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

SAJITH-R

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

CERTIFICATE

This is to certify that Mr. **SAJITH-R** has participated in Interventional and Imaging Cases during the period of Jan 2015 to Dec 2016 while working as a Radiological Technology 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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Sree Chitra Tirunal Institute for Medical Sciences and Technology,
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PREFACE

This work book, I have done as part of my training in the Department of Imaging Sciences & Interventional 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, Colour 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.Prof. Dr.Jayadevan.E.R. Asso. Prof. 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 heart full thanks to all the Radiographers, other staffs of radiology, staff members of different depts, 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 senior 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 & Biopsys)	-	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

- DSA Instrumentation including 3D Rotational angiography
- Multi Detector CT-Technical Aspects &Clinical Application
- Imaging parameters in MRI
- Principles of Ultrasound and Doppler –Advantages &Limitations
- Radiation protection
- Magnetic Resonance Imaging-Instrumentation
- MR Spectroscopy
- Echo Planar Imaging
- Stroke Imaging
- Diffusion &Diffusion Tensor Imaging
- Musculoskeletal MRI

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

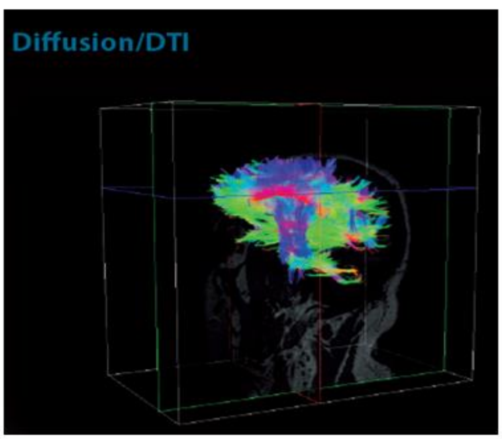
NEW POST PROCESSING SOFTWARE

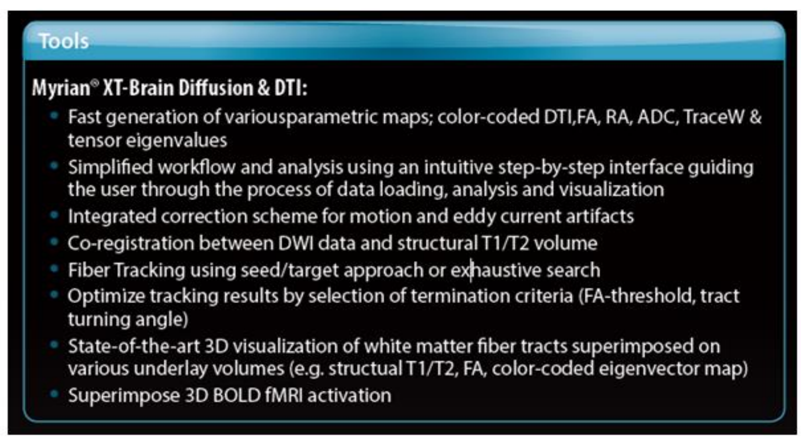
MYRIAN – INTRASENSE

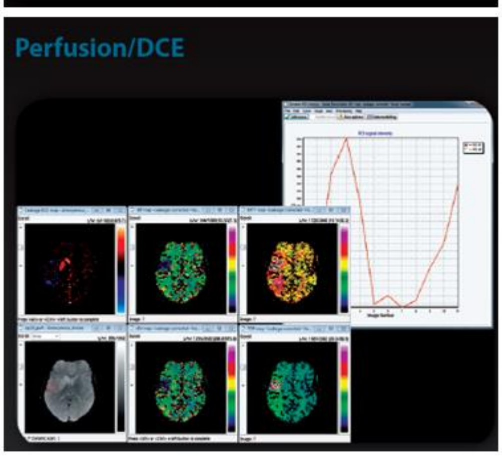
- Module based solution for Diffusion/DTI , Perfusion/DCE imaging
- Windows based software
- Vendor – neutral application , process image from any modality manufacture

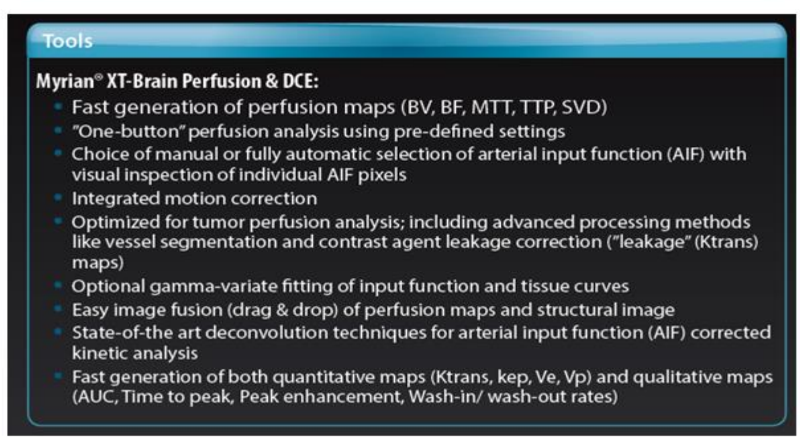
XT- BRAIN nordic ICE

Provide flexibility for research oriented work





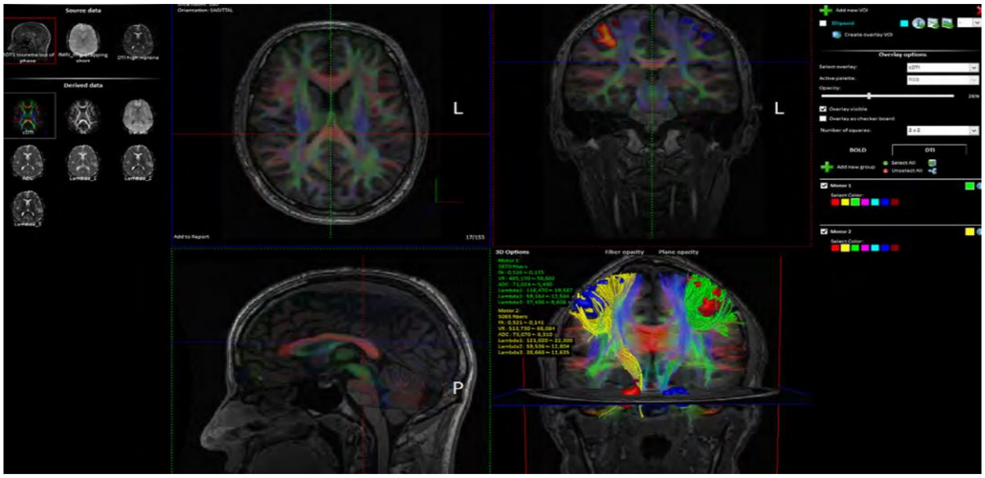




nordic Brain EX :

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

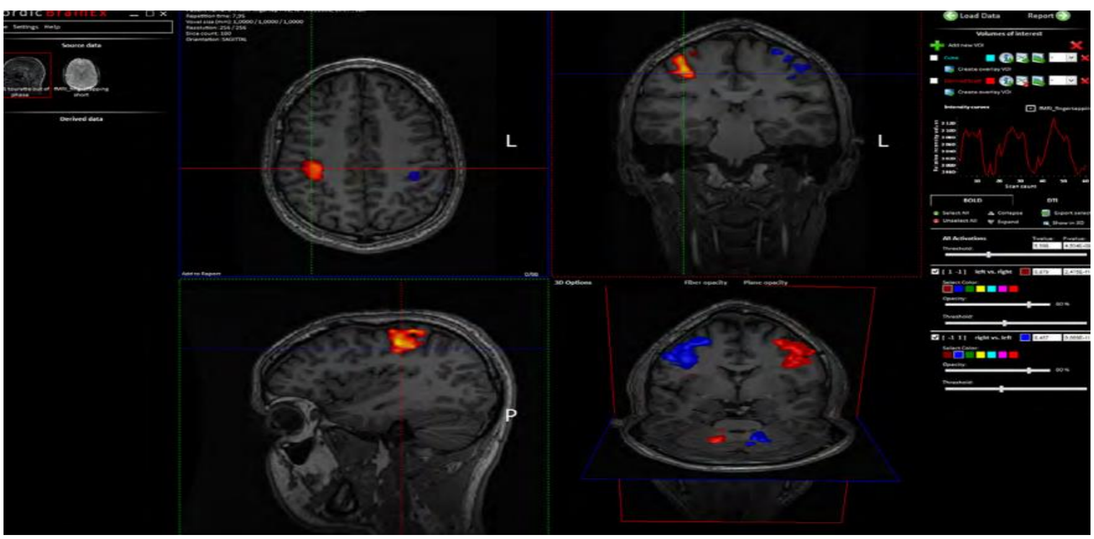
- ➢ DTI Fiber tracking Module



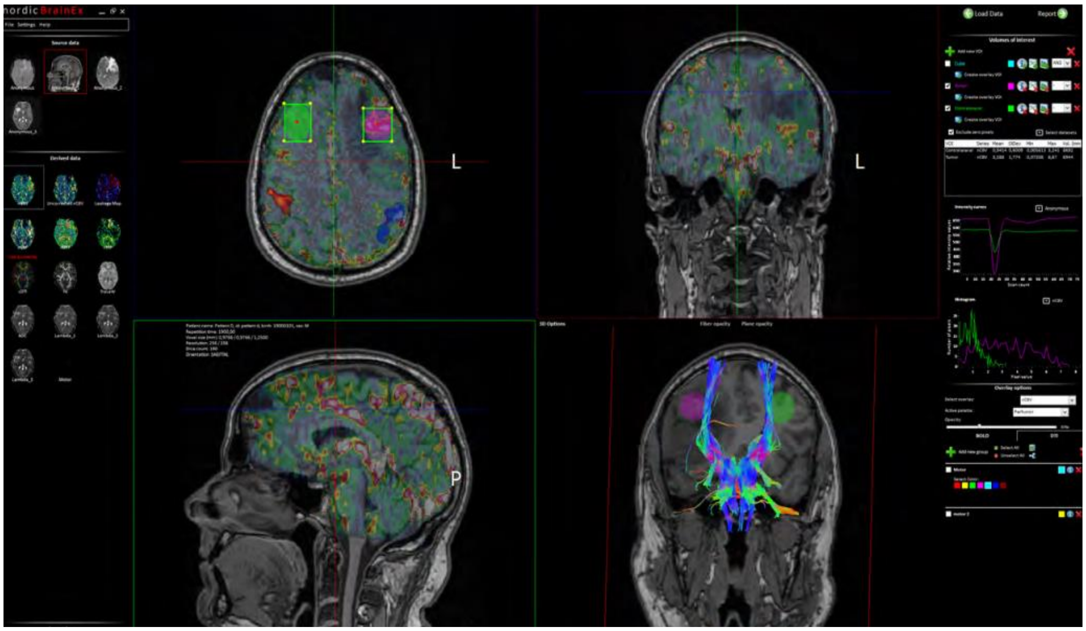
Preprocessing - Motion Correction, Eddy current correction , Smooth , Average ,Adjust noise level

Fibertracking – multiple VOI , AND OR & NOT option

- ➢ BOLD fMRI module



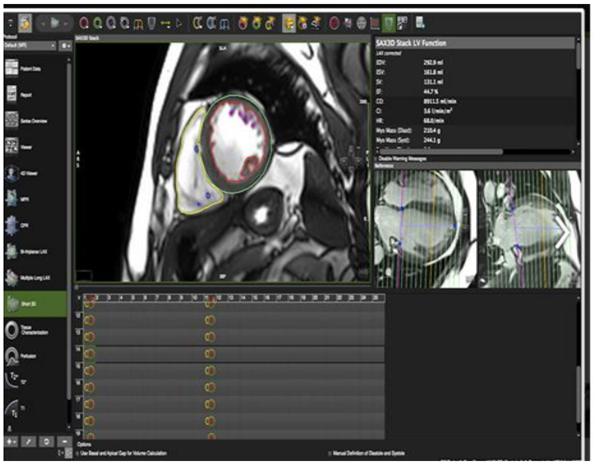
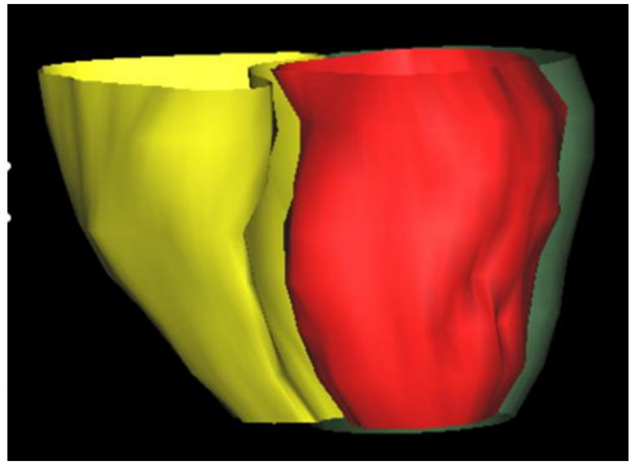
- Perfusion/DSC module



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

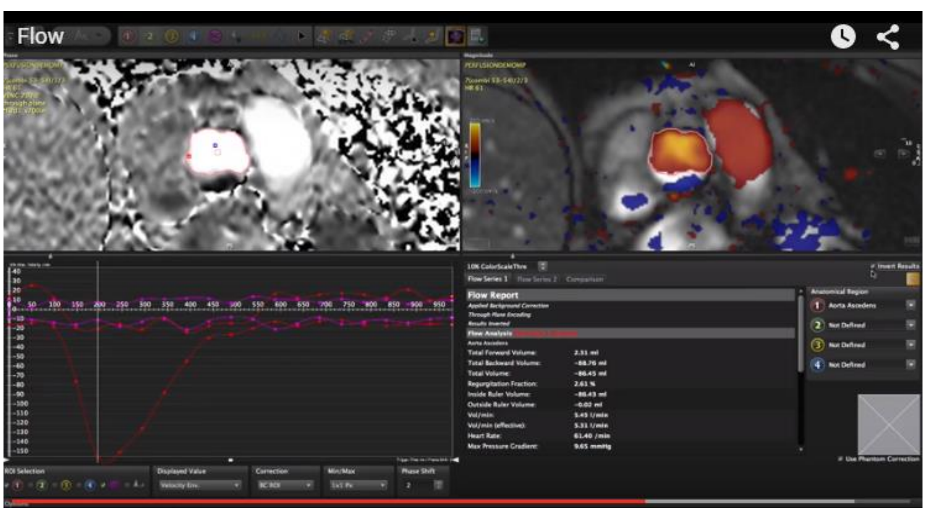
CIRCLE CARDIO VASCULAR IMAGING

- **LV/RV FUNCTION**

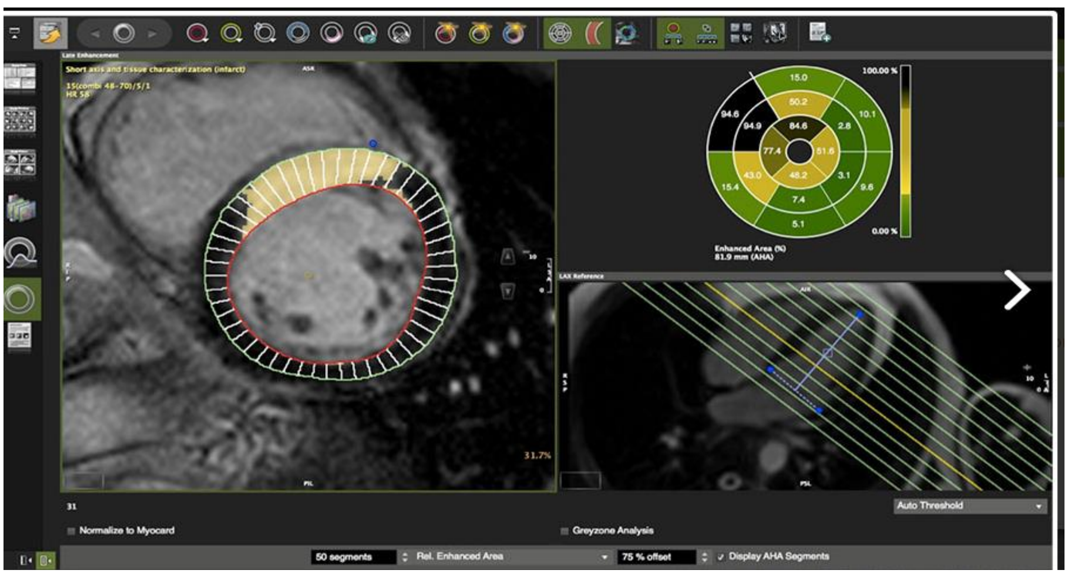
- Left and right atrial volumetry [disk area summation & area length method]
- Polar maps offering customizable segmentation including AHA segmentation model
- Semi-automatic mitral & tricuspid valve correction
- Optional in- or exclusion of trabeculae and papillary muscles in/from myocardial mass
- 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 volumina 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**

