature	Specification
Spatial resolution - Ultra high mode	24.0 Lp/cm @ cut-off
Spatial resolution - High mode	16.0 Lp/cm @ cut-off
Spatial resolution - Standard mode	13.0 Lp/cm @ cut-off
Noise	0.27%
Low contrast resolution	4.0mm @ 0.3%
Absorption range	-1024 to + 3072 Hounsfield units

Advances in CT

- Cardiac CT
- CT perfusion

Cardiac CT

Cardiac CT imaging makes high demands to the CT scanner in temporal and spatial resolutions due to cardiac motion and breathing. High spatial resolution is required, because the cardio vascular system to be examined has vessels, for example coronary arteries, in the millimeter or sub millimeter range. Small lesions of diagnostic value must be identifiable. High temporal resolution is needed, because the heart is in periodic motion. In order to ritually freeze the heart in the diastolic phase of the heart cycle (which is usually used for reconstruction) the temporal resolution has to be better than the length of this diastolic phase. Temporal resolution is the time needed to acquire one image. A short scan time is required because breathing and patient motion reduce the image quality. It also reduces the amount of contrast agent needed for visualizing the cardio-vascular system.

High image quality in cardiac imaging therefore requires sophisticated technical solutions: To visualize the complex anatomic structures of the heart, a collimation smaller than 1 mm is recommended to reconstruct voxels in the sub millimeter range.

To acquire cardiac images, the heart motion has to be virtually frozen during the diastolic phase. Therefore a high temporal resolution of about

100 ms up to 200 ms is possible with PHILIPS BRILLIANCE iCT 256-SLICE CT scanners.

To make it easier for the patient to hold her breath and not move, a short scan time of about 10 s is favorable, which also reduces the total amount of contrast agent needed.

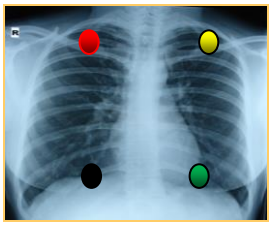
To acquire data over several heart cycles, scanning has to be done in relation to the heart beat. Retrospective ECG gating is therefore useful.

PHILIPS BRILLIANCE iCT 256-SLICE CT SCANNER

High temporal resolution is achieved by scanning of up to 256 slices simultaneously with a minimum gantry rotation time of 0.27 s. This results in a temporal resolution of about 135 ms. High spatial resolution is achieved by scanning with up to 0.625 mm collimated slice width (adaptive detector system). Voxels of 0.35x0.35x0.625 mm resolution are reconstructable. A short examination time is achieved by scanning up to 8cm in one gantry rotation.

ECG CONNECTING TO PATIENT

The correct placement of the ECG electrodes is essential in order to receive a clear and robust ECG signal with marked R-waves. Incorrect placement of the electrodes will result in an unstable ECG signal which is sensitive to movements of the patient during the scan.



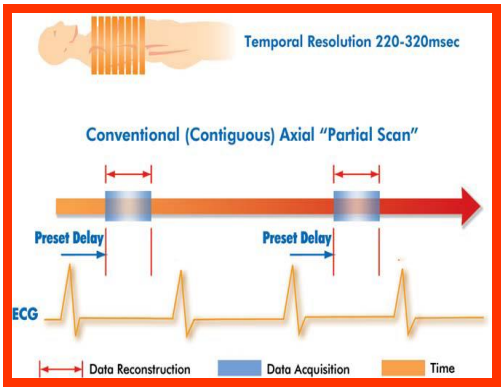
- Red electrode: on the right mid-clavicular line, directly below the clavicle
- Yellow electrode: on the left mid-clavicular line, directly below the clavicle
- Black electrode: right mid-clavicular line, 6 or 7 intercostal space
- Green electrode : on the left mid-clavicular line, 6 or 7 intercostal space

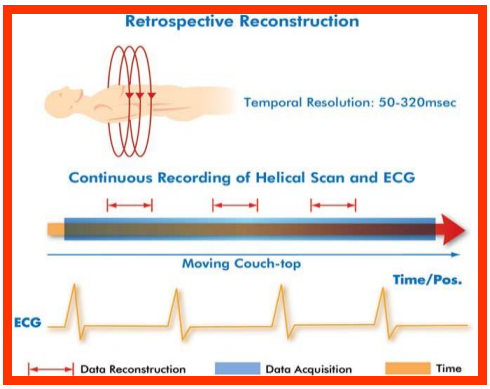
TWO MODES OF ACQUISITION

i. PROSPECTIVE
ii. RETROSPECTIVE

PROSPECTIVE SCANNING (AXIAL)

This mode is also called step and shoot method.in this method system detects the ECG from the patient body and calculates the diastolic phase where heart is at the least motion. It then exposes only the predetermined R-R interval phase after that the table moves to the next region and exposes.





RETROSPECTIVE SCANNING (SPIRAL)

The recommended scan mode for cardiac CT is multi-slice spiral scanning. In this mode, the gantry rotates with constant speed during acquisition while the patient table moves through the gantry. This results in a spiral movement rendering a complete volume data set over the scanned volume (i.e. the patient`s heart). The image on the left hand side schematically shows multi-slice CT acquisition.

Because the acquisition time spans several heart cycles, the spiral is measured in parallel with the patient`s ECG signals. Acquired volume data is later reconstructed according to these ECG signals (retrospective ECG gating). See the illustration below for a schema of retrospective gated multi-slice CT:

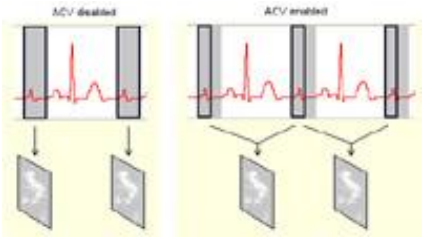
IMAGE RECONSTRUCTION

During scanning, single slices of the volume data are reconstructed in RT mode in full resolution but with reduced diagnostic usability because they originate from different phases of the cardiac cycle. High image quality is reached by reconstructing the volume data set (the spiral) especially from the diastolic phase of least heart motion in post-processing steps:

Shifting the delay time within the diastolic phase of the heart`s cycle allows to define an ideal scan box to be used for reconstruction. Slightly instable heart rates and arrhythmias may be compensated. Preview series can be reconstructed until the best delay is selected.

Synchronizing pulses over the R-peaks allow to edit the ECG and to skip extrasystolse, for example.

The Adaptive Cardio Volume algorithm increases the temporal resolution by reconstructing images with raw data of two adjacent heart cycles (RR cycles). Motion artifacts are reduced.

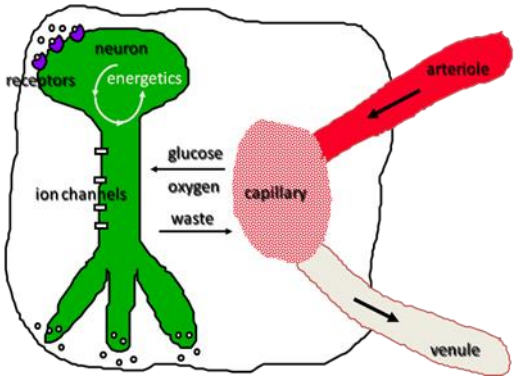


With the collimated slice width used (0.625 mm), images of nominal slice width of 0.625, 1, 2 and 3 mm can be reconstructed. We recommend to use slice widths of 1 mm to increase image quality by reducing artifacts.

The reconstructed images can be used for 3-D imaging such as MPR, Thin MIP or VRT.

PERFUSION CT

It means steady state delivery of blood to tissue parenchyma through the capillaries. Derived from the French verb "per fuser" meaning to "pour over or through."



CERBRAL HEMODYNAMICS

CBV

- Cerebral blood volume (CBV) is the fraction of tissue volume occupied by blood vessels
- Units: ml / 100 g brain
- 4ml/100g
- Flow x circulation time=CBV
- CBF X MTT=CBV

CBF

- Cerebral Blood Flow (CBF)
- Delivery of blood to tissue / unit time
- Units: ml / 100g brain / min
- CBV/MTT=CBF
- 50 ml / 100g brain / min

MTT

- Mean Transit Time (MTT)
- Average time to flow through capillaries (artery → vein)
- MTT=CBV/CBF
- Units: seconds 5 sec

Historical aspects of perfusion imaging

I. 1980-Leon Axel determined the cerebral blood flow from rapid – sequence contrast enhanced CT.
II. Groothius et al created BBP Parametric images of human brain in 1991.
III. Ken miles implement perfusion CT on spiral CT

Applications of CTP

I. Vascular pathology
   - Acute ischemic stroke
   - Chronic ischemia
   - Vasospasm

II. Tumours

Protocol of CTP

I. NCCT-Non contrast CT
II. CTP-CT perfusion
III. CTA-CT angiogram

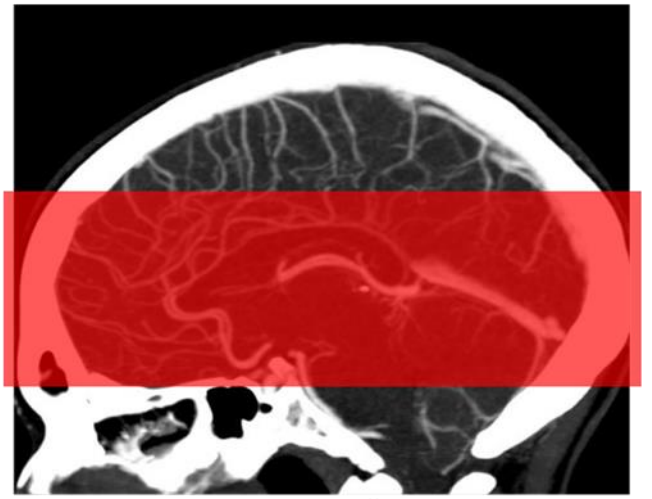
Steps of CT Perfusion Scan

1. Place patient on the table
2. Put an appropriate size IV catheter (18/20 gauge)
3. Center patient for head scan
4. Perform a routine Non contrast study of head
5. Consult with Radiologist for exact location of perfusion scan.
6. Select perfusion protocol
7. Start perfusion scanning and injector at the same time.

We have a 256 slice PHILIPS brilliance iCT scanner which has two type of perfusion methods.