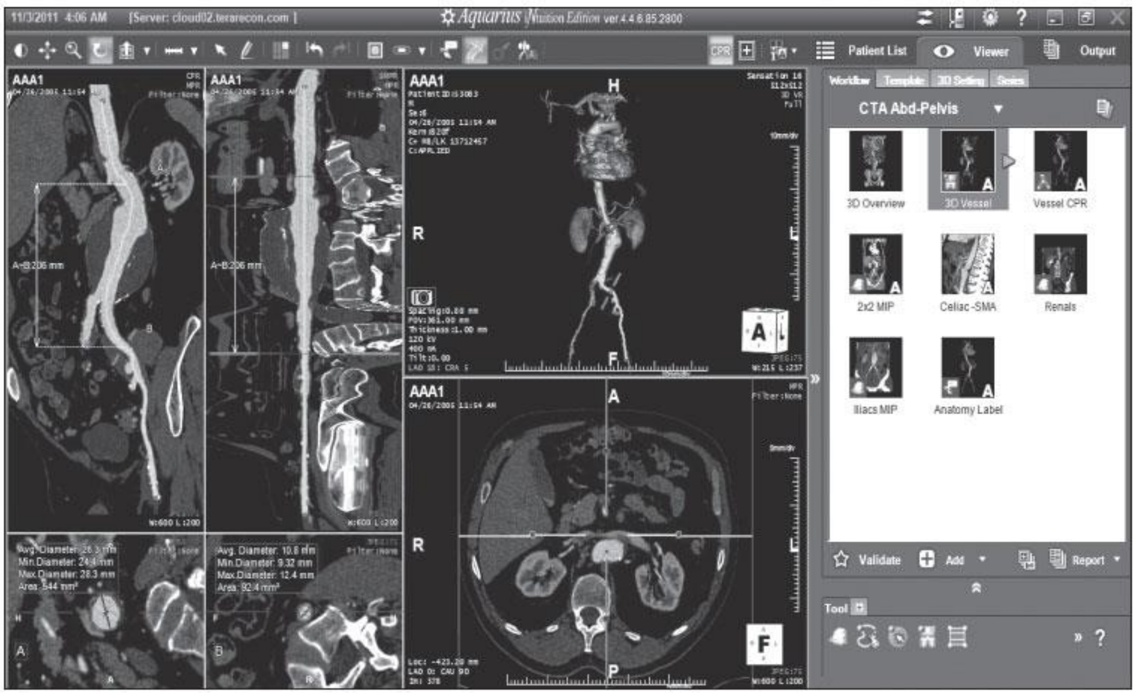
TERARECON – iNtution

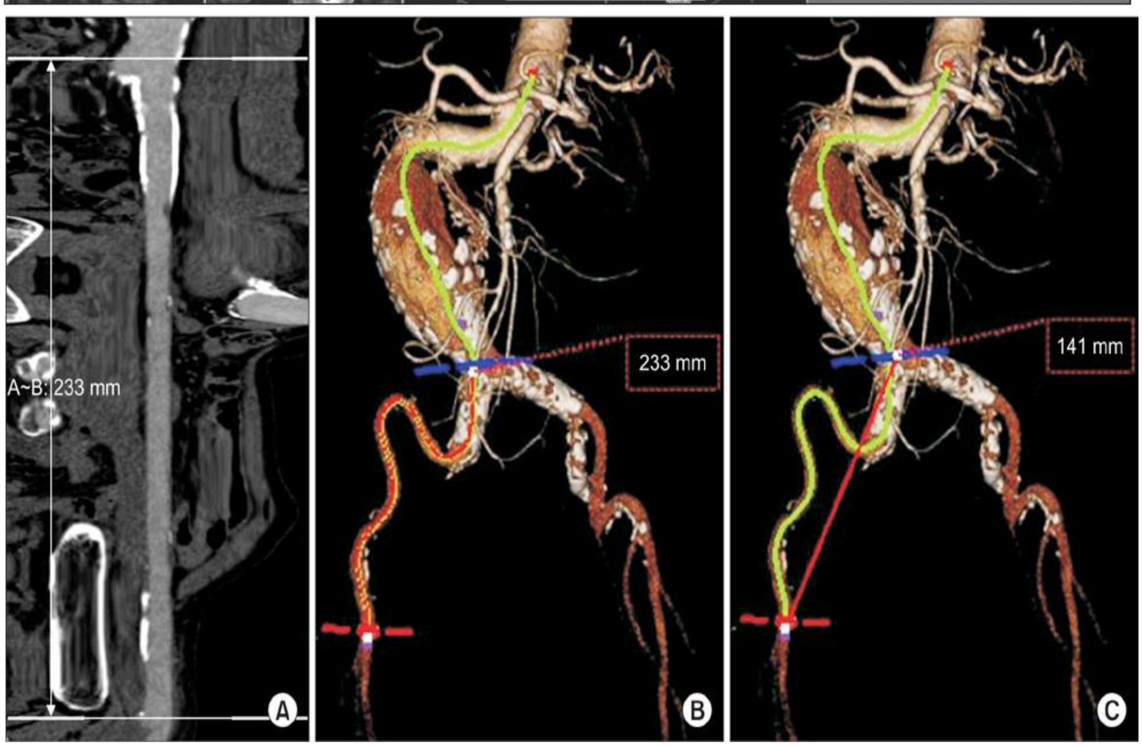
- ✓ Volume rendering applications
- ✓ Perfusion

✓ Image fusion …..etc

Advances in MRI

❖ Advanced sequences for MRA





❖ Perfusion weighted imagi

ng

- 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

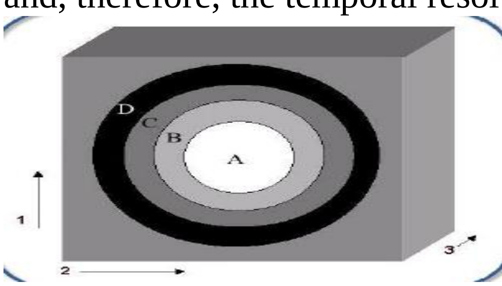
TRICKS / TWIST

. 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.

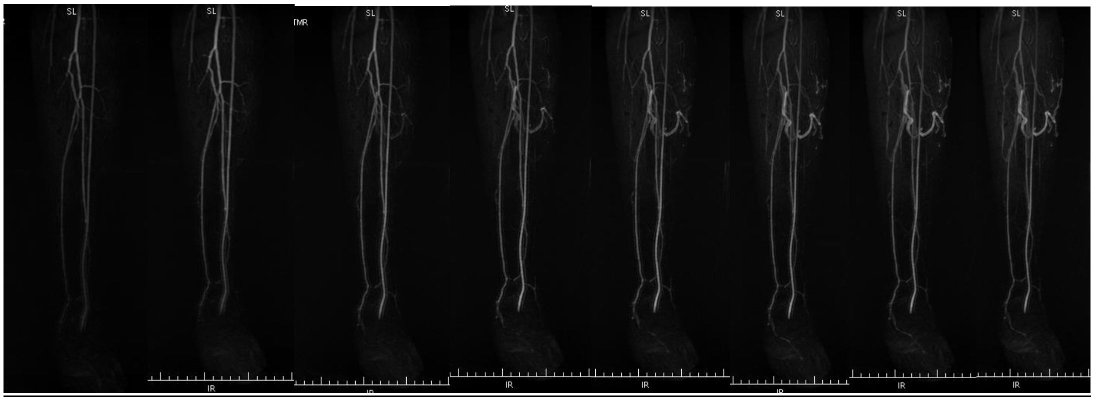
Background:

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.

<u>INHANCE / NATIVE</u> - NON CONTRAST ANGIOGRAPHY

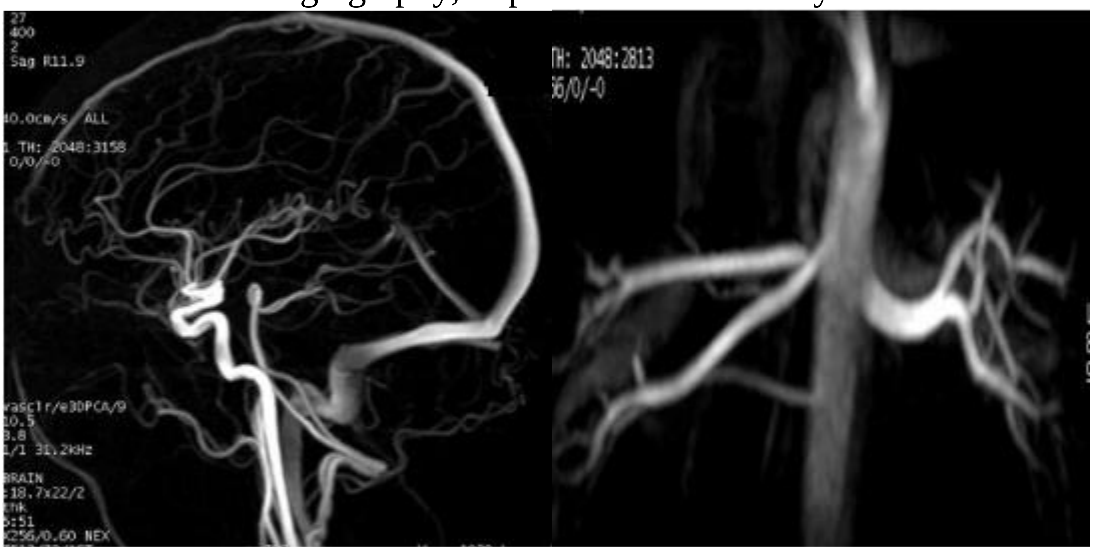
Advances in MRI is help full to provide non contrast MRA in abdominal and peripheral application. The early techniques of NON CONTRAST MRA include 2D &3D TOF IMAGING , GATED 2D TOF , PHASE CONTRAST ANGIOGRAPY

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.

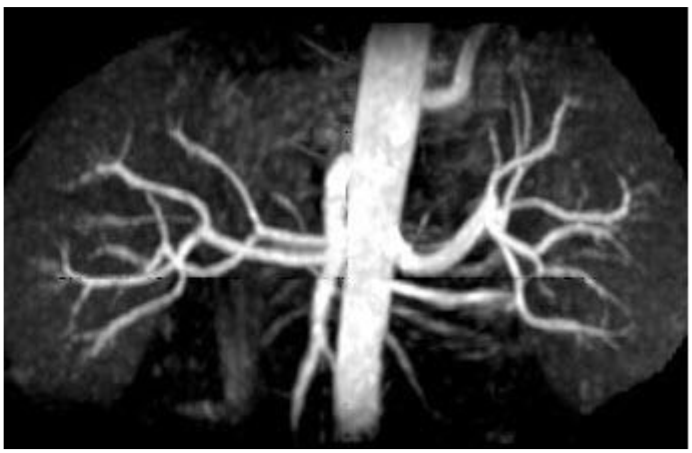
- Shortened scan times through the use of partial k-space filling technique, ASSET compatibility, and dB/dt optimization and RF pulse modifications for shorter TR and TE times.
- A spoiled gradient technique improves SNR and improves background suppression.
- T1-weighted magnitude images can be generated.
- 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]

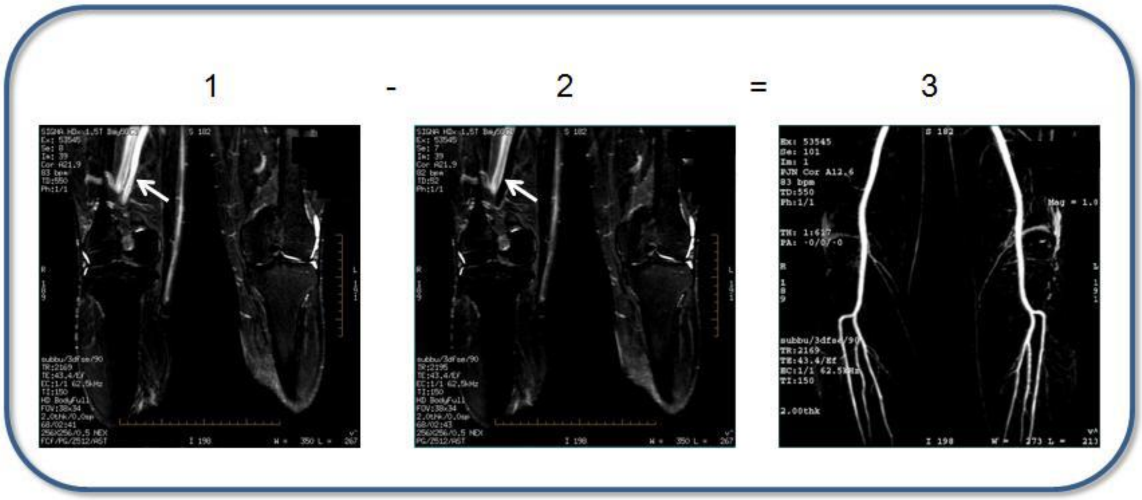
Inhance Deltaflow is a non-contrast agent MRA1 method that is typically used to image peripheral arteries in a run-off exam. Inhance Deltaflow acquires two 3D slabs: one during systolic phase and one during diastolic phase.
A multi-phase SSFSE scan is acquired to determine the diastolic trigger delay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

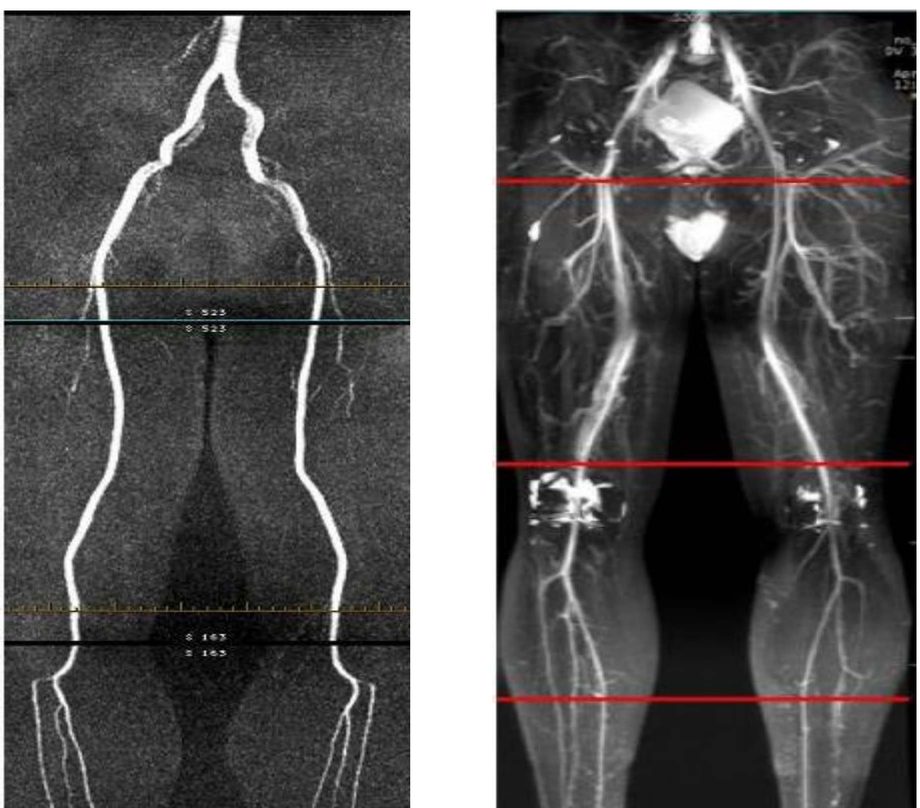
Subtraction of the systolic slab from the diastolic slab results in the visualization of the arteries with good background suppression. A STIR pulse can be applied to both the systolic and diastolic acquisition for additional fat suppression.