1. Jog mode
2. Non-jog mode

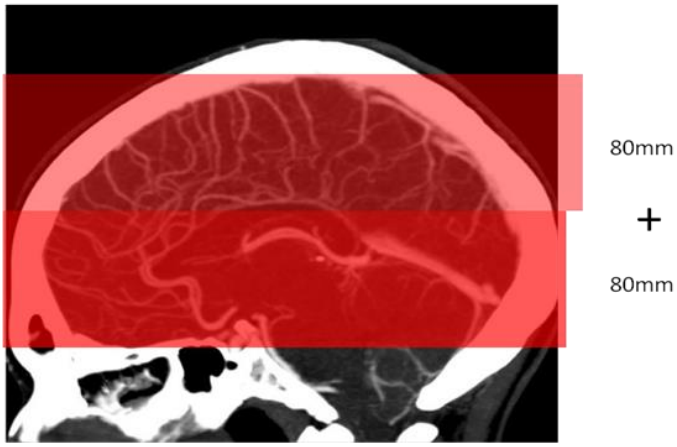
➢ NON-JOG MODE



Collimation: 128x0.625 mm
•Coverage: 80 mm

Jog mode is simply axial scanning .System will perform dynamic scanning while administration of contrast agent with constant table position.

➢ JOG SCAN



Total Scan Area: 160 mm (16cm)

Multiple axial scans at two couch locations with minimal inter-scan delay with single scan at each location between “jogs”.

I. Table Scanner obtains images from a single 360 degree rotation at location A
II. increments by 4 cm to reach position B
III. Scanner obtains Images from a single 360 degree rotation at location B
IV. Table travels 4 cm in opposite direction to return to position A
V. “Jogging sequence” continues for a total of 40-60 seconds.

Digital Subtraction Angiography

System specification

Innova 3131

Company	GE Healthcare
Model	Innova 3131
Type	Biplane digital flat panel fluoroscopic system
Acquisition zoom	Yes
Other imaging software options	Fluoro, DSA, instant mapping, cine, Innova Breeze runoff, Innova Chase, Innova Sub 3-D and CT, stenosis & vent analysis
Minimum room size to accommodate system	19.8 x 24 feet, 6 in. procedure
PATIENT TABLE	
Motion	8-way horizontal float
Length x width, cm (inches)	Omega V table: 333 (131) x 46 (18)
Vertical range, cm (inches)	Omega V table: 30 (12)
Lateral range, cm (inches)	Omega V table: 14 (5.5)
Longitudinal, cm (inches)	All tables up to 170 (66.9)
Tilt	NA
Maximum patient weight, lb.	All tables 450
X-ray density	Omega V table < 1 mm AI
Swivel	NA
Rotational angiography features	A fast rotational 200 rotation at a 40sec spin speed, using a frame rate of30 FPS provides approximately 150 views in a 5 second acquisition

Materials used for Neuro and Peripheral Interventions

MICRO CATHETER

All of the commercially available micro catheters are constructed of polyethylene and are hydrophilic ally coated. Many micro catheters wall contain braided materials, which improves flexibility, push ability, and tractability of the micro catheter. The braided construction lessens the incidence of micro catheter kinking or oval zing as it traverses bends. This braid feature can also cause the micro catheter to move forward and suddenly to retract as the guide wire is removed. Most Currently available micro catheters have similar performance characteristics. All the catheters have a marker at the tip, and most are available in a two-marker variation for the deployment of coils.

FasTRACKER-10

MICROCATHETERS

OVER THE WIRE MICRO CATHETER

FLOW GUIDED CATHETER

OVER THE WIRE MICROCATHETERS

Used for the infusion of thrombolytic agent.

Echelon™ Micro Catheter

These micro catheters provide straightforward access and stability. Proprietary nitinol braided design offers more proximal push with soft distal navigation. Four specific zones utilizing nitinol variable braiding provides control along the length of the catheter with shaft support, tip flexibility and smooth transitions. The large ID of the Echelon micro catheter allows a greater flow rate than competitive micro catheters. The small OD of the Echelon allows more flow in the guide catheter which can be useful for angiographic injections. Echelon pre-shaped micro

catheters offer the best tip shape out of the package and after simulated use.

Rebar™ Micro Catheter

The Rebar™ Micro Catheter is an endhole, single-lumen catheter. The proximal end of the catheter incorporates a standard lure adapter to facilitate the attachment of accessories. The catheter has a semi-rigid proximal shaft which transitions into the flexible distal shaft to facilitate the advancement of the catheter in the anatomy. Single or dual radiopaque markers at the distal end facilitate fluoroscopic visualization.

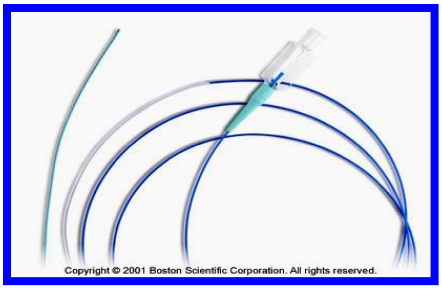
Prowler micro catheter (braided)

The prowler micro catheters are also available in a preshaped 45-degree, 90-degree angle, J-tip. The preshaped curves keep the operator's fingers from the steam, and the micro catheter seems to maintain their shape longer .At times, as mentioned earlier, the braided catheter will retract as the guide wire is removed. Similarly braided catheters have a tendency to suddenly move forward.

FLOW GUIDED MICROCATHETERS

These are very flexible hydrophilic-coated catheters that are primarily designed to deliver liquid embolic such as glue, onyx, and dehydrated alcohol, PVA (less than 500µm) can be administrated through these micro catheters as well.

SPINNAKER ELITE



Developed specially for flow directed applications, the spinnaker elite flow directed micro catheter might be used for regional infusion of diagnostic agents and vascular occlusion with Bernstein liquid coil-10. The flow-directed spinnaker elite (Boston) is not approved for use with glue or other liquid agents, which would seem to be its purpose.

Marathon™ Flow Directed Micro Catheter

Developed as an Onyx Delivery Catheter, the Marathon offers the user the lowest available tip profile while providing unmatched burst and tensile strength, making it the ideal catheter for the treatment of Brain AVMs.It has proximal push ability due to the stainless steel coil reinforcement in proximal shaft. Soft flow-direct able distal segment

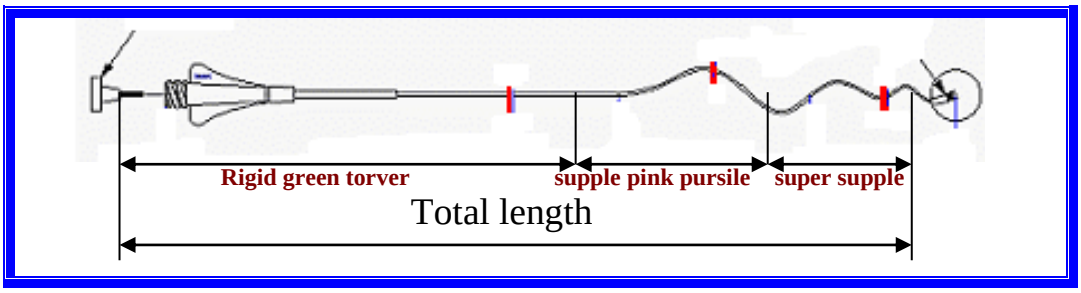
Distal tip of 1.3F, marker band profile of 1.4F and robust reinforcement

Nitinol braid reinforcement in distal "floppy" segment and has lubricious (PTFE) ID liner - from hub to tip for excellent guide wire interaction

BALT MAGIC

MAGIC catheters are designed for general intravascular use. They may be used for the controlled, selective regional infusion of therapeutic agents or embolic materials in to vessels. The MAGIC catheter is intended to facilitate access through distant, tortuous vasculature. Progressive suppleness ranging from a super supple distal shaft to a rigid

proximal shaft allows the catheter to be advanced by the physician. The rigid proximal shaft allows torque control to facilitate the advancement of the catheter. The MAGIC catheter tip(ring)and shaft are radiopaque.

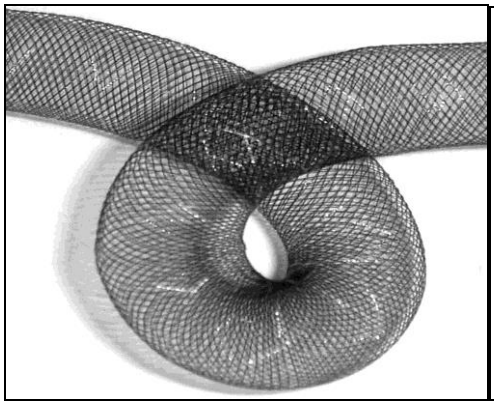


OBLITERATION PROCEDURE

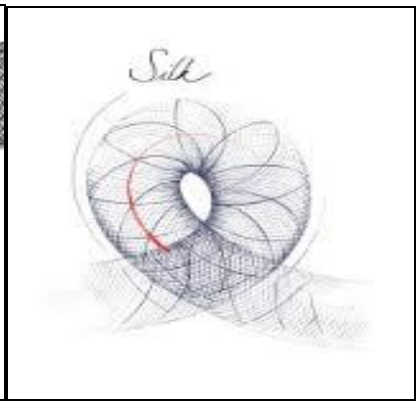
Otherwise referred to as 'Therapeutic Embolisation', using particulate materials delivered through micro catheters can be used in settings of acute bleeding from tumor vessels, vascular malformations, Aneurysms, Vascular tumors. Embolic materials in use include alcohol, metallic coils, gel foam,vascular plugs flow diverter etc.