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

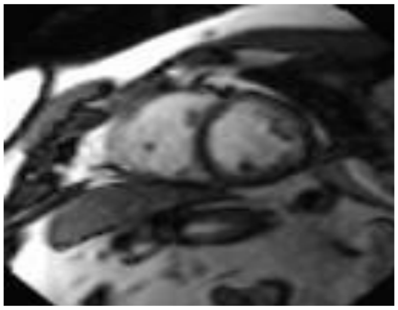
The ***MR-Echo*** application is for cardiac real-time prescription and acquisition. Real time acquisition is particularly useful in patients with irregular heart beats and with patients who cannot perform a breathhold acquisition. Using real-time images as localizers, the following batch scans can be efficientlyperformed 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

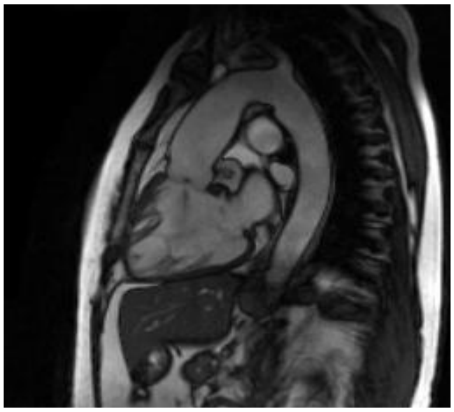
Background

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

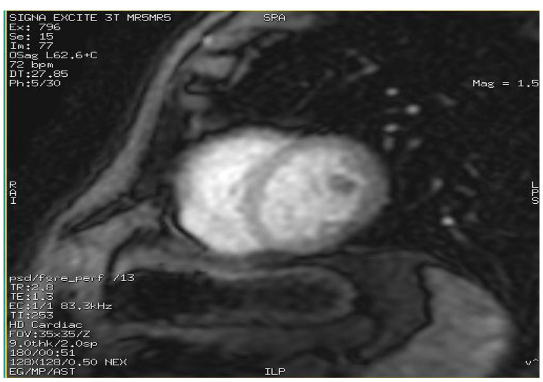
Realtime uses a non-gated 2DFIESTA PSD for acquiring real-time images of the heart using a FIESTA (bright blood) pulse sequence. The PSD acquires images at a high-frame rate for localization and qualitative ventricular function assessment.



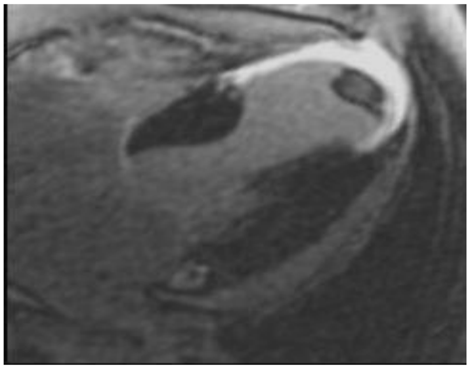
Function uses a gated 2D FIESTA PSD. It provides a multi-phase CINE high-frame rate acquisition mode for high-image quality breath-hold cardiac images that are added to the image database. This mode functions with both ECG2 or peripheral gating.



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, cardi ac-triggered Fast GRE with an IR1-Prep pulse.

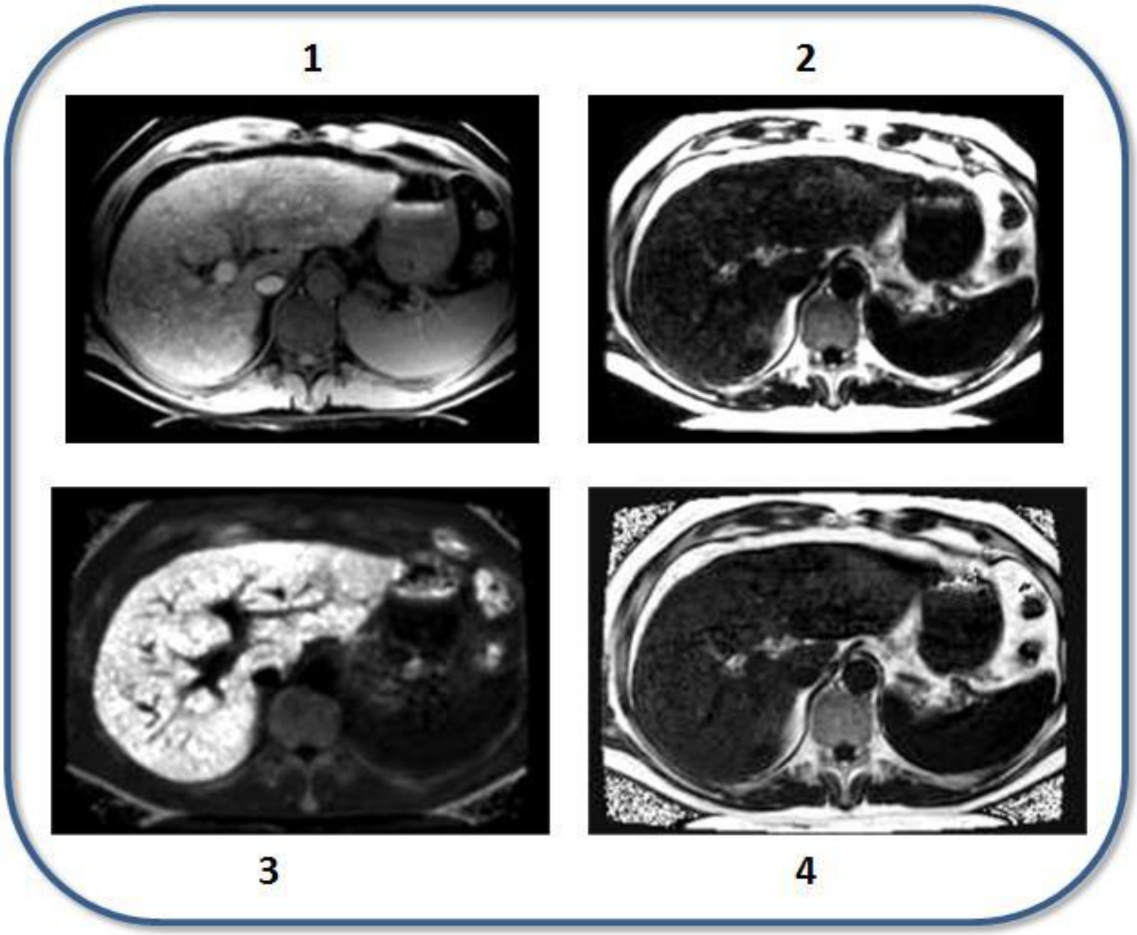


IDEAL IQ

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 imagesof 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

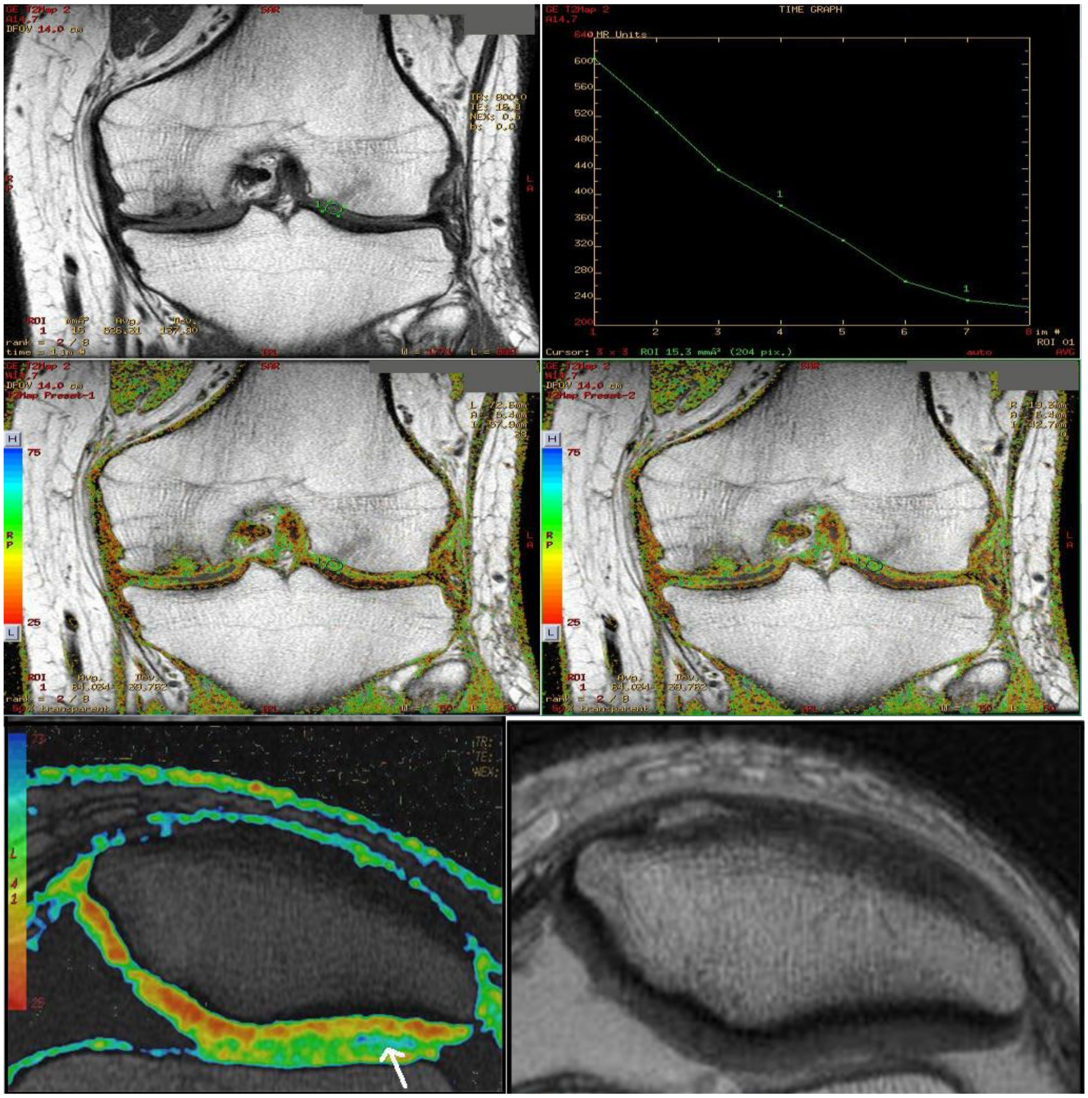


1= T2* corrected waterIDEAL IQ image ,2 T2* corrected triglyceride fat IDEAL IQ image ,3 R2* map IDEAL IQ image , 4 Triglyceride fat-fraction IDEAL IQ image

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.



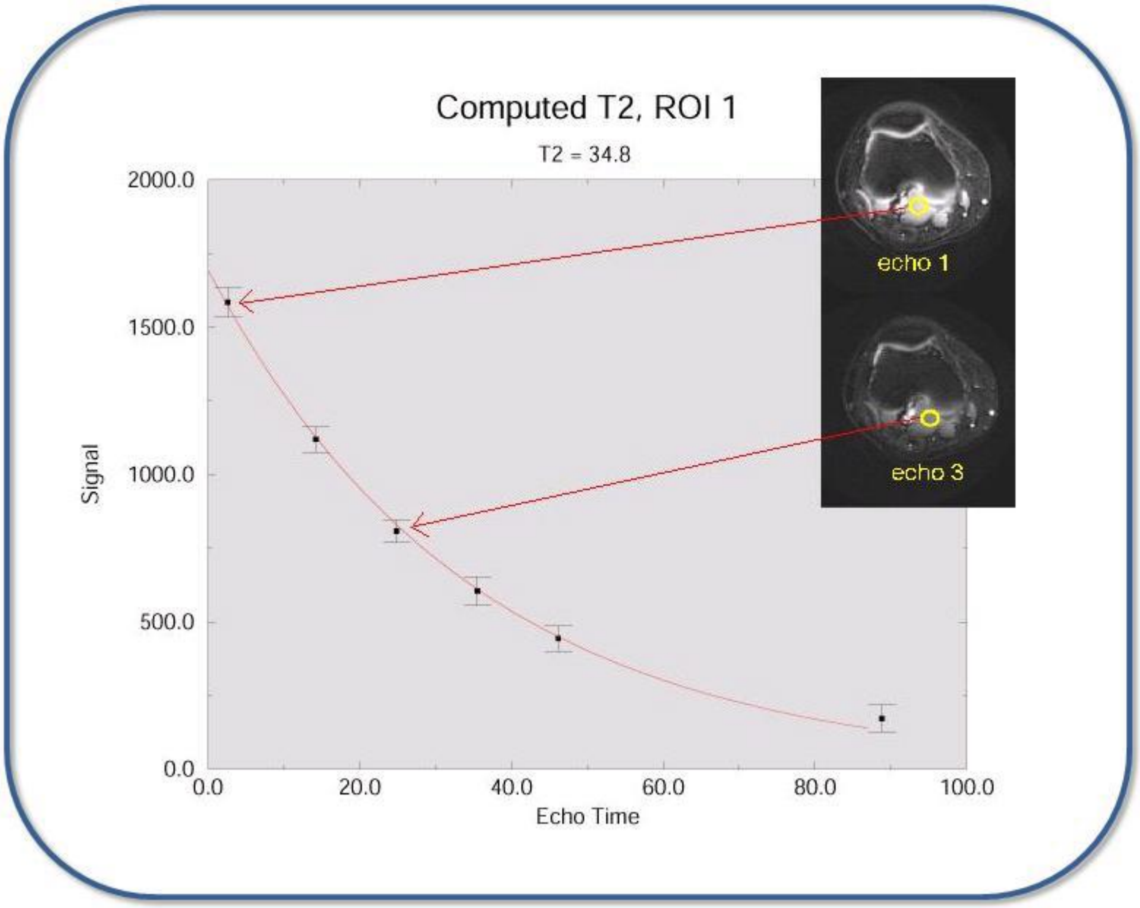
T2 Map

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 bolustracking 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 dropin the MR signal when a T2- or T2*-weighted sequence is used. Thissignal–time course is used to compute important haemodynamic 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.