Flow Diverter:
New Endovascular treatment option for complex inracranial aneurysms. The endo-vascular management of intracranial aneurysms include coil embolization techniques, such as balloon assisted and stent assisted coiling, are targeted towards the aneurysm sac, but flow diverters are endovascular devices placed within the parent artery rather than the aneurysm sac Presently available flow diverters are

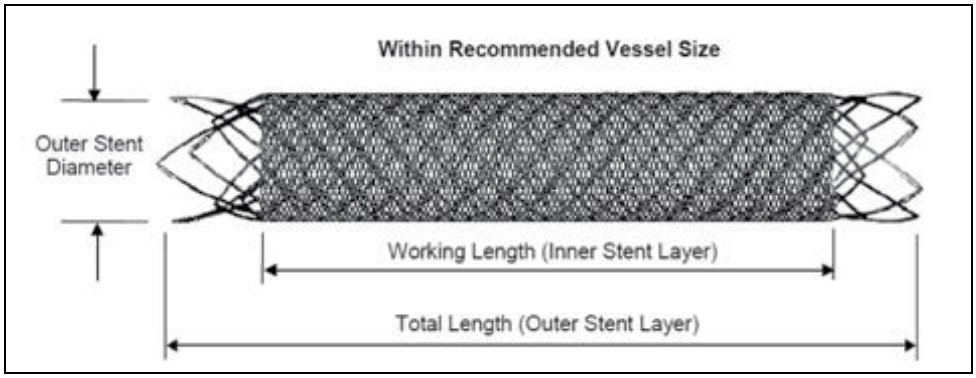
- **Pipeline embolization device** (PED ev3/ Covidien, Irvine, California)
- **Silk flow diverter (**SILK; Balt Extrusion, Montmorency, France)
- **Fred flow diverter(**FRED, Microvention, Terumo,P64)
- **Surpass flow diverter(**SURPASS; Stryker Neurovascular, Fremont)
- **phenox64 (p64)**



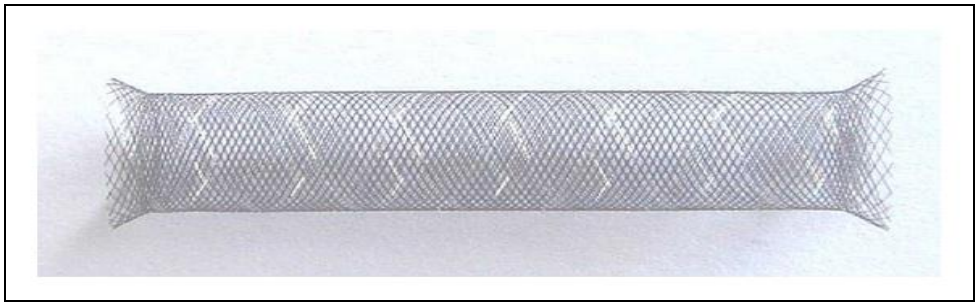
Pipeline flow diverter



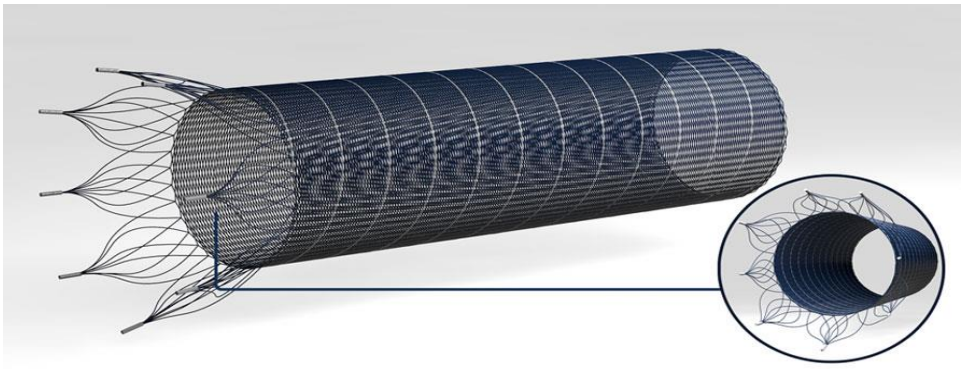
Silk flow diverter



Fred system



Surpass flow diverter



P64 by phenox

Aortic and Carotid Stents

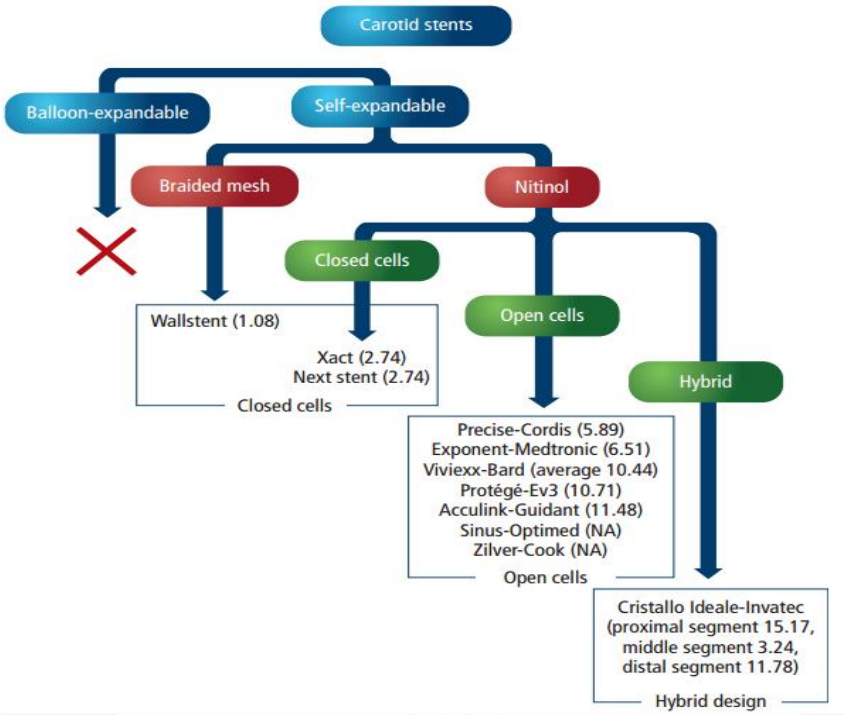
- Widest range of diameters currently available
  - Proximal five-peak bare spring allows for crossing the LCC or LSA without occluding blood flow4
  - Tapered distal main
  - Distal bare spring option to avoid covering the celiac artery

Thoracic covered stent graft

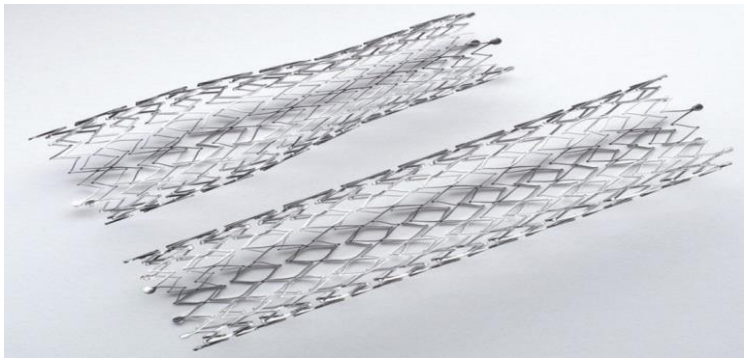
Carotid stent

Stent Technical Features

- Foreshortening
- Conformability/flexibility
- Vessel wall adaptability
- Scaffolding Radial strength
- Radial stiffness Lesion covering



Cristallo ideale…. …..Protage Rx



LIQUID EMBOLIC AGENTS

Liquid agents for interventional procedures consist of,

CYANOACRYLATES (GLUE)

- Histoacryl-(n-butyl 2-cyano acrylates) is commonly used
- Need skill full& care full handling.
- Capable of reaching distal small vessel.
- Exposure of glue to the ionic solution cause polymerization.
- Polymerization can be slowed by addition of iophendylate or glacial acetic acid.
- Tantalum, bismuth or lipidol gives better radiopacity to the glue.
- Speed of the polymerization can controlled by addition of lipidol.

HISTOACRYL CONCENTRATION CHART

NO	CONCENTRATION	HISTOACRYL	LIPIDOL
1	15%	0.5ml	2.8ml
2	17%	0.5ml	2.4ml
3	20%	0.5ml	2ml
4	22%	0.5ml	1.7ml
5	25%	0.5ml	1.5ml
6	33%	0.5ml	1ml
7	40%	1ml	1.5ml
8	50%	0.5ml	0.5ml
9	60%	1.5ml	1ml
10	66%	1ml	0.5ml
11	75%	1.5ml	0.5ml
12	80%	2ml	0.5ml

DEHYDRATED ALCOHOL

It is a liquid agent used in the same way as cyanoacrylates for the treatment of AVM's and some tumors. In the past the alcohol was opacified by dissolving metrizamide powder in it, and the solution was injected under fluoroscopic control. Because metrizamide powder is no longer available, operator's opacity the alcohol with a small amount of concentrated nonionic contrast material.

Alcohol injures tissue by denaturing proteins of the cell wall, particularly the endothelial cells, and causing precipitation of the protoplasm. This

leads to the thrombus formation and a coagulate necrosis. Alcohol injection is very painful, general anesthesia is usually required. The maximum volume of alcohol used in a treatment session is 1cc/kg body weight and this is usually well tolerated .The alcohol may cause a significant rise in pulmonary vascular resistance and pulmonary arterial pressures.

ONYX/SQUID

This liquid is a proprietary ethylene alcohol copolymer suspended in DMSO and opacified with tantalum powder. It stays in liquid form until it contacts blood or other aqueous solutions. The onyx then begins to precipitate, quickly changing from a liquid to a solid from the outside to the inside. Its prepared by shaking the vial at least 1 hour prior to the injection by using a shaker or vibrator. Its major advantage is that it adheres to itself but not to the delivery catheter, so that slow injections with slight reflux along the micro catheter tip can be used without fear of adherence of the cast to the micro catheter. However, if significant reflux occurs, catheter retrieval may be impossible.

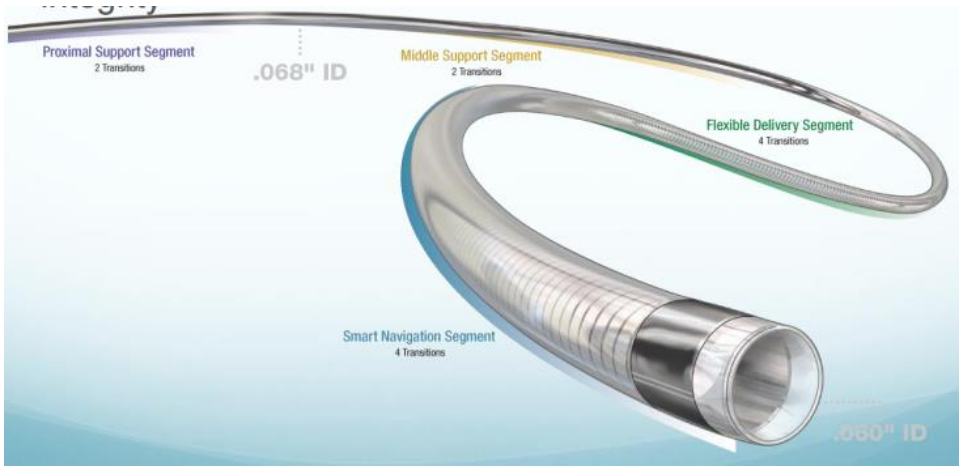
PHIL- Precipitating Hydrophobic Injectable Liquid

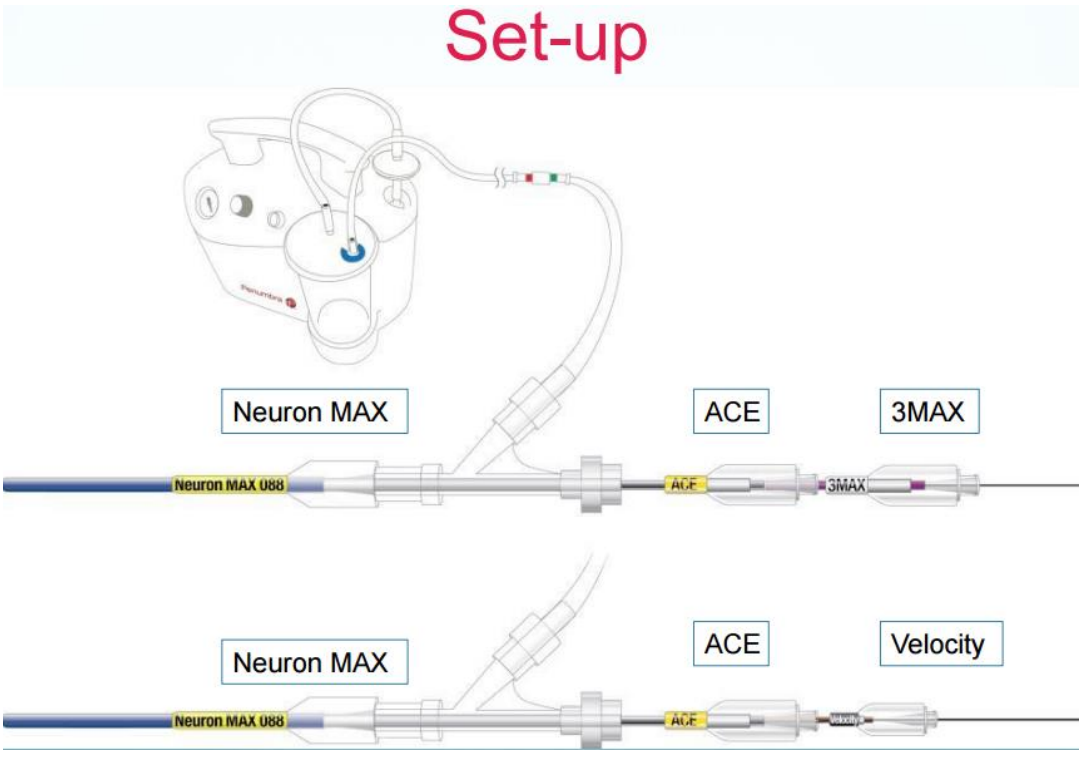
It is a non-adhesive liquid embolic agent comprised of a biocompatible polymer dissolved in dimethyl sulfoxide (DMSO) solvent. An Iodine component is covalently bonded to the polymer to provide homogenous fluoroscopic visualization.
No risk of micro catheter blockage due to Tantalum aggregation Minimize (streak) artifact during control imaging. Pre-filled sterile syringes – No preparation required
Iodine component is covalently bonded to the co-polymer – No shaking needed – Perfect homogeneity of PHIL radiopacity same visibility regardless the procedure length

PENUMBRA –ACE

- 12 Transition Zones enable outstanding force transmission and exceptional kink resistance
- Advanced Polymer provides flexibility for superior tracking
- Nitinol Round Wire Reinforcement maintains lumen integrity

- **Designed to optimize aspiration from Pump MAX™ to the tip of the** reperfusion catheter





CLINICALLY FEASIBLE KURTOSIS CHARACTERIZATION OF GLIOMA USING MB EPI AT 3T

SUBMITTED IN FULLFILLMENT OF THE COURSE OF

(DAMIT)

DIPLOMA IN ADVANCED MEDICAL IMAGING TECHNOLOGY

PERIOD: JAN 2015-DEC 2016

TINTU THOMAS.

INDEX

AIM OF THE STUDY

To develop a technique for high-resolution diffusion weighted imaging (DWI) and to compare it with standard DWI methods. Diffusional kurtosis imaging (DKI) is an approach to characterizing the non-Gaussian fraction of water diffusion in biological tissue.

Advanced Diffusion and Distortion Correction (ADDC) is intended to provide distortion correction for susceptibility and eddy-currents, as well as gradient non-linearity correction to diffusion-weighted magnetic resonance imaging (MRI) data before further processing to produce fractional anisotropy, apparent diffusion coefficient and kurtosis-related images.

INTRODUCTION

The study of diffusion properties by MRI has gained significant importance in clinical research of the human brain. It is so far the only method available to analyse the diffusion behaviour of tissue noninvasively. By far the most widely used model to quantify diffusion in the human brain is the diffusion tensor (DT) model. This technique uses a three-dimensional (3D) second order diffusion tensor to describe the directional dependence of diffusion as an ellipsoid. Several rotationally invariant diffusion metrics can be derived from the DT, including mean diffusivity (MD) and fractional anisotropy (FA), which are used extensively to analyse structural integrity of white matter (WM).

DKI can be described by a 3D 4th order diffusion kurtosis tensor (DKT), adding 15 further independent coefficients to the DTI model. Therefore, the DKI model is altogether parameterized by 22 elements: the non–diffusion-weighted b0 signal, the 6 independent elements of the DT and the 15 independent elements of the DKT. Several rotationally invariant, scalar metrics for DKI exist, including different kinds of mean values such as MK (mean kurtosis in the spherical coordinate system, also referred to as MS), ME (mean kurtosis in the elliptical coordinate system), MZ (mean kurtosis in the scaled elliptical coordinate system), directional metrics such as radial kurtosis (AKC), and axial kurtosis (AKC), as well as extreme values like maximum kurtosis (AKCmax) and minimum kurtosis (AKCmin). Several studies reported changes of mean kurtosis and AKC. For a wide range of diseases, including white matter infarctions traumatic brain injury & stroke.

SCIENCE AND LITERATURE

ANATOMY AND PATHOPHYSIOLOGY

The human brain is the main organ of the human central nervous system. It is located in the head, protected by the skull. Much of the size of the human brain comes from the cerebral cortex, especially the frontal lobes, which are associated with executive functions such as self-control, planning, reasoning and abstract thought.

The human cerebral cortex is a thick layer of neural tissue that covers the two cerebral hemispheres that make up most of the brain. This layer is folded in a way that increases the amount of surface area that can fit into the volume available. The pattern of folds is similar across individuals but shows many small variations. The cortex is divided into four lobes – the frontal lobe, parietal lobe, temporal lobe, and occipital lobe. (Some classification systems also include a limbic lobe and treat the insular cortex as a lobe) Within each lobe are numerous cortical areas, each associated with a particular function, including vision, motor control, and language. The left and right hemispheres are broadly similar in shape, and most cortical areas are replicated on both sides. Some areas, though, show strong lateralization, particularly areas that are involved in language. In most people, the left hemisphere is dominant for language, with the right hemisphere playing only a minor role. There are other functions, such as visual-spatial ability, for which the right hemisphere is usually dominant.

Despite being protected by the thick bones of the skull, suspended in cerebrospinal fluid, and isolated from the bloodstream by the blood–brain barrier, the human brain

is susceptible to damage and disease. The most common forms of physical damage are closed head injuries such as a blow to the head or other trauma, a stroke, or poisoning by a number of chemicals that can act as neurotoxins, such as alcohol. Infection of the brain, though serious, is rare because of the protective blood-to brain and blood-to cerebral fluid barriers. The human brain is also susceptible to degenerative disorders, such as Parkinson's disease, forms of dementia including Alzheimer's disease, (mostly as the result of aging) and multiple sclerosis. A number of psychiatric conditions,such as schizophrenia and clinical depression, are thought to be associated with brain dysfunctions, although the nature of these is not well understood. The brain can also be the site of brain tumors and these can be benign or malignant.

There are several methods for detecting brain activity changes using three-dimensional imaging of local changes in blood flow. The older methods are SPECT and PET, which depend on injection of radioactive tracers into the bloodstream. A newer method, functional magnetic resonance imaging (fMRI), has considerably better spatial resolution and involves no radioactivity. Using the most powerful magnets currently available, fMRI can localize brain activity changes to regions as small as one cubic millimeter. The downside is that the temporal resolution is poor: when brain activity increases, the blood flow response is delayed by 1–5 seconds and lasts for at least 10 seconds. Thus, fMRI is a very useful tool for learning which brain regions are involved in a given behavior, but gives little information about the temporal dynamics of their responses. A major advantage for fMRI is that, because it is non-invasive, it

can readily be used on human subjects. Another new non-invasive functional imaging method is functional near-infrared spectroscopy.

TUMORS

A **glioma** is a type of tumor that starts in the brain or spine. It is called a glioma because it arises from glial cells. The most common site of gliomas is the brain. Gliomas make up about 30% of all brain and central nervous system tumors and 80% of all malignant brain tumors.

CLASSIFICATION

Gliomas are classified by cell type, by grade, and by location.

By type of cell

Gliomas are named according to the specific type of cell with which they share histological features, but not necessarily from which they originate. The main types of gliomas are:

- Ependymomas: ependymal cells
- Astrocytomas: astrocytes (glioblastoma multiforme is a malignant astrocytoma and the most common primary brain tumor among adults).
- Oligodendrogliomas: oligodendrocytes
- Brainstem glioma: develop in the brain stem
- Optic nerve glioma: develop in or around the optic nerve
- Mixed gliomas, such as oligoastrocytomas, contain cells from different types of glia

By grade

Gliomas are further categorized according to their grade, which is determined by pathologic evaluation of the tumor.

- Low-grade gliomas [WHO grade II] are well-differentiated (not anaplastic); these tend to exhibit benign tendencies and portend a better prognosis for the patient. However, they have a uniform rate of recurrence and increase in grade over time so should be classified as malignant.
- High-grade [WHO grade III–IV] gliomas are undifferentiated or anaplastic; these are malignant and carry a worse prognosis.

Of numerous grading systems in use, the most common is the World Health Organization (WHO) grading system for astrocytoma, under which tumors are graded from I (least advanced disease—best prognosis) to IV (most advanced disease—worst prognosis).

By location

Gliomas can be classified according to whether they are above or below a membrane in the brain called the tentorium. The tentorium separates the cerebrum (above) from the cerebellum (below)

- The supratentorial is above the tentorium, in the cerebrum, and mostly found in adults (70%).
- The infratentorial is below the tentorium, in the cerebellum, and mostly found in children (70%).
- The pontine is located in the pons of the brainstem. The brainstem has three parts (pons, midbrain, and medulla); the pons controls critical functions such as breathing, making surgery on these extremely dangerous.

Signs and symptoms

Symptoms of gliomas depend on which part of the central nervous system is affected. A brain glioma can cause headaches, vomiting, seizures, and cranial

nerve disorders as a result of increased intracranial pressure. A glioma of the optic nerve can cause visual loss. Spinal cord gliomas can cause pain, weakness, or numbness in the extremities. Gliomas do not metastasize by the bloodstream, but they can spread via the cerebrospinal fluid and cause "drop metastases" to the spinal cord.