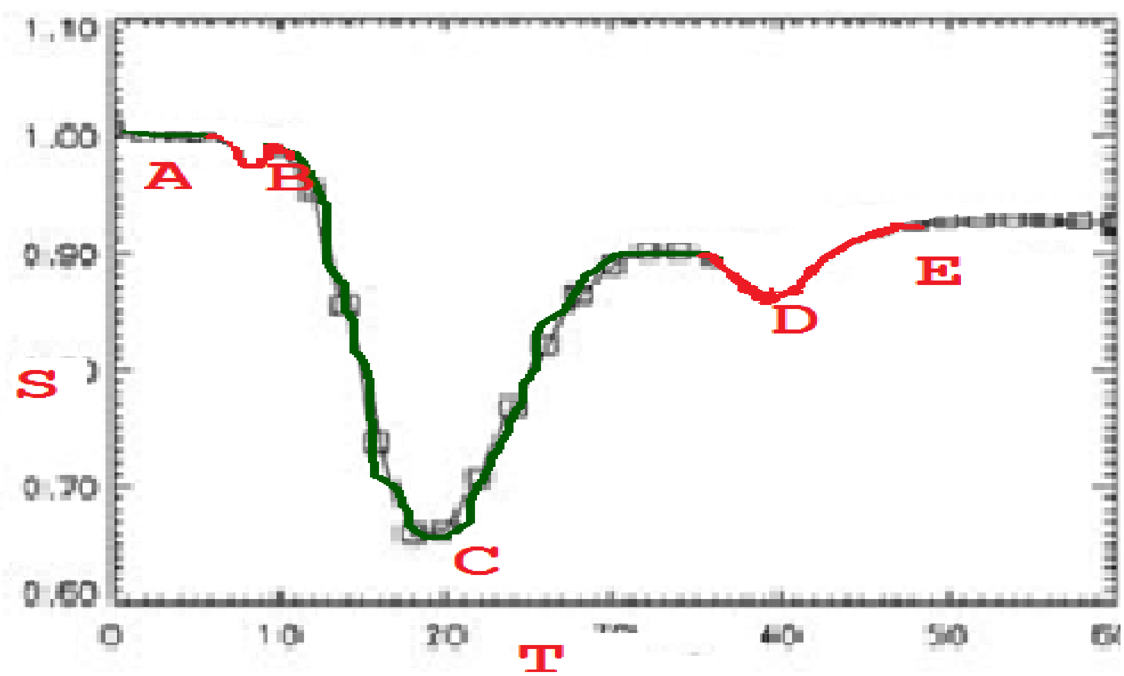
Alternative (less commonly available) acquisition methods have been implemented with a view to reduce EPI artifacts, whilst improving susceptibility contrast, spatial and temporal resolution. Segmented EPI has the advantage of less distortion, but is more sensitive to T1 effects because of shorter TRs. 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 minimise 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)

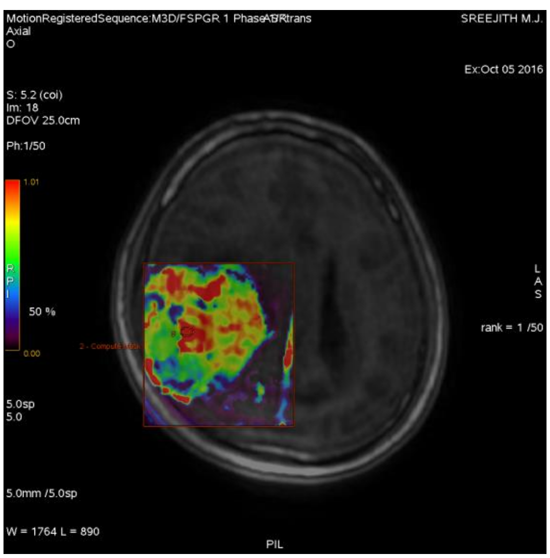
- Mean Transit Time (MTT)
- Average time to flow through capillaries (artery → vein)
- MTT=CBV/CBF
- Units: seconds
- 5 S

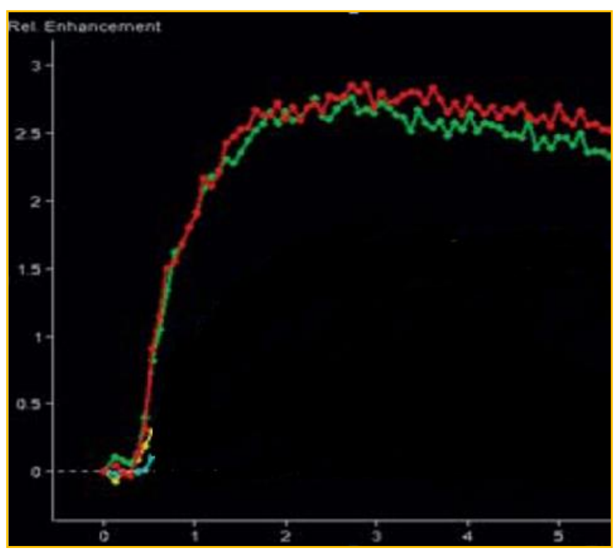
Time to maximum (Tmax)

- 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). Semiquantitative 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 postprocessing 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.

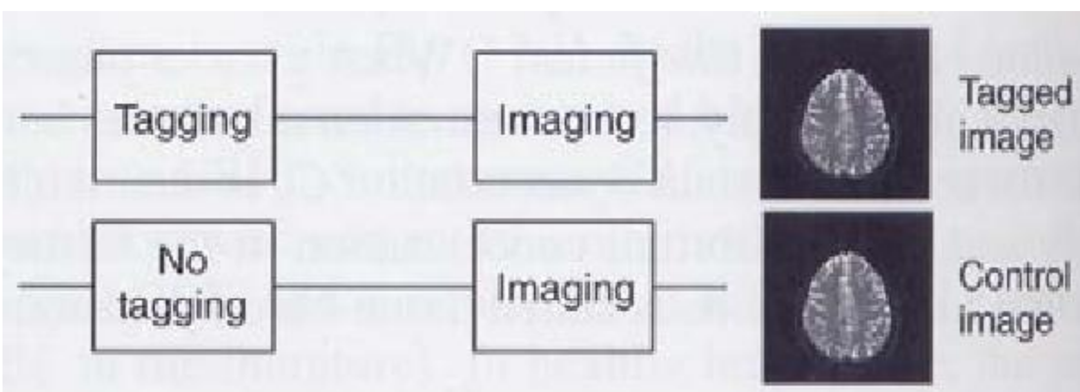
- Grading of brain tumor.
- Cerebral infarction risk assessment
- Selection of patients for extracranial to intracranial bypass surgery
- Moyamoya evaluation
- Assessing risk of hyperperfusion syndrome
- Balloon test occlusion with CVR
- Selection of patients for medical intervention

ASL

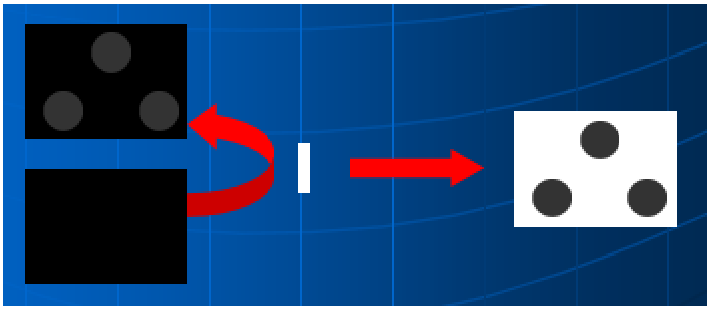
- ASL technique was conceived more than 15yrs ago.

- No exogenous contrast bolus required.

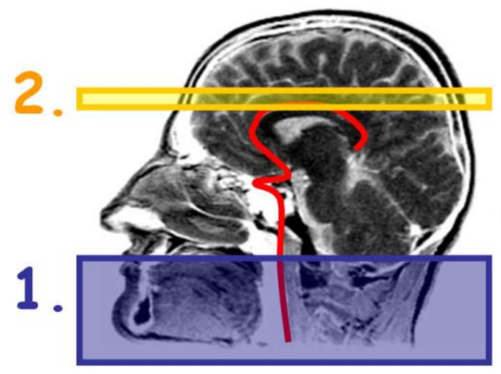
- ASL is based on labeling protons in the blood in supplying vessels outside the imaging plane and waiting for a period called post delay period for reaching the parenchyma.



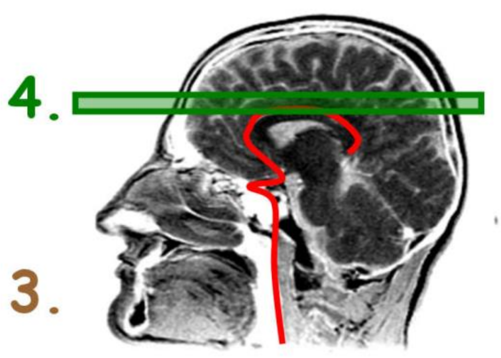
- Images are obtained from the parenchyma in labeled and controlled state.
- Subtracting these two type of images eliminates the static tissue signal will give CBF images.



Principle of ASL



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

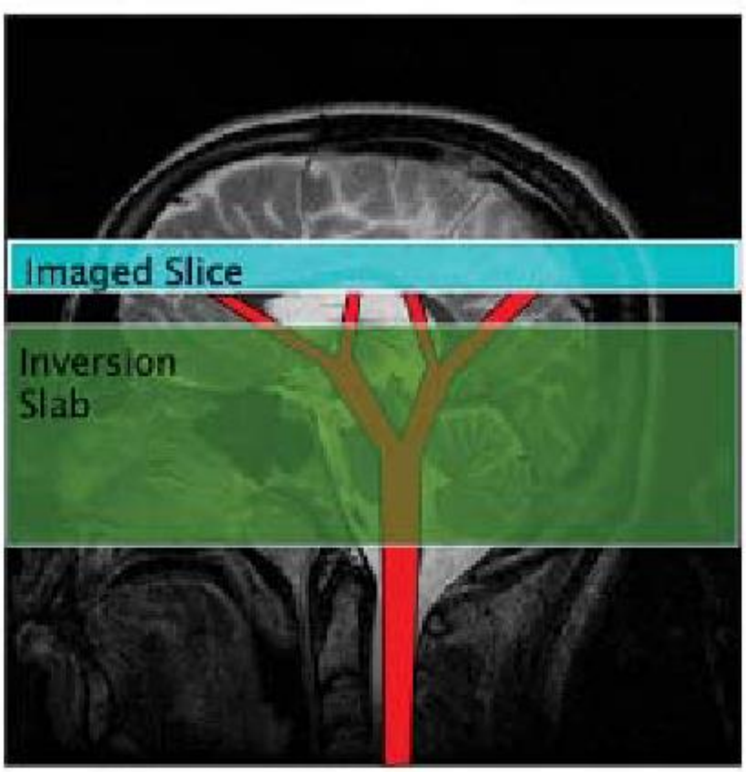


3. Repeat experiment without **tag**
4. Acquire the **control image**

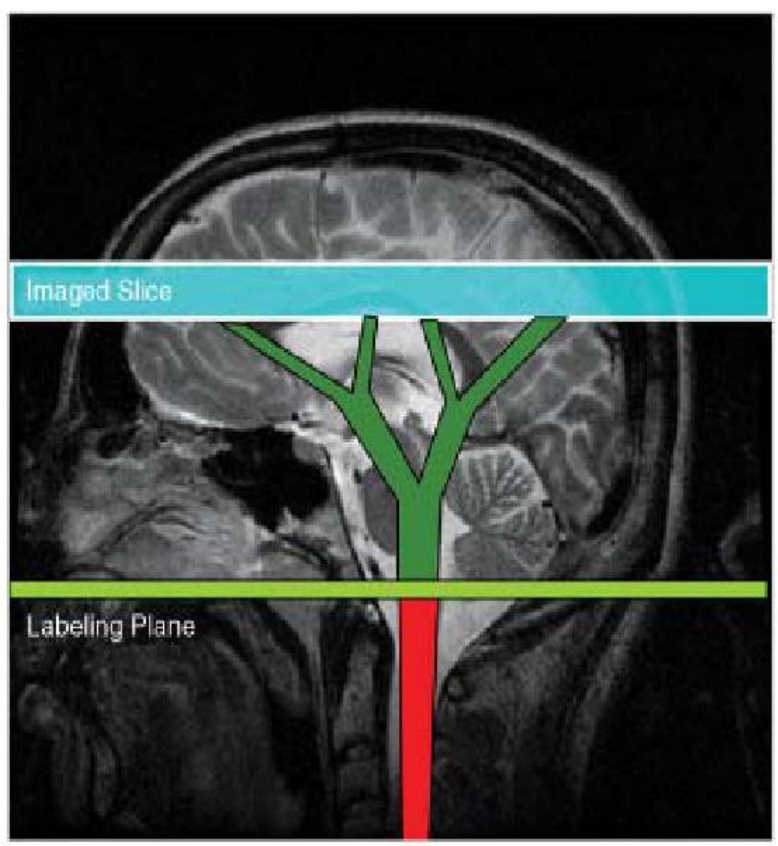
TYPES OF ASL

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

PASL



CASL

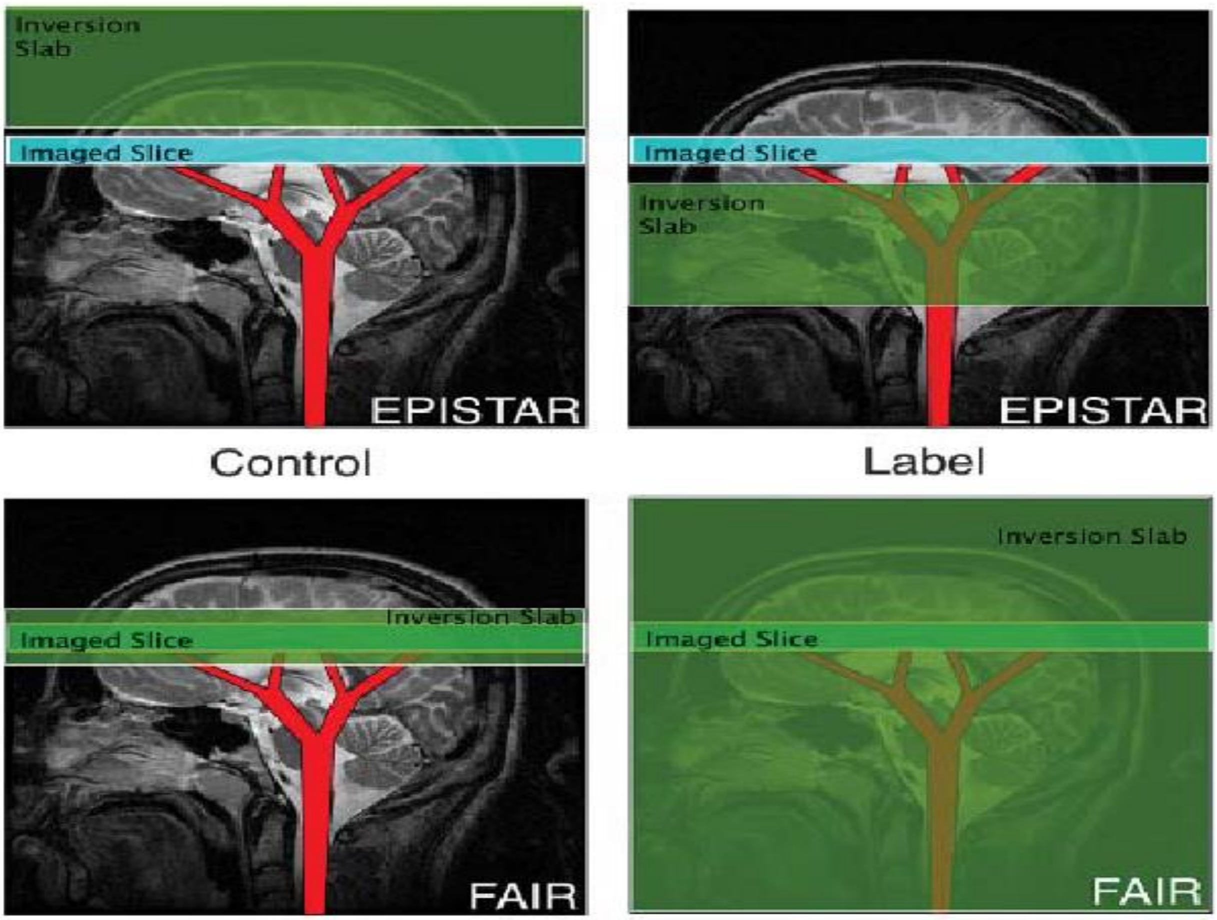


ASL Types	Advantages	Disadvantages
PASL	Higher tagging efficiency Lower SAR	Lower SNR
CASL	Higher SNR than PASL	Lower tagging efficiency Continuous RF transmit hardware required Higher SAR Magnetization Transfer effects
pCASL	Higher SNR than PASL Higher tagging efficiency than CASL	Higher SAR Limited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

Sequence for ASL

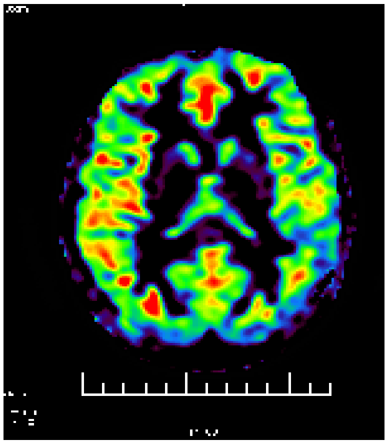
- EPISTAR-Echo planar imaging and signal targeting with all radiofrequency.
- PICORE-proximal imaging with a control for off resonance effect.
- TILT-transfer insensitive labeling technique.
- FAIR-flow sensitive alternating inversion recovery.
- FAIRER-FAIR with extra radiofrequency pulse.

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.

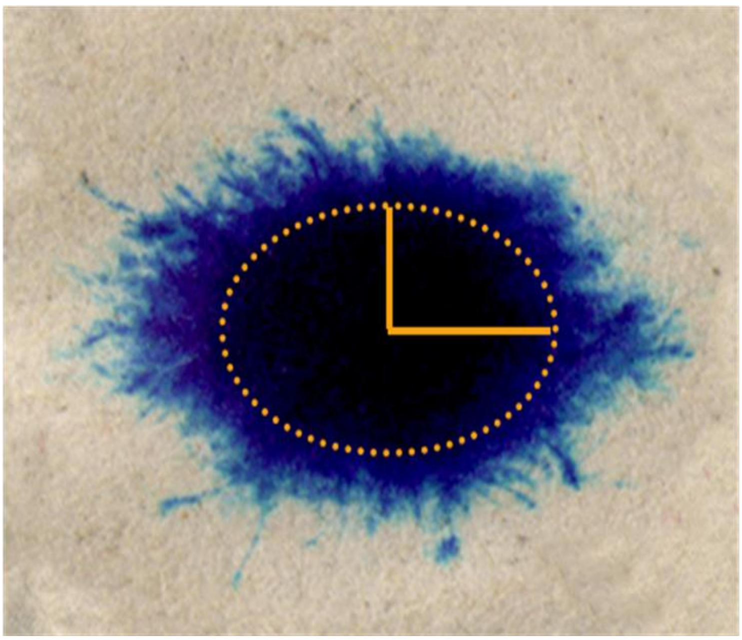
Observed in 1827, by Robert brown.

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.

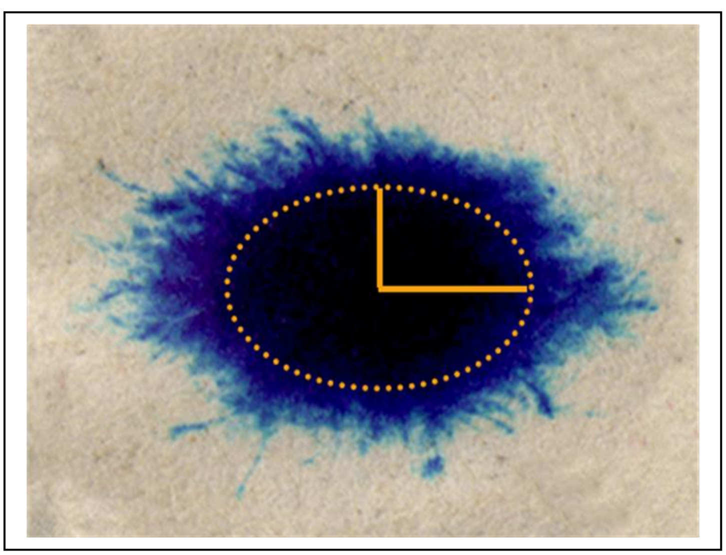
Isotropy and anisotropy

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.



Isotropic



Anisotropic

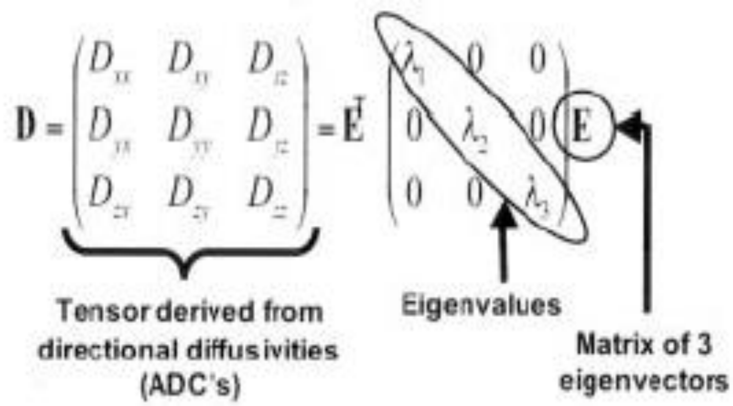
Diffusion-Weighted Imaging

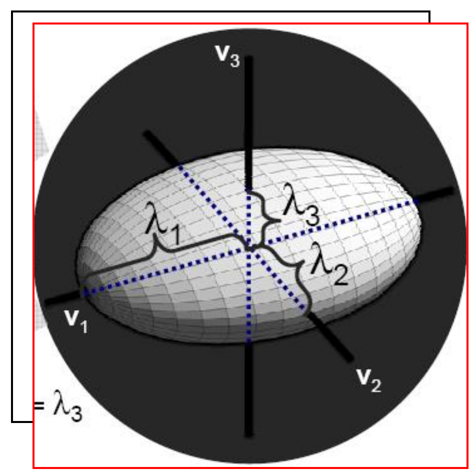
MR image contrast is based on intrinsic tissue properties and the use of specific pulse sequences and parameter adjustments. The image contrast is based on a combination of tissue properties and is denominated "weighted," as the contribution of different tissue properties are present, but one of them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

- Trace / 3 can be thought as mean diffusivity**.**

<u>b-Value</u>

- 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).

<u>ADC maps</u>

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

<u>FA</u>

- 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.

<u>SWI / SWAN</u>

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 signalfrom pial veins located within the cerebral spinal fluid (CSF) The acquisition time was 2.58 min with the use of iPAT factor-2.

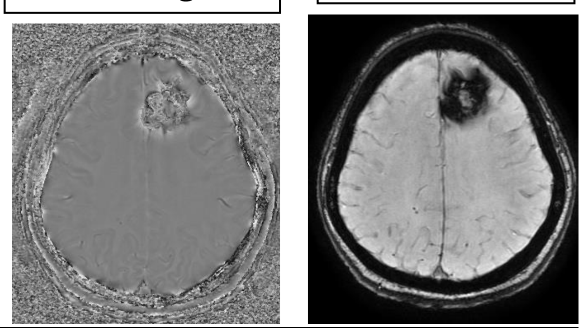
Usefulness of SWI phase imaging

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. Deoxyhemoglobin 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, vasculitis 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.

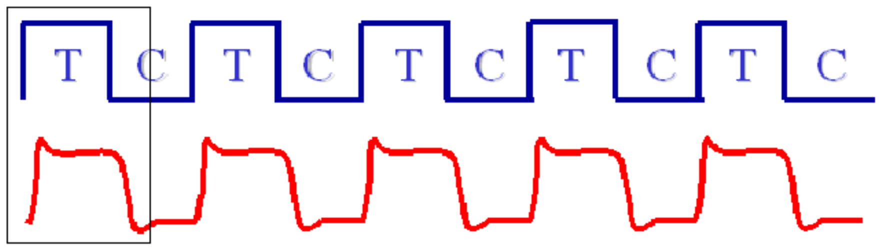
Hence there has been a push for larger field scanners to both improve localization and increase the signal

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

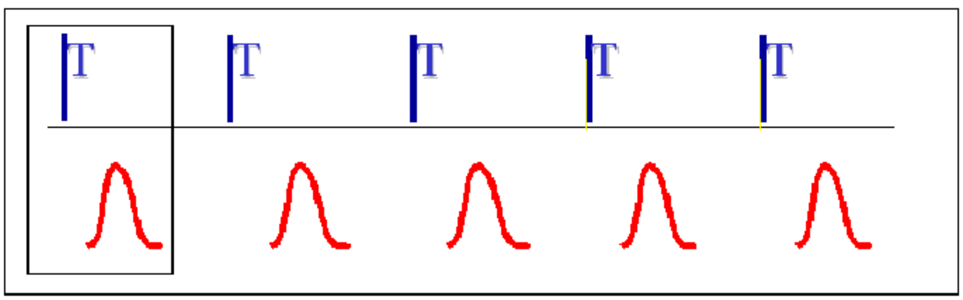
- First used in f MRI and still and the most useful in prevalent neurosurgery.
- It involves subject performs a task, alternated for a similar time with one or multiple control tasks.



Event related f MRI

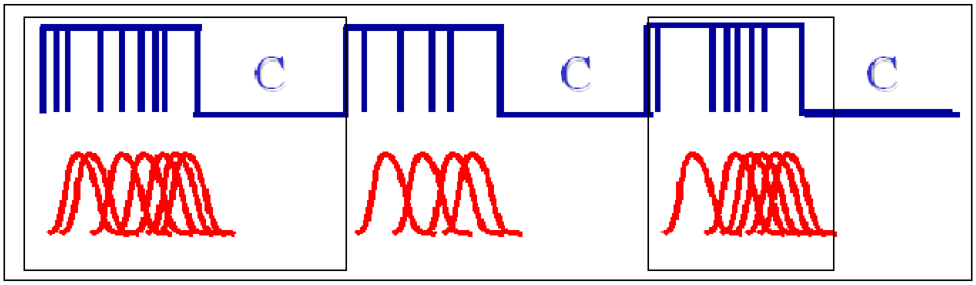
- The individual trials are randomized.

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

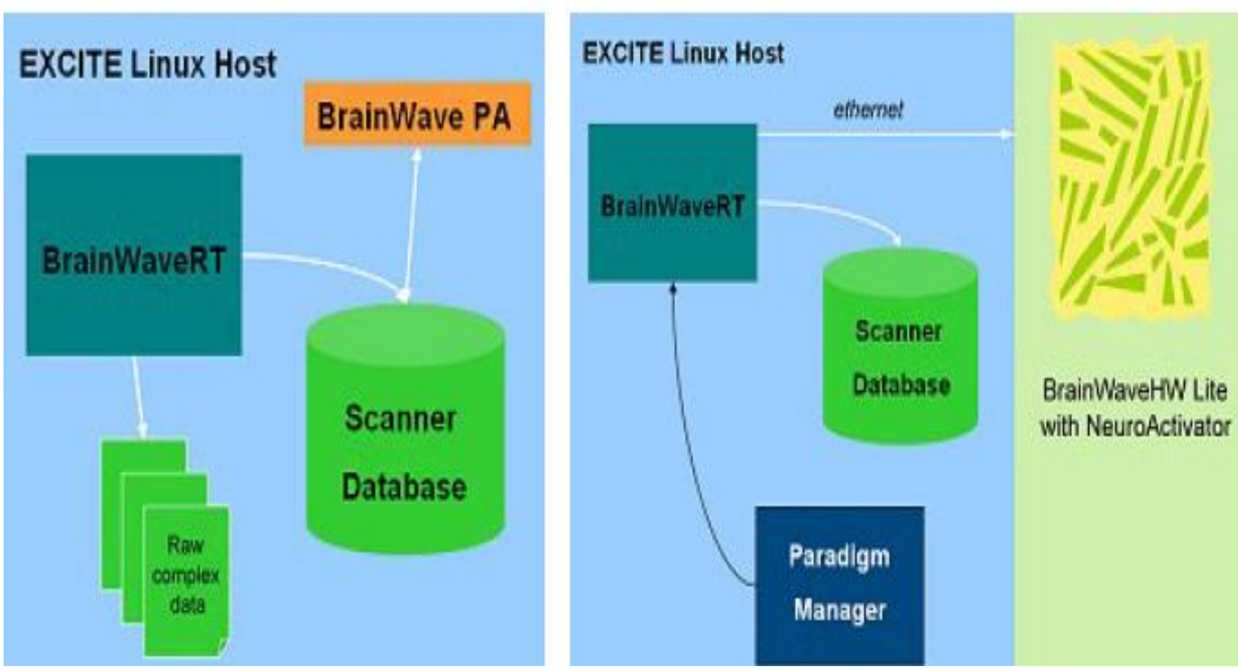
1. Motor paradigms
2. Bilateral finger tapping Vs Rest
3. Lip Pouting vs rest
4. Bilateral leg motor vs Rest
5. Language paradigms
6. Verb generation
7. Word pair
8. Syntax
9. Sematics

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

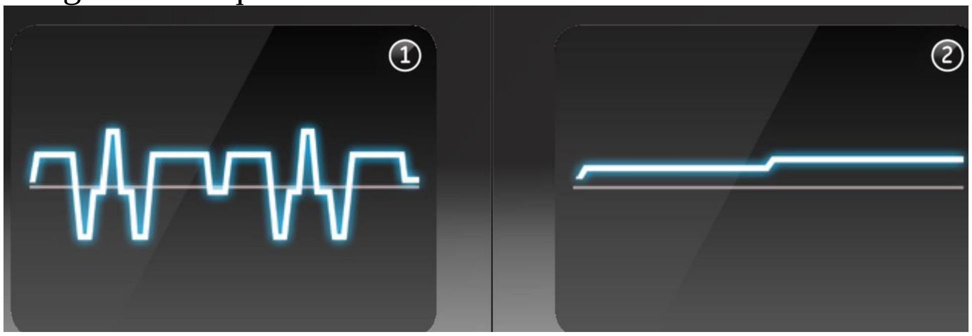


BrainWaveHW Lite comprises equipment used to create custom audio, visual, language and motor paradigms and play them out into the patient environment when used with BrainWaveRT. This equipment consists of a stimulus computer mounted in a rack in the MR equipment room. Paradigm Studio software on
the 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 irtually 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 submillimeter 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.