CAUSES

The exact causes of gliomas are not known. Hereditary genetic disorders such as neuro fibromatoses (type 1 and type 2) and tuberous sclerosis complex are known to predispose to their development. Different oncogenes can cooperate in the development of gliomas.

PATHOPHYSIOLOGY

High-grade gliomas are highly vascular tumors and have a tendency to infiltrate. They have extensive areas of necrosis and hypoxia. Often, tumor growth causes a breakdown of the blood–brain barrier in the vicinity of the tumor. As a rule, high-grade gliomas almost always grow back even after complete surgical excision, so are commonly called recurrent cancer of the brain.

Conversely, low-grade gliomas grow slowly, often over many years, and can be followed without treatment unless they grow and cause symptoms.

Several acquired (not inherited) genetic mutations have been found in gliomas. Tumor suppressor protein 53 (p53) is mutated early in the disease. p53 is the "guardian of the genome," which, during DNA and cell duplication, makes sure the DNA is copied correctly and destroys the cell (apoptosis) if the DNA is mutated and cannot be fixed. When p53 itself is mutated, other

mutations can survive. Phosphatase and tensin homolog (PTEN), another tumor suppressor gene, is itself lost or mutated. Epidermal growth factor receptor, a growth factor that normally stimulates cells to divide, is amplified and stimulates cells to divide too much. Together, these mutations lead to cells dividing uncontrollably, a hallmark of cancer. Recently, mutations in *IDH1* and *IDH2* were found to be part of the mechanism and associated with a more favorable prognosis. The *IDH1* and *IDH2* genes are significant because they are involved in the citric acid cycle in mitochondria. Mitochondria are involved in apoptosis. Furthermore, the altered glycolysis metabolism in some cancer cells leads to low oxygen (hypoxia). The normal response to hypoxia is to stimulate the growth of new blood vessels (angiogenesis). So, these two genes may contribute to both the lack of apoptosis and vascularization of gliomas.

TREATMENT

Treatment for brain gliomas depends on the location, the cell type, and the grade of malignancy. Often, treatment is a combined approach, using surgery, radiation therapy, and chemotherapy. The radiation therapy is in the form of external beam radiation or the stereotactic approach using radiosurgery. Spinal cord tumors can be treated by surgery and radiation. Temozolomide, a chemotherapeutic drug, is able to cross the blood–brain barrier effectively and is currently being used in therapy for high-grade tumors.

REVIEW OF LITERATURE

High-Resolution Diffusion-Weighted Imaging of the Breast with Multiband 2D Radiofrequency Pulses and a Generalized Parallel Imaging Reconstruction

Valentina Taviani, Marcus T. Alley, Suchandrima Banerjee, Dwight G. Nishimura, Bruce L. Daniel, Shreyas S. Vasanawala, and Brian A. Hargreaves

To develop a technique for high resolution diffusion weighted imaging and to compare with standard diffusion weighted method. Results show that rFOV DWI using the tilted 2DRF pulse provides increased signal-to-noise ratio, extended coverage, and robust fat suppression, without any scan time penalty.

Bias and Precision Analysis of Diffusional Kurtosis Imaging for Different Acquisition Schemes

Tim Sprenger, Jonathan I. Sper, Brice Fernandez, Vladimir Golkov et al 2015: Magnetic resonance in medicine

Diffusional kurtosis imaging (DKI) is an approach to characterizing the non-Gaussian fraction of water diffusion in biological tissue. However, DKI is highly susceptible to the low signal-to-noise ratio of diffusion-weighted images, causing low precision and a significant bias due to Rician noise distribution

MATERIALS AND METHOD

Multiband EPI was conducted with a quadrature transmit and 32-channel receive head coil on GE scanners. Diffusion-weighted imaging acquisitions were obtained from two healthy volunteers and six tumour patients. The data were acquired with a 3 T GE MR750 scanner at the **Sree Chitra Tirunal Institute of Medical Sciences & Technology Trivandrum Kerala**, with a maximum gradient strength of gmax 50 mT/m.

INCLUSION CRITERIA

- Patients having tumours (gliomas)
- Co- operative patients above 12 years

EXCLUSION CRITERIA

- Non co- operative patients below 12 years

MULTIBAND ACQUISITION

Three slices were simultaneously excited (multiband factor of 3, or MB = 3) with a three-band RF excitation (no inter-slice shift) and axial spin-echo echo planer (SE-EPI) readout with phase encoding (PE) in the anterior–posterior (AP) direction, resulting in 19 slices for brain coverage at the level of the corpus callosum with isotropic voxels of 2×2×2mm3 over a field of view of 256 × 256mm2. 75% partial Fourier k-space sampling was employed to reduce TE and an in-plane acceleration factor of 3 (R = 3) was used, which we found to be the best trade-off between TE and distortion. With a 50 mT/m amplitude gradient system at b=2800 s/mm2, TE was minimum ms and TR was 2900 ms. Calibration images were acquired at the beginning of the sequence with the same three-band excitation pulses but with different phase offsets applied between the bands so that they could be separated through a Fourier Transform (FT).

DWIs with five different acquisition schemes in q space have been obtained with a maximal b-value of 2800 s/mm2. Two versions of the three-shell acquisition scheme based on with 147 directions and corresponding b-values of 0, 1000, 2800, and s/mm2 were acquired

OFFLINE DATA RECONSTRUCTION

The raw data file (P file) and the calibration files associated with the EPI acquisition get saved in a folder the name of which contains the exam number, series number and timestamp, in desired folder. These files

will be needed by the user for offline reconstruction of the multiband EPI data. Please note that the raw data size for diffusion tensor imaging is typically 20 gigabytes or more.

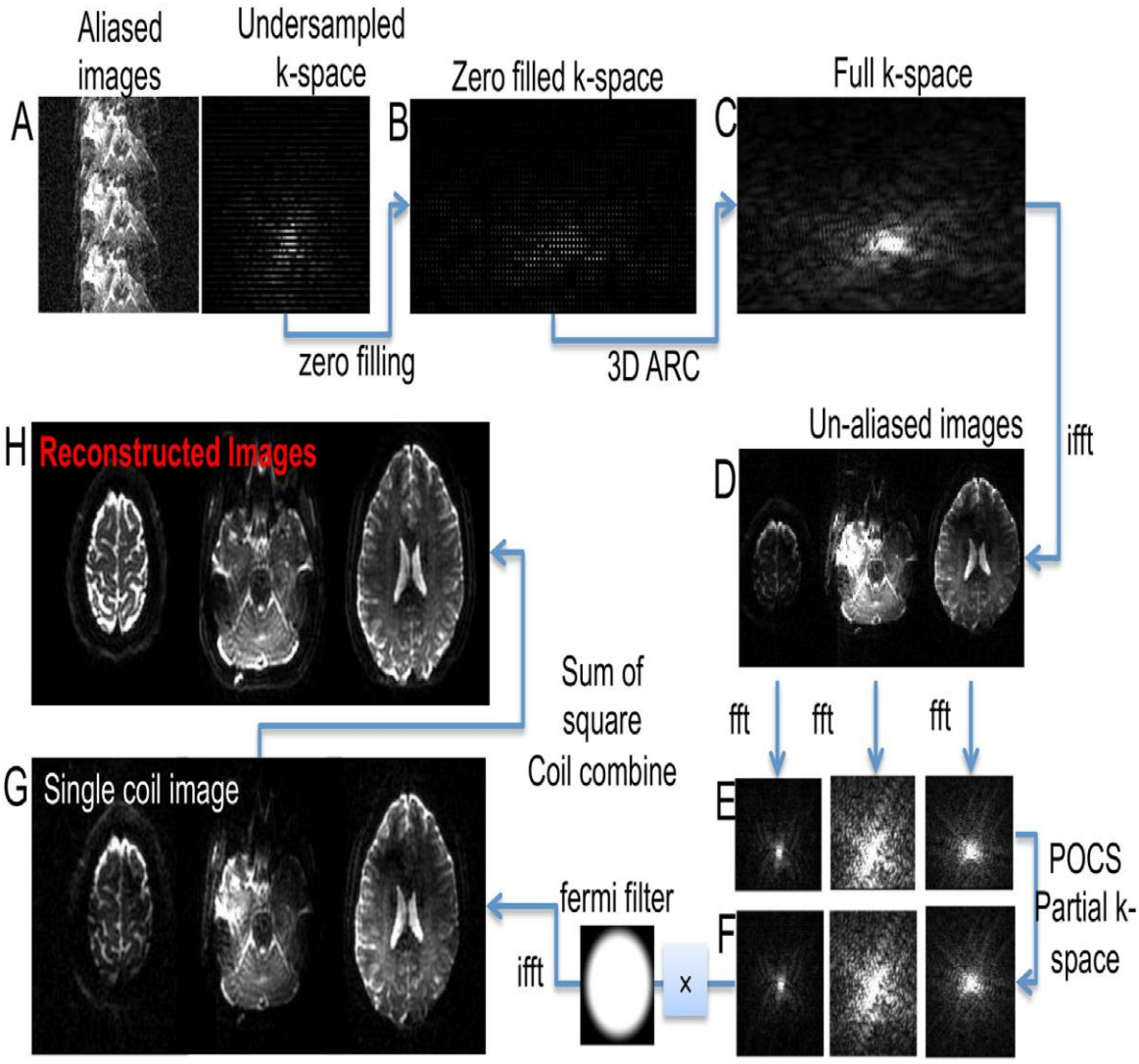
CONTROL DATA ACQUISITION

2 volunteers were scanned with both GE 3 T MR 750 and GE 3T MR 750 W scanners using 32-channel head coils and the same gradient system (50 mT/m amplitude). b = 0, 1000, 2800 (T2 weighted) images were repetitively acquired with both standard MB = 3 using the acquisition parameters described above. With the same TR, only the central slab of the brain was acquired for MB = 3.

MULTIBAND IMAGE RECONSTRUCTION

The image was aliased in both SI and AP directions, and was unfolded using the SENSE/GRAPPA procedure. The calibration data were first concatenated and Fourier transformed (FT) to generate the fully sampled k-space. Once the kernel has been generated, aliased images went through the reconstruction pipeline as illustrated below. The under sampled k-space was first zero filled in the direction that no acceleration was performed and a standard GRAPPA/ARC procedure was applied to reconstruct the k-space data. After an inverse Fourier Transform (ifft), the unaliased images were individually transformed into k-space again to reconstruct the full k-space through a partial k-space reconstruction method using projection onto convex sets (POCS). A 2D Fermi filter was then applied to reduce Gibbs ringing, and

single coil images were combined with a sum of squares coil combination



DATA PROCESSING

After the image is reconstructed, a susceptibility distortion correction was applied. ADDC KURTOSIS software were fitted in advance workstation and select both T1 series and diffusion series. After three hour processing twelve (12) new series will appear when the processing is complete. The new series are numbered of the original series number. The letters “RM-AW” (if not

already present) are prepended to the series description to indicate Research Mode.