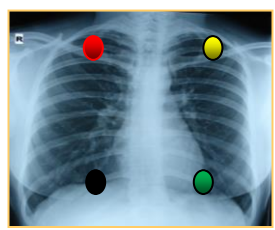
To acquire data over several heart cycles, scanning has to be done in relation to the heart beat. Retrospective ECG gating is therefore useful.

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

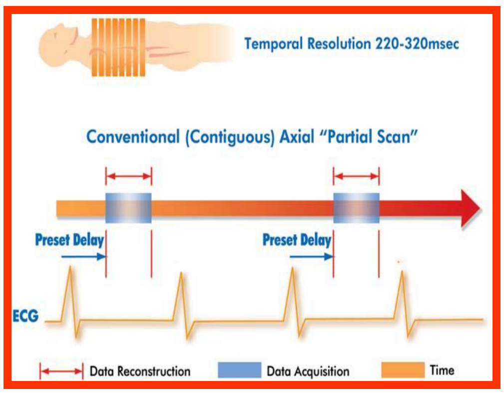
TWO MODES OF ACQUISITION

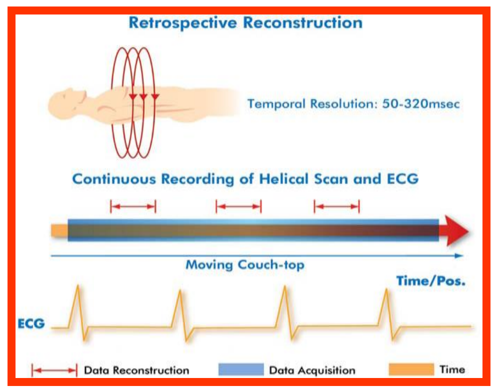
i. PROSPECTIVE

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:

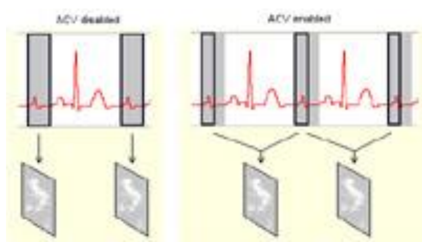
IMAGE RECONSTRUCTION

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.

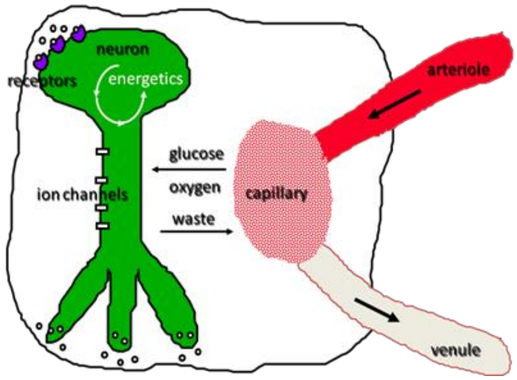


With the collimated slice width used (0.625 mm), images of nominal slice width of 0.625, 1, 2 and 3 mm can be reconstructed. We recommend to use slice widths of 1 mm to increase image quality by reducing artifacts.

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

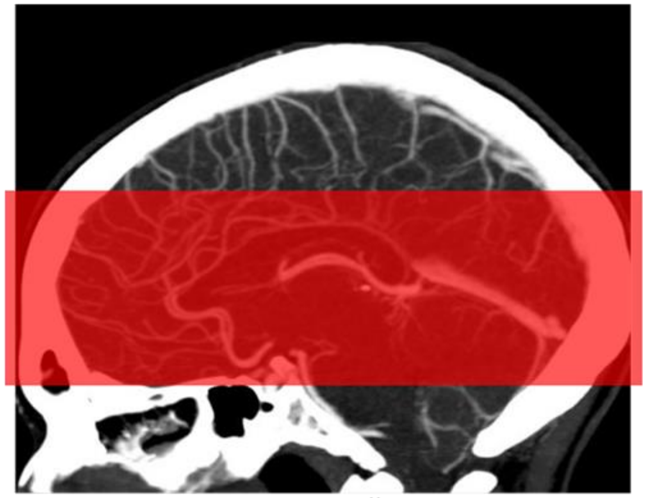
Steps of CT Perfusion Scan

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

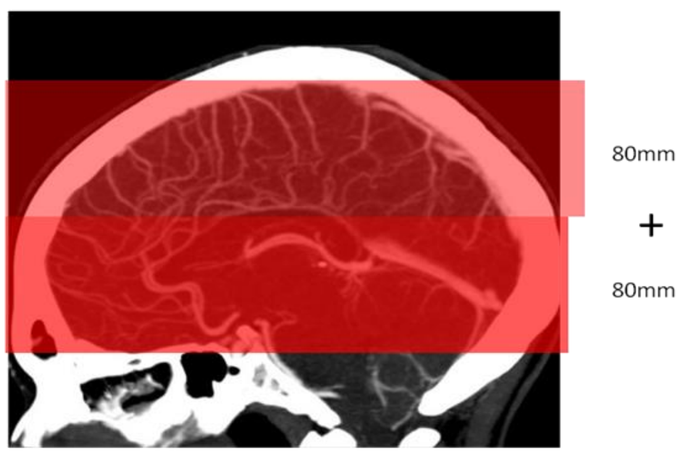
➢ NON-JOG MODE



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 hydrophilically coated. Many micro catheters wall contain braided materials, which improves flexibility, pushability, and trarckability of the microcatheter. The braided construction lessens the incidence of micro catheter kinking or ovalizing as it traverses bends. This braid feature can also cause the microcatheter 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 microcatheter allows a greater flow rate than competitive microcatheters. The small OD of the Echelon allows more flow in the guide catheter which can be useful for angiographic injections.Echelon pre-shaped microcatheters 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 luer 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.

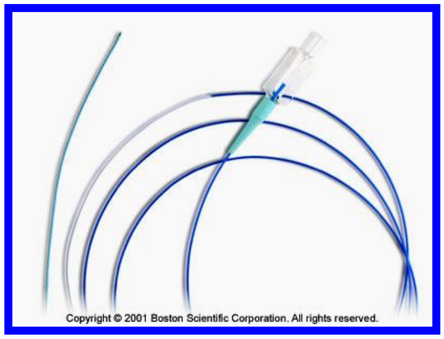
Prowler microcatheter(braided)

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 microcatheter 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

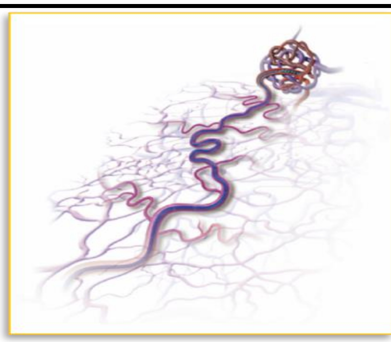
These are very flexible hydrophilic-coated catheters that are primarly designed to deliver liquid embolics such as glue, onyx, and dehydrated alcohol, PVA (less than 500µm) can be administrated through these microcatheters as well.

SPINNAKER ELITE



Developed specially for flow directed applications, the spinnaker elite flow directed microcatheter might be used for regional infusion of diagnostic agents and vascular occlusion with berenstein 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



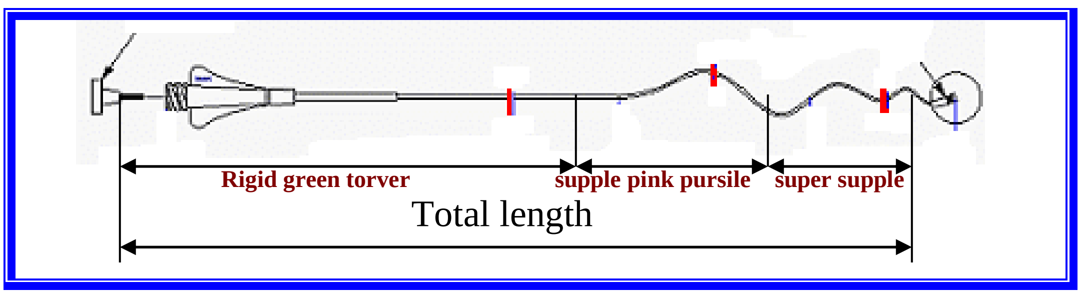
Developed as an Onyx Delivery Catheter, the Marathon offers the user the lowest available tip profile while providing unmatched burst and tensile strength, making it the ideal catheter for the treatment of Brain AVMs.It has proximal pushability due to the stainless steel coil reinforcement in proximal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

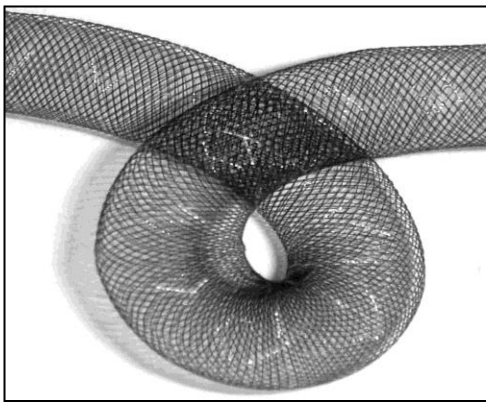


OBLITERATION PROCEDURE

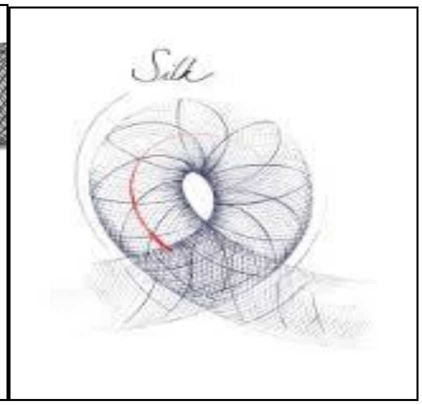
Otherwise referred to as ‘Therapeutic Embolisation’, using particulate materials delivered through micro catheters can be used in settings of acute bleeding from tumor vessels, vascular malformations, Aneurysms, Vascular tumors. Embolic materials in use include alcohol, metallic coils, gel foam,vascular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

Flow Diverter:
New Endovascular treatment option for complex inracranial aneurysms. The endovascular 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

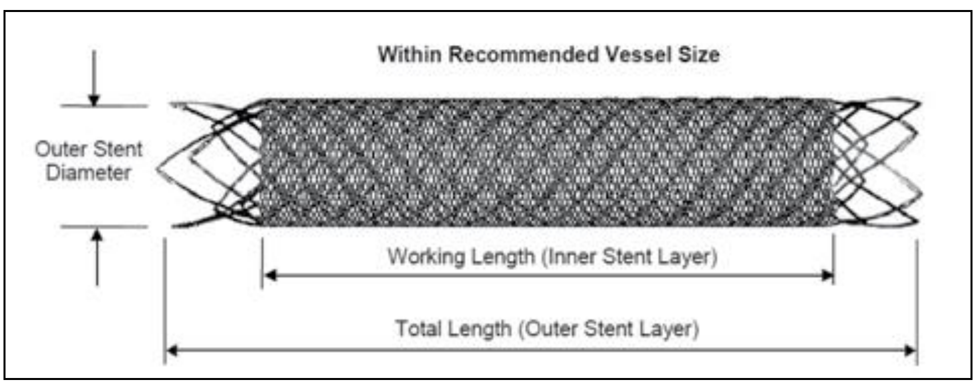
- **Pipeline embolization device** (PED ev3/ Covidien, Irvine, California)
- **Silk flow diverter (**SILK; Balt Extrusion, Montmorency, France)
- **Fred flow diverter(**FRED, Microvention, Terumo,P64)
- **Surpass flow diverter(**SURPASS; Stryker Neurovascular, Fremont)
- **phenox64 (p64)**



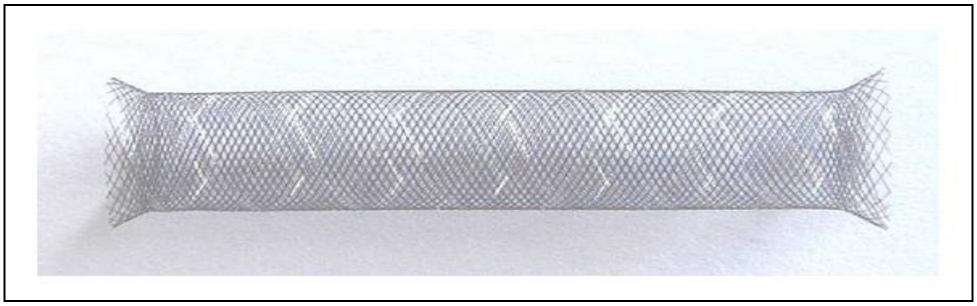
Pipeline flow diverter



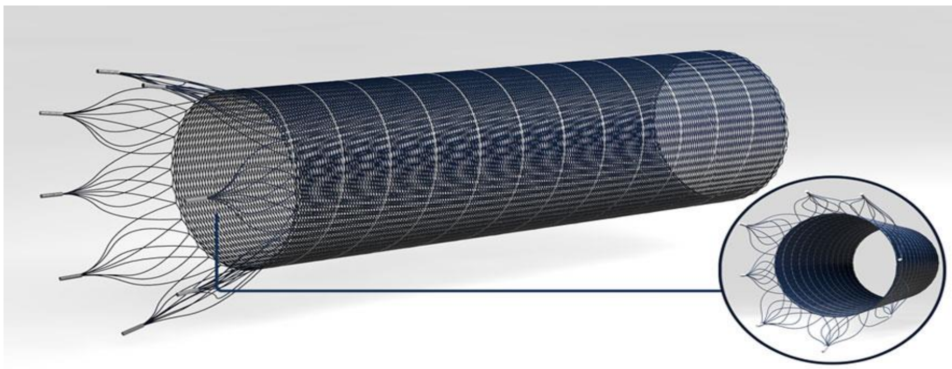
Silk flow diverter



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

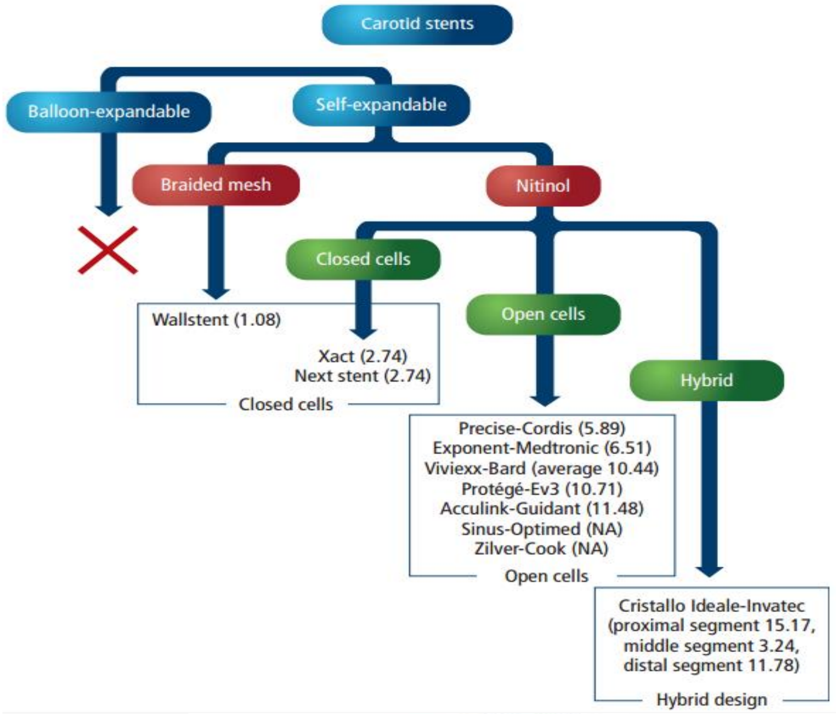
Thoracic covered stent graft

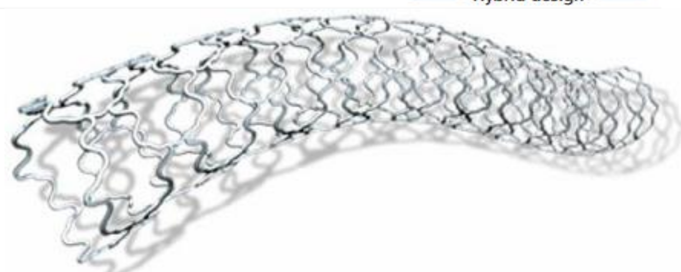
Carotid stent

Stent Technical Features

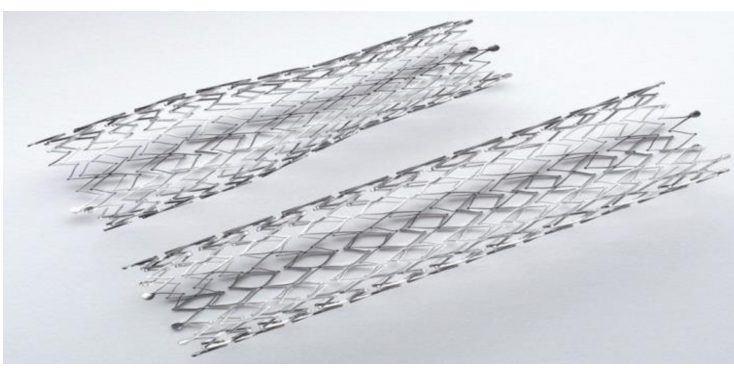
- Foreshortening
- Conformability/flexibility
- Vessel wall adaptability
- Scaffolding Radial strength

* 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 sameway 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, operators opacify 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 coagulative necrosis.Alcohol injection is very painful, general anesthesia is usally 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 out side 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 microcatheter tip can be used without fear of adherence of the cast to the microcatheter. However, if significant reflux occurs, catheter retrieval may be impossible.