DKI FITTING

The DKI model parameterizes the MR signal S with the no weighted signal S0, the symmetric second-order diffusion tensor D and the symmetric 4th order kurtosis tensor W

$$S(\vec{g}, S_0, D, W) =$$

$$S_0 \cdot \exp\left(-b\sum_{i,j} g_i g_j D_{ij} + \frac{b^2}{6}\left(\sum_i \frac{D_{ii}}{3}\right)^2 \sum_{i,j,k,l} g_i g_j g_k g_l W_{ijkl}\right)$$

where ~g is a normalized vector defining an arbitrary direction. Because both tensors are fully symmetric, D and W have 6 and 15 independent coefficients, respectively. To avoid confusion in the notation of the standard DTI fit and the DT of the DKI fit, we will add the index "DKI" to all metrics related to a DKI fit.

The 12 new images are

AKC-Apparent kurtosis coefficient (AKC min- minimum AKC, AKC max- maximum AKC, K= KURTOSIS)

Par K-K parallel as shown below (axial kurtosis)

Ortho K-K perpendicular as shown below (radial kurtosis)

GNC-gradient non linearity correction map

Mean K-Mean Kurtosis

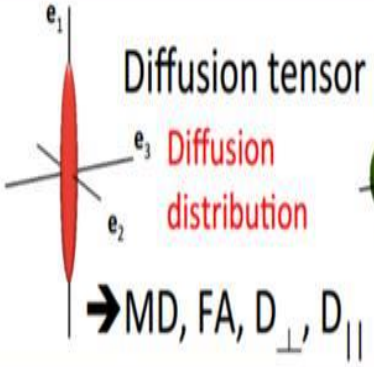
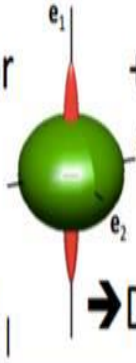
FA K-Fractional Anisotropy obtained from kurtosis computation

FA- Fractional Anisotropy obtained from DTI computation

ADC- Mean Apparent Diffusion Coefficient (MD)

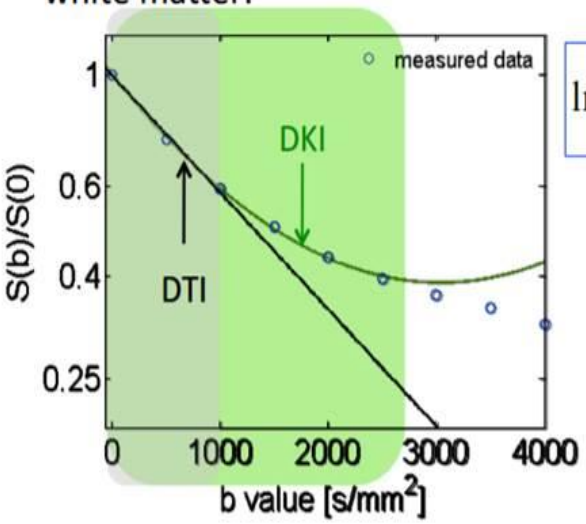
eADC- Exponential ADC

MuMin &Max K-Eigen vector max and min Kurtosis

Diffusion signal	Gaussian	Non-Gaussian
Metrics	 Diffusion tensor Diffusion distribution →MD, FA, $D_{\perp}$, $D_{\parallel}$	 + Kurtosis tensor Kurtosis distribution →DTI + MK, $K_{\perp}$, $K_{\parallel}$

Diffusional Kurtosis Imaging (DKI)

Non-Gaussian diffusion signal in white matter:



$$\ln\left[S(b)\right] = \ln\left[S(0)\right] - bD + \frac{1}{6}b^2D^2K + O\left(b^3\right)$$

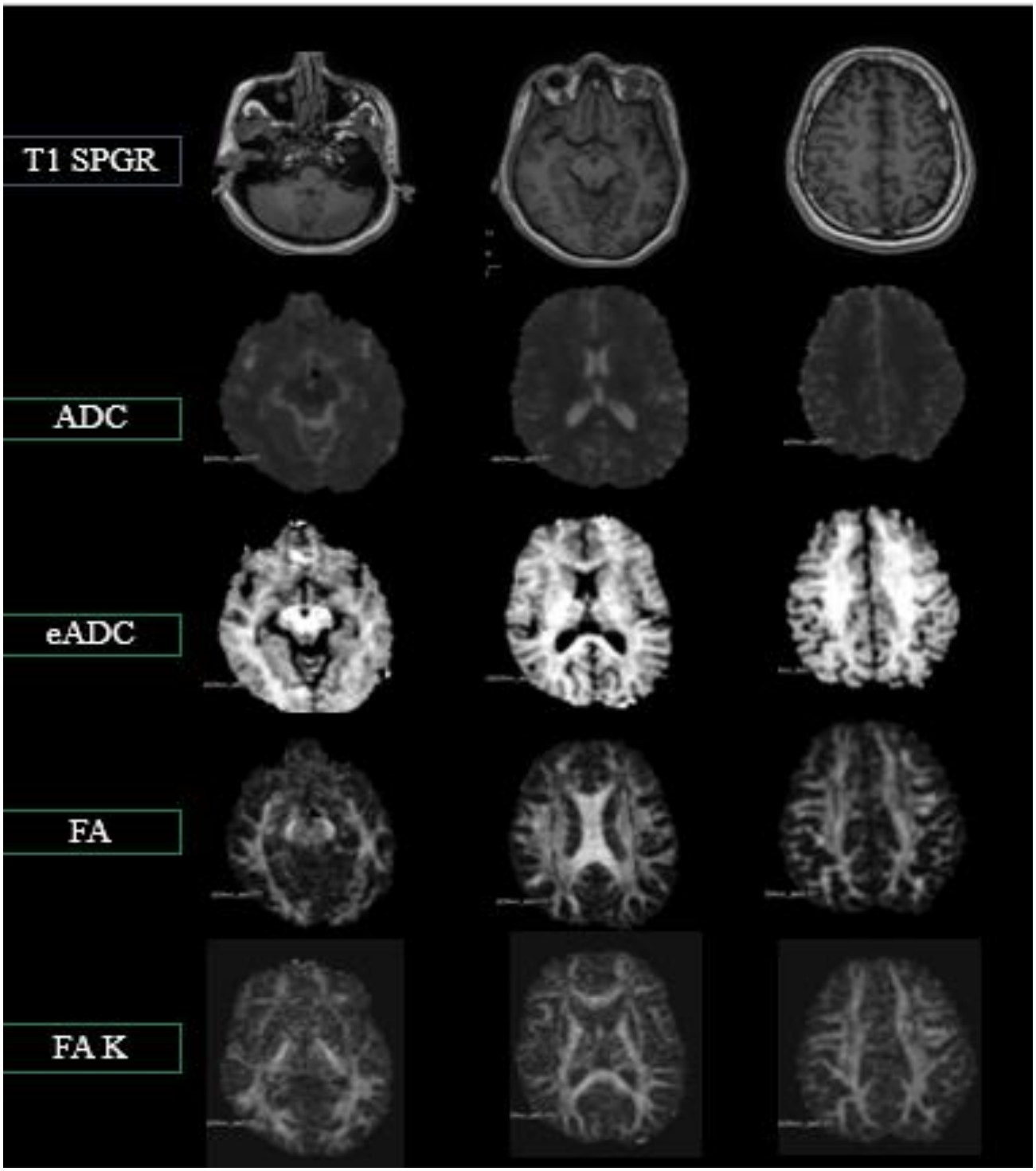
For isotropic tissues, 1 direction is sufficient.

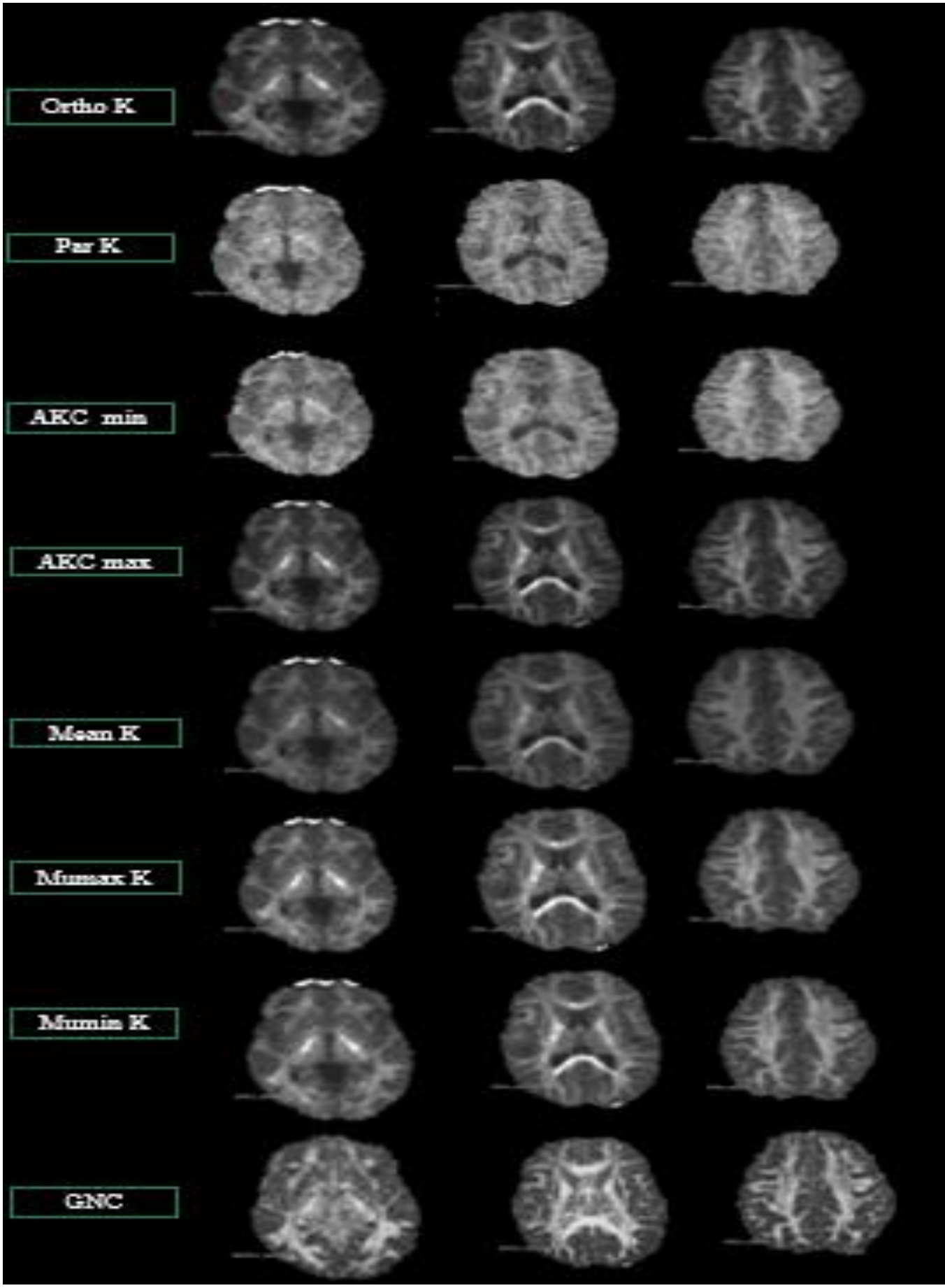
For anisotropic tissues, 15 or more directions are needed to construct the kurtosis tensor

DKI is based on a quadratic expansion of ln[S(b)]

Jensen JH MRM 2005
Lu H NMR Biomed 2006
Jensen JH NMR Biomed 2010

The twelve of set of images are shown below, these are done in volunteers. These are normal scan shows both T1 SPGR sequence, MB images & DWI images.




Ortho K
Par K
AKC min
AKC max
Mean K
Mumax K
Mumin K
GNC

Summary of data acquisition with volunteers and patients

	Volunteers	Patients
Purpose	calibration	Diffusion kurtosis Imaging
Subjects	2	8
Sequence	MB- 2 SPGR T1 DWI	MB- 2 SPGR T1

CHARACTERSTICS OF PATIENTS

No	Age	Sex	Grade	Chemotherapy	Image comments
1	14	M	2	NONE	STABLE
2	35	F	3	NONE	STABLE
3	38	F	3	NONE	STABLE
4	44	M	3	NONE	STABLE
5	50	F	3	NONE	STABLE
6	58	M	3	NONE	STABLE
7	24	M	2	DONE	STABLE
8	62	M	2	DONE	STABLE

RESULTS AND OBSERVATION

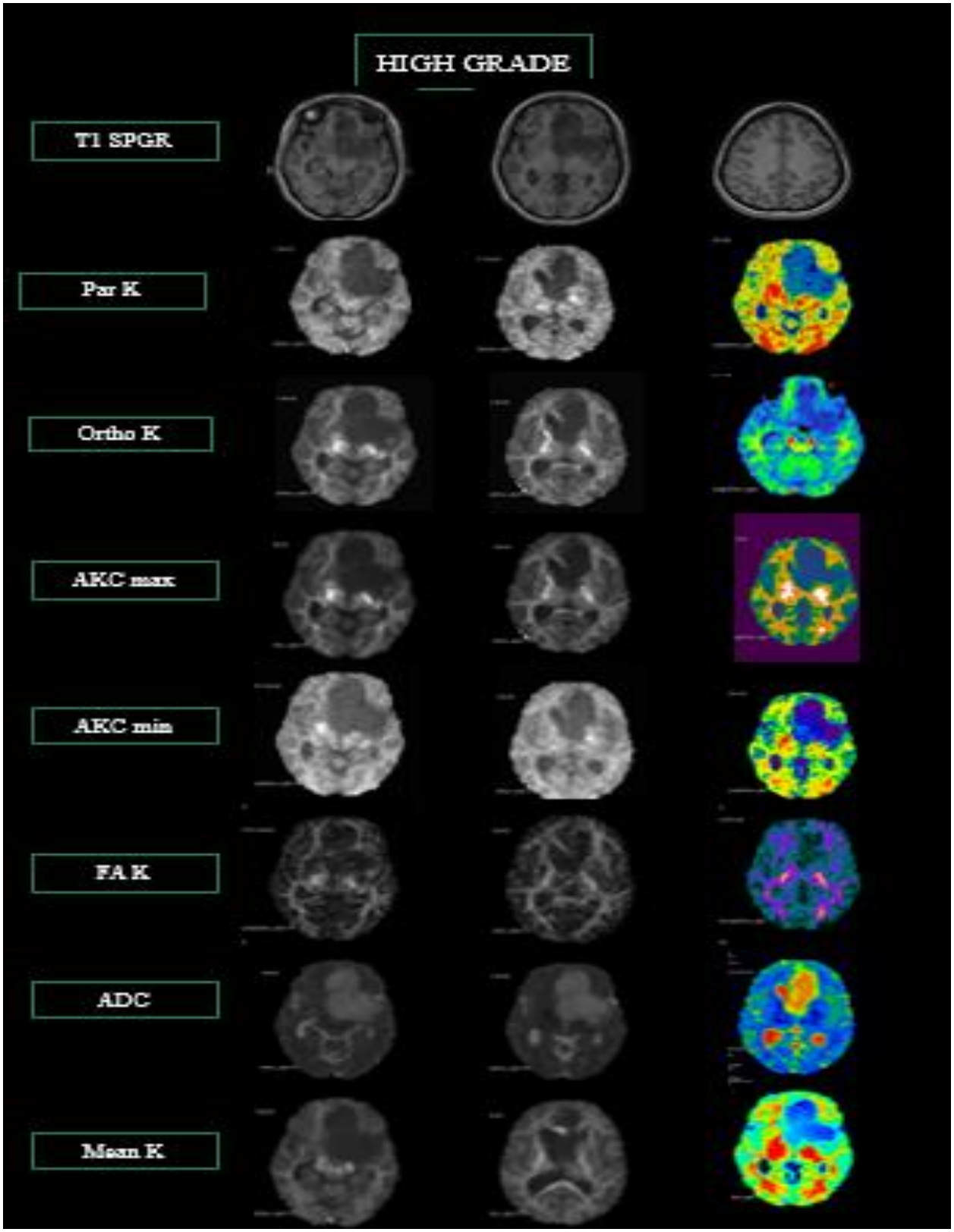
DATA PROCESSING

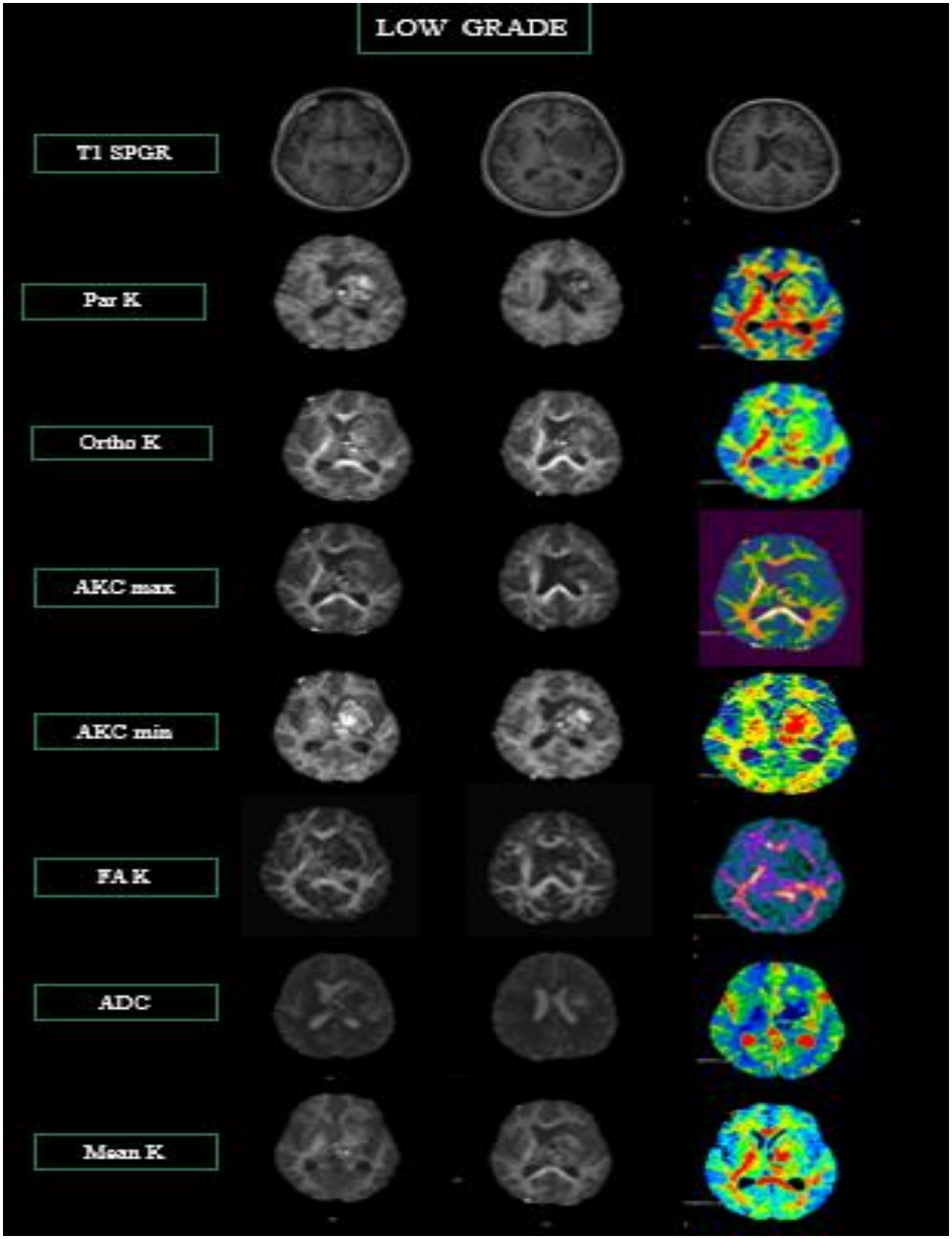
After the Multiband data were reconstructed a susceptibility distortion correction was applied. The after we got the image each of twelve set were processed in VOLUME MB DWI software and give appropriate color code for each of the image. The average of axial kurtosis, radial kurtosis, mean kurtosis, FA obtained from mean kurtosis, apparent diffusion kurtosis, ADC were taken, processed and plotted in table. The values were shown in the table were obtained by putting ROI in the tumor and normal region.