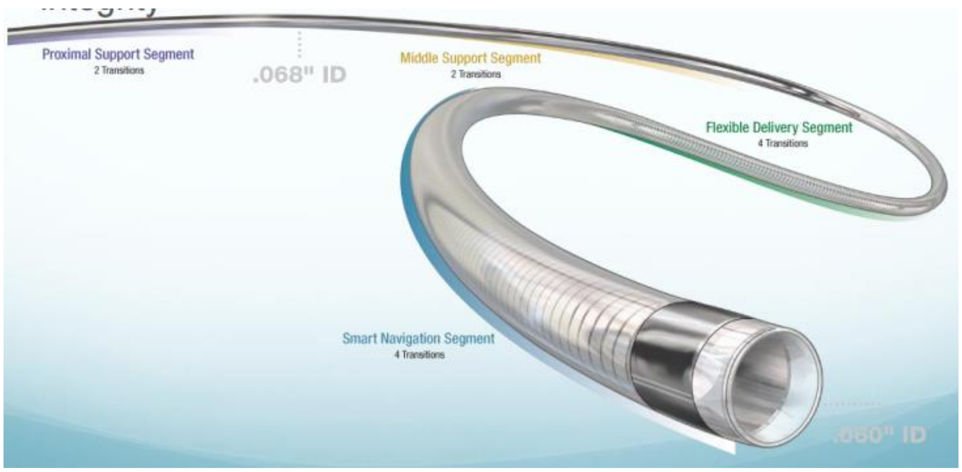
PHIL- Precipitating Hydrophobic Injectable Liquid

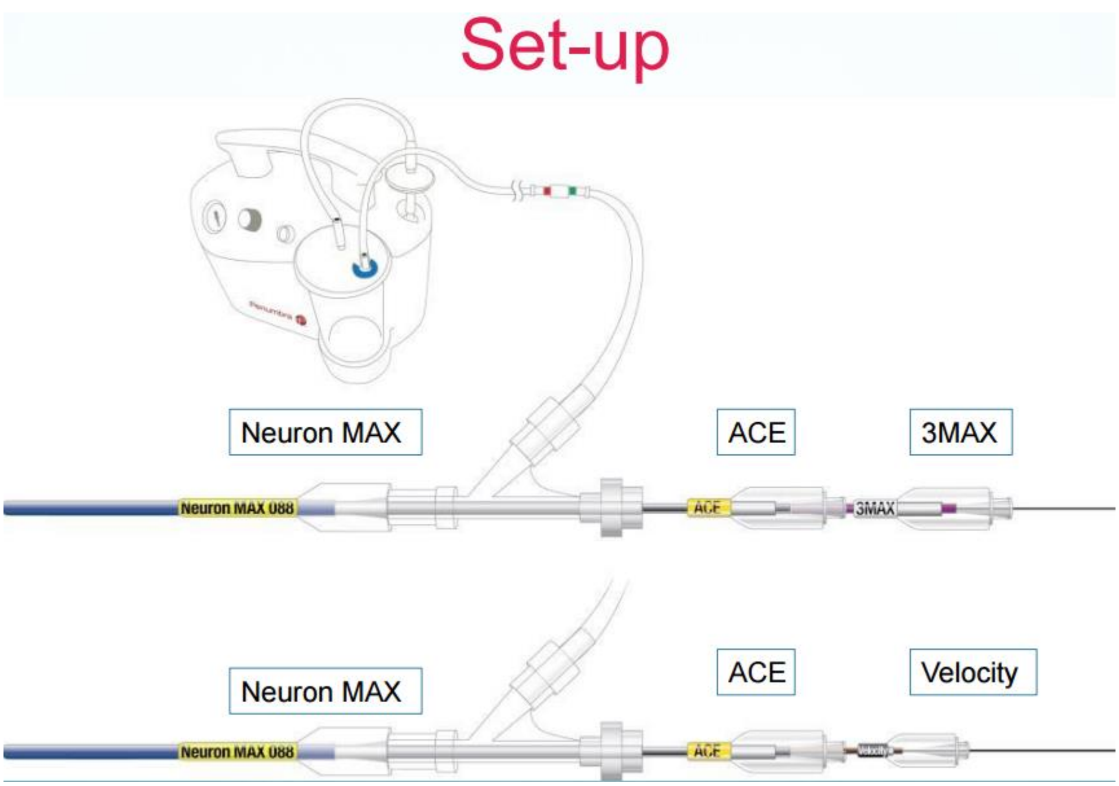
It is a non-adhesive liquid embolic agent comprised of a biocompatible polymer dissolved in dimethyl sulfoxide (DMSO) solvent. An Iodine component is covalently bonded to the polymer to provide homogenous fluoroscopic visualization.
No risk of microcatheter blockage due to Tantalum aggregation Minimize (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





PROJECT

PERFUSION FROM DIFFUSION-A FEASIBILITY STUDY OF INTRAVOXEL INCOHERENT MOTION IMAGING

SAJITH-R
DIPLOMA IN ADVANCED MEDICAL IMAGING TECHNOLOGY
DEPT.OF IMAGING SCIENCES&INTERVENTIONAL RADIOLOGY
SCTIMST ,TRIVANDRUM
YEAR:2015-2016

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I would like to thank our senior residents,Technologists,PhD students,senior and junior DAMIT Students.for their support.

<u>INDEX</u>

AIM OF THE STUDY

The objective of this project is to determine the feasibility of Intravoxel incoherent motion perfusion measurements in the brain using multiple b-values in a 3 Tesla MRI scanner.

REVIEW OF LITERATURE

Intravoxel incoherent motion imaging or IVIM Imaging is a MR imaging method to visualize microscopic motions of water in the tissue level.in biological tissues these motion include molecular diffusion of water and microcirculation of blood in the capillary network.

Principles of diffusion measurements[1]

Diffusion refers to the random,microscopic movement of water and other small molecules due to the thermal collisions.so the Brownian motion is responsible for this diffusion phenomenon.we can calculate the attenuation term due to molecular diffusion by the equation.

$$B=\exp(-b.D)$$

Where D is the diffusion coefficient and b is a factor depending only on the gradient pulse sequence.simply the strength of the gradient magnetic field.the diffusion coefficient D is related to the molecular mobility. By using statistical approach,the Brownian motion can be described by a series of molecular jumps.if ℓ is the mean length and v be the mean molecular velocity,then the resulting diffusion coefficient D can be calculated by the following equation.

$$D=\ell v/6$$

Typical values for ℓ and v are about 10^{-10} m and several hundred meters per second respectively.for pure water at 40˚C , $D=2.5\times10^{-3} mm^2/sec$. in case of biological tissues,diffusion coefficients are lower, due to viscosity and restricted diffusion effects.the sequence used to acquire diffusion weighted imaging is based on stejskal tanner technique.this sequence consists of symmetric,strong diffusion sensitizing gradients applied on either side of 180˚ RF pulse.the phases of stationary spins are unaffected by the diffusion gradient pair since any phase accumulation from the first gradient lobe is reversed by the second diffusing spins,however move into different locations between the first and second lobes results in failing out of phase and losing signal.

The steps during the DW Imaging sequence includes initial acquisition of images without using diffusion sensitizing gradients.this generates a set of B0 images that are T2 weighted and will serve as a baseline for later calculated maps.the second step is to acquire images with the diffusion sensitizing gradients turned on at various strengths.after acquiring, these data sets can be post processed and ADC maps are calculated.these ADC maps consists of data from the B0 and source images in which T2 effects have been removed.further advanced post processing can be optionally performed,creating additional calculated image sets for analysis.these includes,exponential ADC maps,fractional anisotropy images,principal diffusion direction maps,and fiber tracking maps.

<u>Principles of IVIM to measure microcirculation</u>[1]

Consider the fraction of water diffusing and flowing in the capillaries of a given voxel,the signal attenuation term B in the presence of diffusion sensitizing gradients will include an additional term F due to microcirculation.the value of which will depend on capillary geometry and blood velocity. So the signal intensity B can be calculated by the following equation.

$B=\exp(-b\ D).F$

Where F is the term related to the microcirculation.the value for F can be calculated on a statistical basis because of high quantity of capillaries in a voxel.(5700 per cu.mm in a brain cortex) assuming that the capillary network can be modelled by a network made of straight capillary segments.then the expression for F will depends on the mean length l of the segments.the mean velocity (v) of the segments and the mean measurement time T (which is equal to TE)

IVIM model

The IVIM model was proposed by Le Bihan et.al to explain the biexponential decay of signal amplitude as a function of b-value.this model proposes that the signal arises from two physically distinct compartments.a “vascular”and a “non vascular” compartment.each with different exponential decay rates.
The vascular compartment is assumed to be made of a sufficiently dense,isotropic,microvascular network presents statistical properties.then can be decribed macroscopically with a pseudodiffusion coefficient (D*) the fractionof signal arising from the vascular compartment is called perfusion fraction (f) and the apparent diffusion coefficient observed in the non vascular compartment is called the diffusion coefficient (D). biexponential equation is described as following.

$S/S0=(1-f).\exp(-b.D)+f.\exp(-b.D)$

where S is the mean signal intensity; $S0$ is the signal intensity without diffusion; a pseudodiffusion coefficient D^* can be defined,which describes macroscopically the incoherent movement of blood in the microvasculature compartment; a perfusion fraction,*f*, describes the fraction of incoherent signal that arises from the vascular compartment in each voxel over the total incoherent signal; and D is the diffusion parameter representing true molecular diffusion (the slow component of diffusion) The IVIM signal equation was fitted on a voxel-by-voxel basis by using Osirix software.Two different approaches were implemented to generate IVIM parametric images (D, D*, and f): first, full biexponential fit, and second, initial estimation of D by using a reduced set of b-values of _200 s/mm2. In the second method,because D* contribution can be neglected at high b-values (*b* =200 s/mm2), D was extracted by using high b-values and a monoexponential fit. Subsequently, with the resulting D as a fix parameter,the curve was fitted for f and D* with a nonlinear regression IVIM parameters were calculated by using the second approach in all patients.

MATERIALS & METHODS

This study consists of 6 patients with various diseases which affects the capillary perfusion. MRI scanning were performed on a 3 Tesla mri system (Discovery MR 750w GE Medical systems,Milwaukee,WI) with a 24 channel receiver head coil.IVIM Sequence consists of a standard diffusion weighted spin echo-echo planar imaging with16 b-values(0,10,20,40,80,110,140,170,200,300,400,500,600,700,800,900 and 1000 s/mm^2) in three orthogonal directions.With the following parameters.TR/TE=3000ms/87.5ms field of view (FOV) =24.0 cm base resolution=128x128 , slice thickness=5 mm. With the increase of b-values, the number of excitations (NEX) also increased accordingly to ensure a good SNR. The acquisition time for IVIM Sequence is 4.02 minutes.

The imaging parameters for DSC perfusion are as follows. the sequence used for perfusion study was based on standard echo planar imaging.with TR/TE=2050ms/30ms slice thickness=6mm ,field of view (FOV)=23cm base resolution=128x128 The total acquisition time for DSC perfusion study was 2.48 minutes.

Post processing of IVIM and DSC perfusion imaging

IVIM data post processing were done in osirix image processing system by using biexponential method. after the processing,we can generate maps of D,D*and f where D and D* are the diffusion parameters related to the molecular diffusionand to the perfusion-related diffusion, respectively, $S/S0$ is the normalized signal attenuation, and f is the perfusion fraction. Setting 200 s/mm2 as the cutoff of the low b values,the high values will generate the D first, and the low b values will yield the $D*$ and f at the same time after removing the effects of D, finally producing the D, $D*$, and f maps. ADC map was also calculated by b values of 0 and 1000 s/mm2 with monoexponential equation.

DSC perfusion post processing was done on advantage workstation 4.6 GE Healthcare by using functool.Brain stat is an MR Time course imaging Functool protocol that provides accurate spatial resolution for the brain tissue viability given by the hemodynamic parameters such as rcbf and rcbf and MTT. These parameters can provide unique information on tissue changes and improves the delineation of vascular –deficient or vascular-rich regions in normal and abnormal anatomy.

RESULTS

Meningioma

Figure 1 shows two well defined extra axial mass lesions seen in the frontal region.these lesions are hypointense on T1 WI and hyperintense on T2WI and FLAIR images.these lesions shows hyperintensity on DWI but there is no obvious diffusion restriction of diffusion.DSC perfusion study was done which shows increased perfusion.the patient underwent IVIM imaging prior to the administration of intravenous contrast media.which shows increased D* and f values on the corresponding maps.