These are done in Advance Workstation

The table below explains the relative scaling or unit used in the values of imaging

QUANTTITY	UNIT OR SCALING
ADC	μm2/sec
Eadc	1
FA & ALL KURTOSIS	1000


HIGH GRADE
T1 SPGR
Par K
Ortho K
AKC max
AKC min
FA K
ADC
Mean K

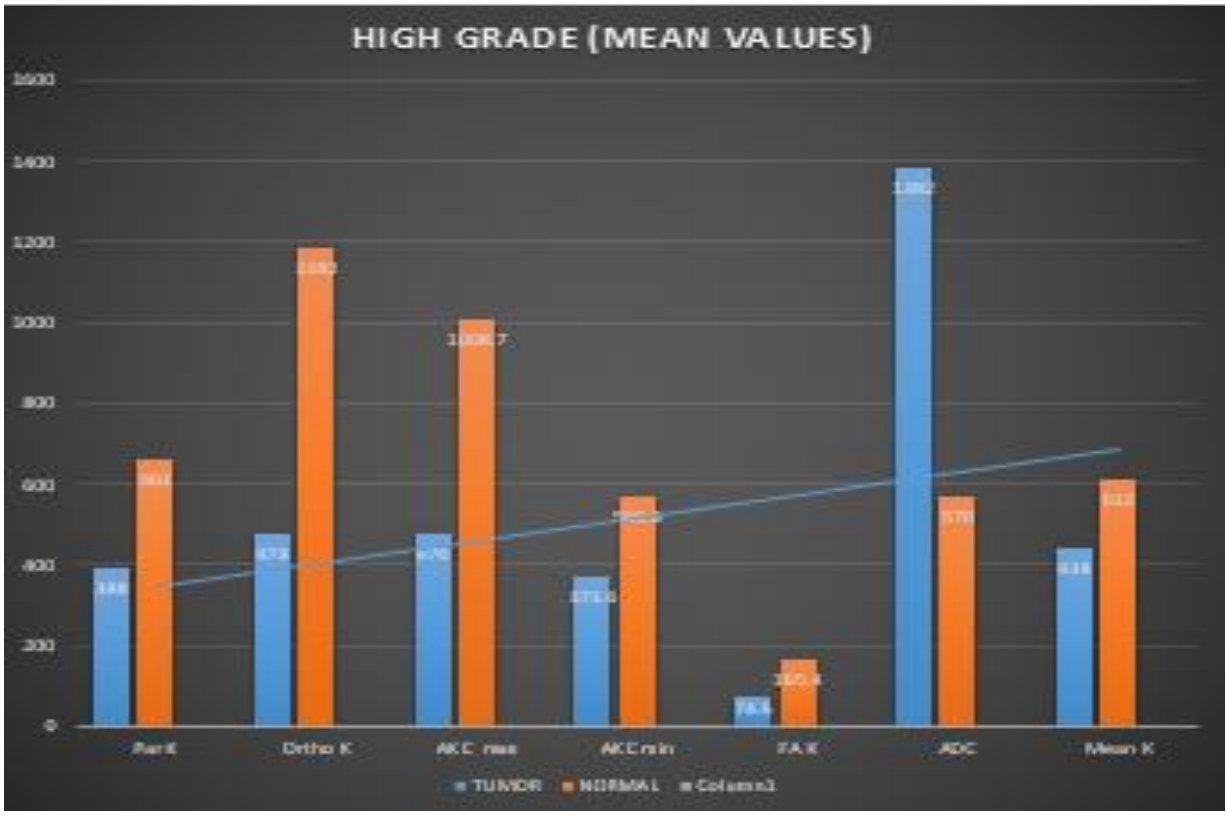

LOW GRADE
T1 SPGR
Par K
Ortho K
AKC max
AKC min
FA K
ADC
Mean K

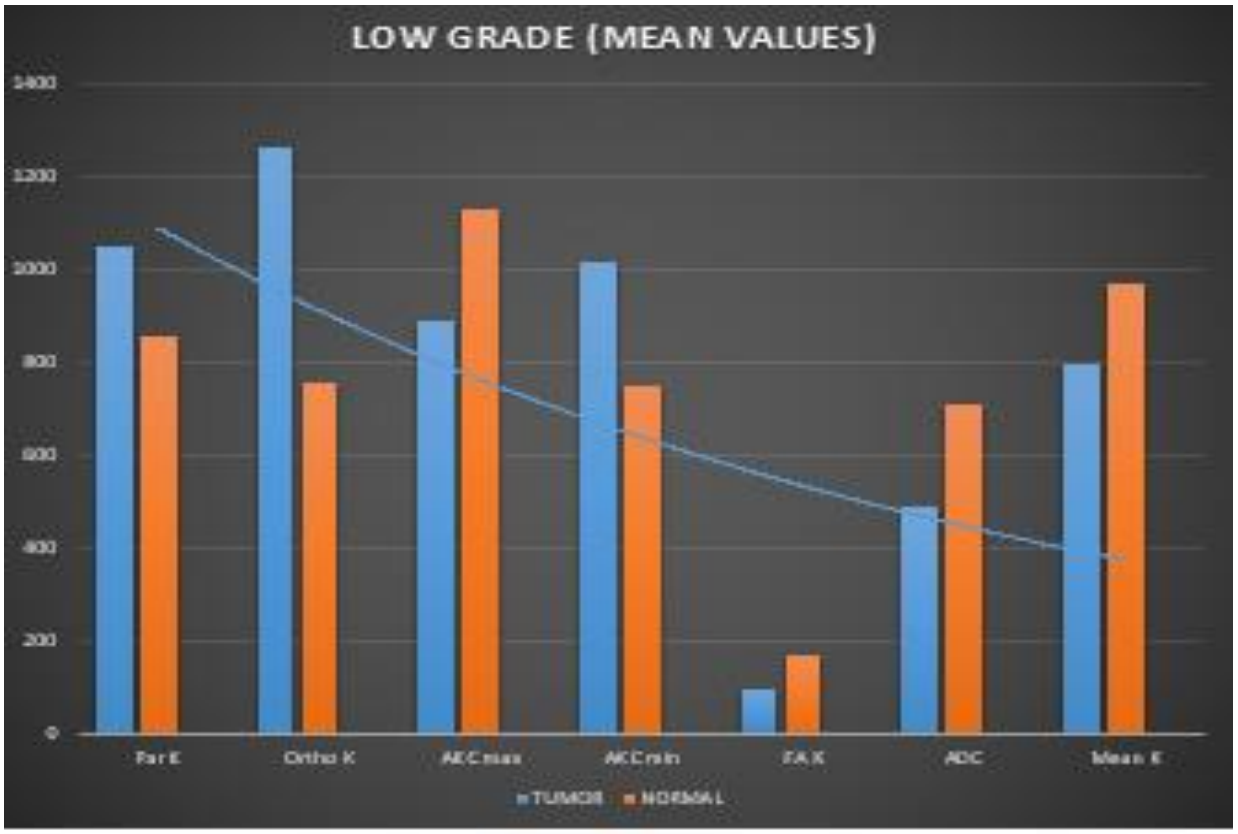
High grade glioma

	Tumor region	**Normal region**
Par K	.401± .30	.668±.24
Ortho K	.489±.55	1.18±.22
AKC max	.469±.10	1.08±.09
AKC min	.373±.32	.569±.,10
FA K	.0746±.45	.165±.22
ADC	1.382±.18	.573±.02
Mean K	.432±.10	.612±.08

Low grade tumor

	Tumor region	**Normal region**
Par K	1.049±.32	.854±.08
Ortho K	1.269±.20	.753±.20
AKC max	.888±.04	1.13±.24
AKC min	1.016±.02	.746±.12
FA K	.092±.18	.166±.32
ADC	.98±.32	.706±.10
Mean K	.797±.20	.97±.20


HIGH GRADE (MEAN VALUES)
1600
1400
1200
1000
800
600
400
200
0
Part E
Ortho K
AEC max
AECmin
FA K
ADC
Mean K
TUMOR
NORMAL
Column1


LOW GRADE (MEAN VALUES)
1400
1200
1000
800
600
400
200
0
Part E
Ortho K
AECmax
AECmin
FA K
ADC
Mean E
TUMOR
NORMAL

DISCUSSION

The multiband diffusion as a research tool. So the offline data reconstruction and the processing of the image take long time to get the image. The kurtosis images and values are above shown are the mean standard deviation of Par K, Ortho K, AKC min. AKC max, FA K, ADC, Mean K in low grade and high grade glioma. The MB diffusion was good for getting the DKI images, but one of the major problem was it take around 8 minutes to acquire the sequence.one of the important factor is patients co- operation, if the was moves between the scan we have to repeat the scan again for better reconstruction.

The use of sophisticated diffusion model provides characterization of tissue composition is a promising technique for evaluating lesion heterogeneity in patients with glioma. The application of these models has typically been limited by the need to acquire a large number of distortion at B values which is not feasible in clinical setting. In this study I demonstrated the feasibility of acquiring multiband diffusion weighted data in the whole brain.

The performance of the EPI sequence at ultra-high field has been difficult to access because the T2 values of brain tissue are difficult to measure. During acquisition if we use the MB factor as 2 the time and the SNR was increased. Here I am done with MB factoer-3. Here in 3 T the geometry factor and coil sensitivity grows progressively asymmetric and become increasingly structure due to the shortening of RF wave length and related interference effect.

The multiband diffusion sequence was applied to the characterization of glioma using 3 shell, 147 direction protocol that is straight forward to implement and sufficiently economical for research application and clinical application are yet sophisticated enough to distinguish the MD images and kurtosis images in the brain.The processed image provide a unique contrast across the tumor and highlighted interesting area. The 3-fold acceleration in the slice direction was the highest that could be obtained with our current multiband technique, as the separation of aliased slices is close to the coil size and SNR lost would be exacerbated if a higher acceleration factor was used in that direction. Another technique, termed blipped-CAIPIRINHA can be implemented to both increase the SNR and achieve a higher acceleration factor. This technique can reduce the g-factor in simultaneous multi-slice acquisitions by introducing inter-slice image shifts and thus increase the distance between aliased voxels. Another limitation was that we used the Shinnar–Le Roux (SLR) optimized RF pulses where the high RF energy transmission limited the optimal TR that can be achieved at high field due to specific absorption rate (SAR).

In my study most of the patients are complained with body heating, so this was one of the reason of in-co preparations of patients. Advance RF techniques have been reported the use of lower the peak of RF power at ultra- high field. Implementation of these techniques will further improve SNR and reduce the acquisition time. I have demonstrated the feasibility of using multiband diffusion weighted imaging at 3T with in 8 minute is clinically helpful to characterizing kurtosis imaging glioma.

CONCLUSION

The Multiband diffusion data quality and quantities measurements in diffusion kurtosis image was generally much better than DWI image in 3T, because these images have less artifacts. Anatomical images in 3T benefits from the higher SNR and the ability to consistently obtain high quality diffusion data at 3T will contribute towards the implementation of comprehensive brain MRI examination of ultra-high field.

REFERENCES

High-Resolution Diffusion-Weighted Imaging of the
Breast with Multiband 2D Radiofrequency Pulses and a Generalized Parallel Imaging Reconstruction

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