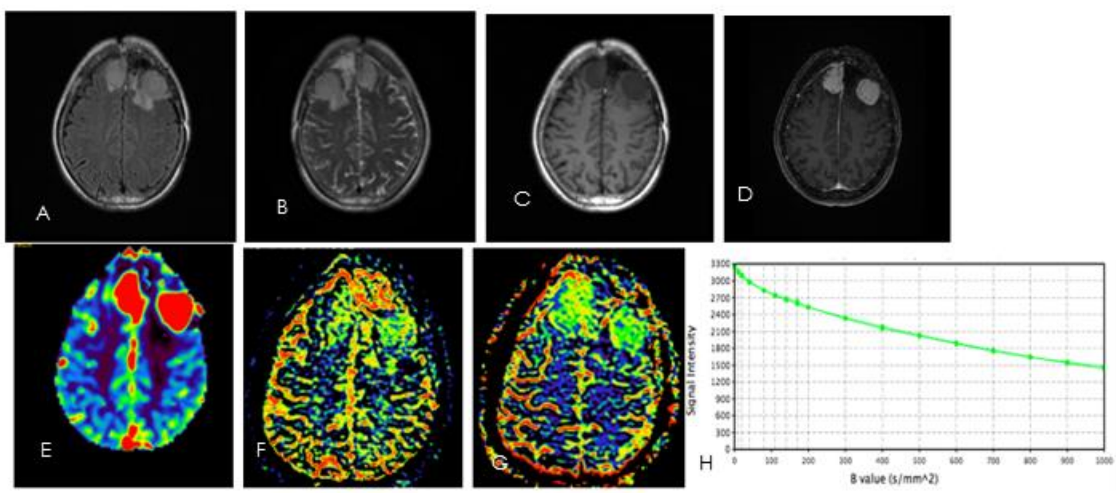


Figure 1 A-C: T2 FLAIR,T2WI,TIWI ,D: Post contrast BRAVO, E :RCBV Map of DSC Perfusion,F-G : D* and f Map of IVIM Imaging,H : Logarithmic plot of signal intensity decay as function of b value

Figure 2 shows another case of extra axial lesion in the basisphenoid region involving the right temporal lobe.the lesion appears to be iso to hypointense on T1WI and hyperintense on T2WI and FLAIR images.DSC perfusion study showed significantly increased perfusion in the solid part of the lesion.on IVIM imaging,the lesion shows increased D* and f value on the corresponding IVIM maps.

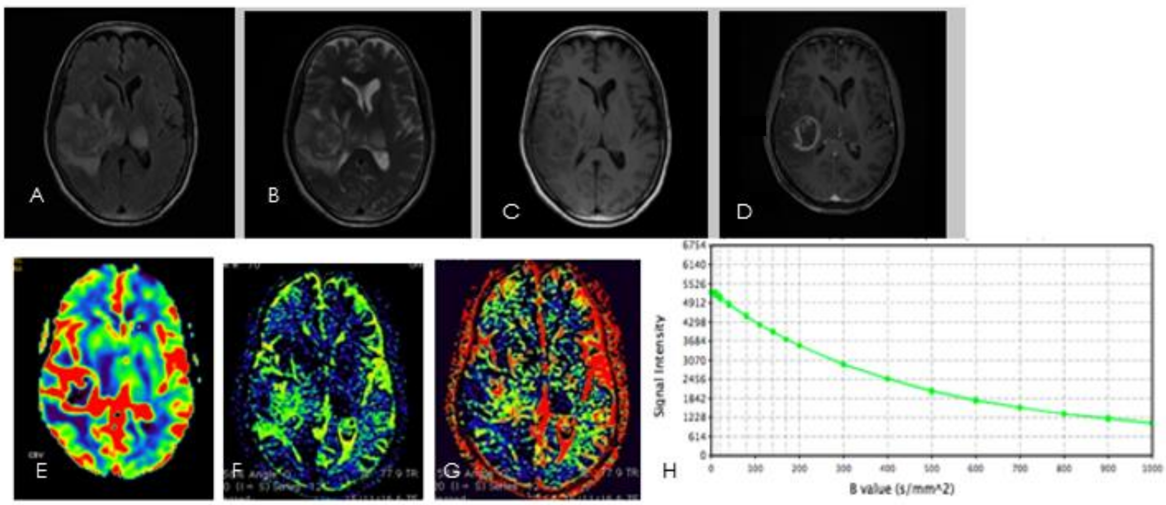


Figure 2 A-C: T2 FLAIR,T2WI,TIWI ,D: Post contrast BRAVO, E :RCBV Map of DSC Perfusion,F-G : D* and f Map of IVIM Imaging,H : Logarithmic plot of signal intensity decay as function of b value.

High grade glioma

Figure 3 shows well demarcated lesion seen in the right frontal lobe.the solid component of the lesion appears to be heterogenous post contrast enhancement.which is hyperintense on T2WI and FLAIR. DSC Perfusion study was performed after the administration of intravenous contrast media.which shows significantly increased perfusion in the solid part of the lesion. On IVIM imaging there is an increase in D* and f values.

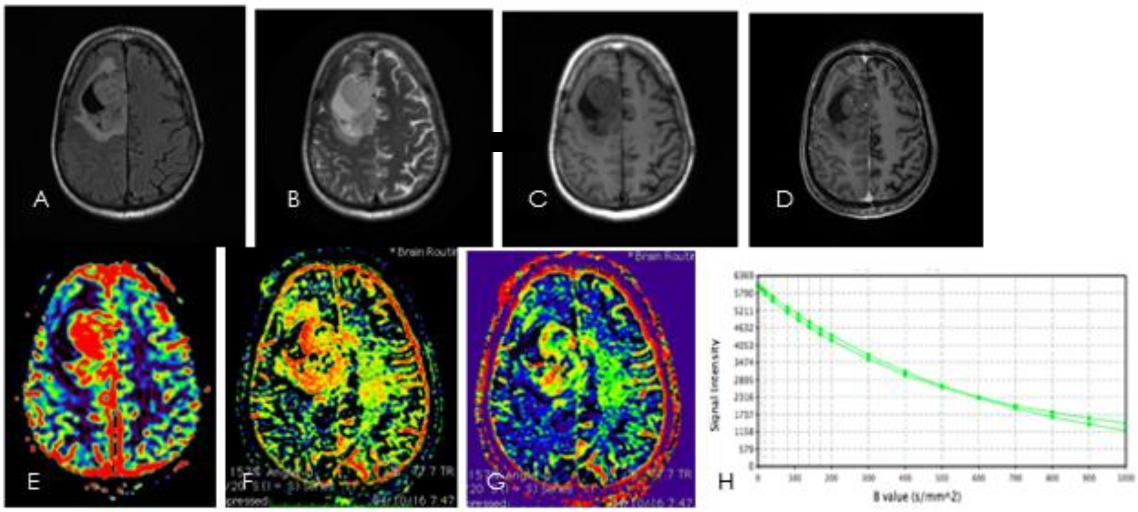


Figure 3 A-C: T2 FLAIR,T2WI,TIWI ,D: Post contrast BRAVO, E :RCBV Map of DSC Perfusion,F-G : D* and f Map of IVIM Imaging,H : Logarithmic plot of signal intensity decay as function of b value

Figure 4 shows well defined large enhancing lesion in the left cerebral hemisphere involving the left temporal lobe,thalamus,lentiform nucleus,insula,hypothalamus and internal capsule.the lesion appears hyperintense on T2WI and FLAIR images. The enhancing areas showed increased perfusion on DSC perfusion imaging. There is an increased perfusion fraction(f) and D* on IVIM imaging.

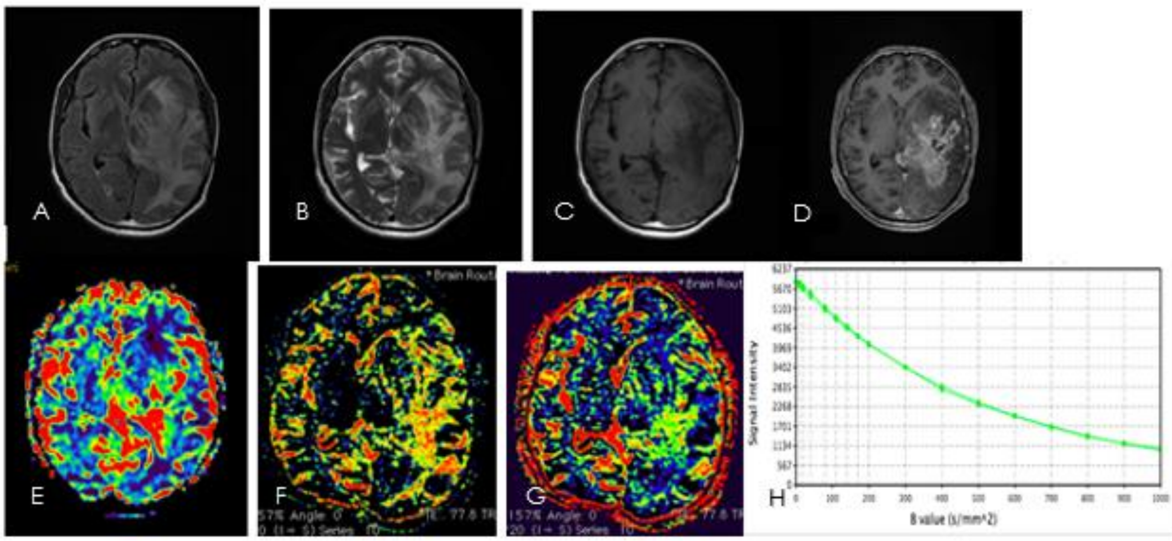


Figure 4 A-C: T2 FLAIR,T2WI,TIWI ,D: Post contrast BRAVO, E :RCBV Map of DSC Perfusion,F-G : D* and f Map of IVIM Imaging,H : Logarithmic plot of signal intensity decay as function of b

Lowgrade glioma

Figure 5 shows T2& FLAIR hyperintense lesion involving the left superior frontal gyrus.this lesion is hypointense on T1WI. This lesion shows slightly elevated rcbv on the DSC Perfusion sudy.post contrast images showed focal areas of enhancement.on IVIM imaging it is found to be slightly increased perfusion fraction (f). Low grade glioma

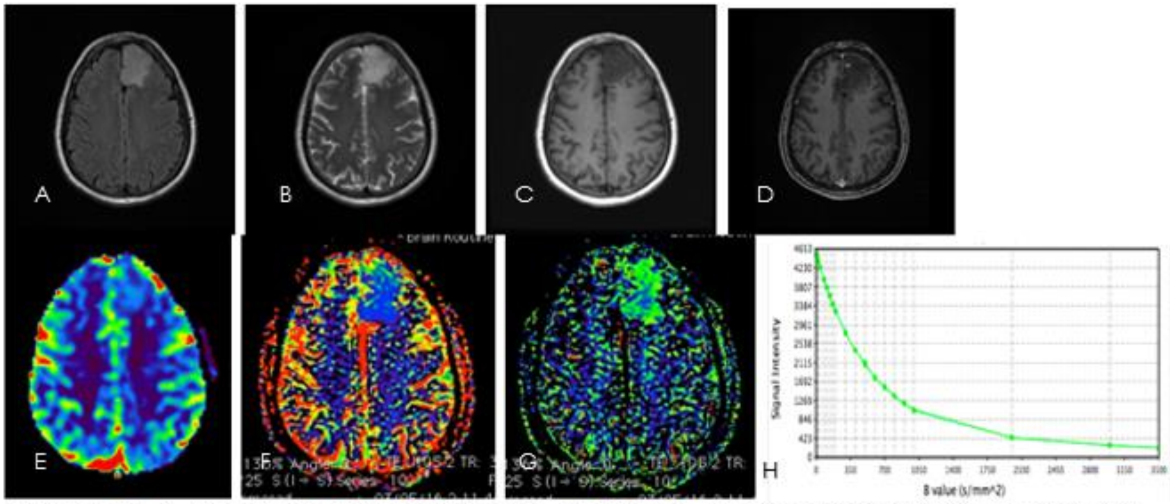


Figure 5 A-C: T2 FLAIR,T2WI,TIWI ,D: Post contrast BRAVO, E :RCBV Map of DSC Perfusion,F-G : D* and f Map of IVIM Imaging,H : Logarithmic plot of signal intensity decay as function of b value

<u>Space occupying lesion (SOL)</u>

T2 & FLAIR hyperintense lesion in the left frontal lobe.the lesion appears hypointense on T1WI.on post contrast study there is no enhancement.DSC Perfusion study reveals low perfusion.on IVIM Imaging,these lesion showed reduced microcirculation in which the D* and f values are reduced.

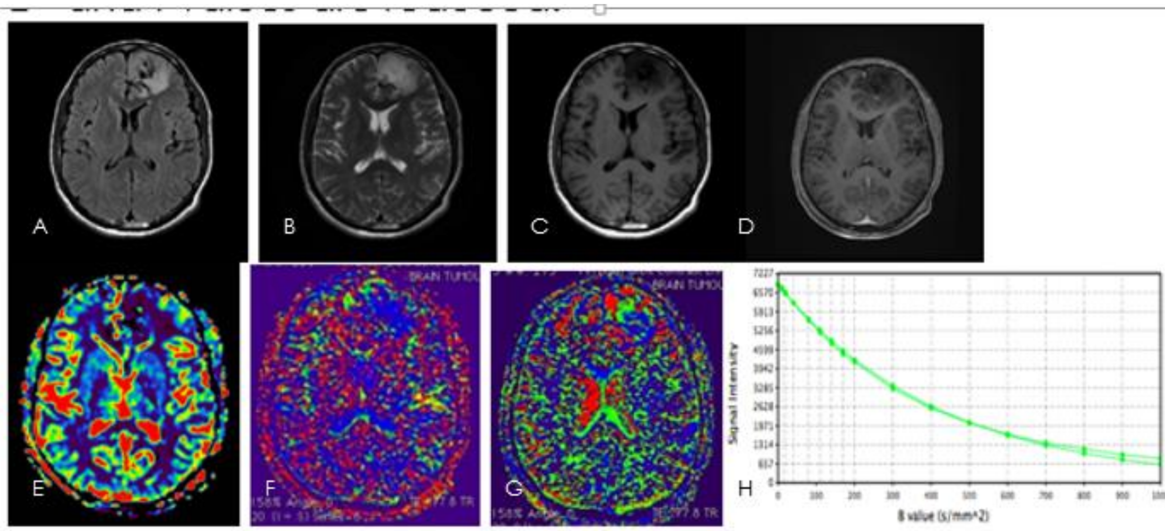


Figure 6 A-C: T2 FLAIR,T2WI,TIWI ,D: Post contrast BRAVO, E :RCBV

Map of DSC Perfusion,F-G : D* and f Map of IVIM Imaging,H : Logarithmic plot of signal intensity decay as function of b

ROI Analysis

A ROI was drawn in every lesion presented, and in control contralateral healthy parenchyma. The signal was averaged inside this ROI for each value of b, and
Fitted in the graph.

D*(lesion)	D*(Control)	f (lesion)	f (control)
63.56	20.317	12.23	1.62
57.008	14.472	12.431	1.157
50.934	14.565	15.794	1.304
45.334	18.226	14.572	2.573

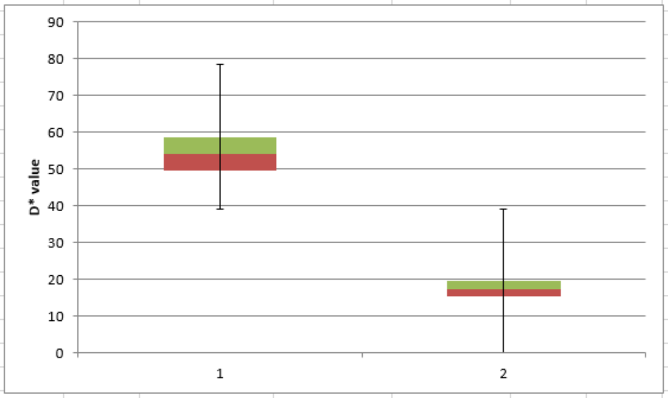
Table 1 shows ROI Values measured from the lesion and contralateral control areas of the brain parenchyma in patients with meningioma and high grade glioma.

STATISTICAL ANALYSIS

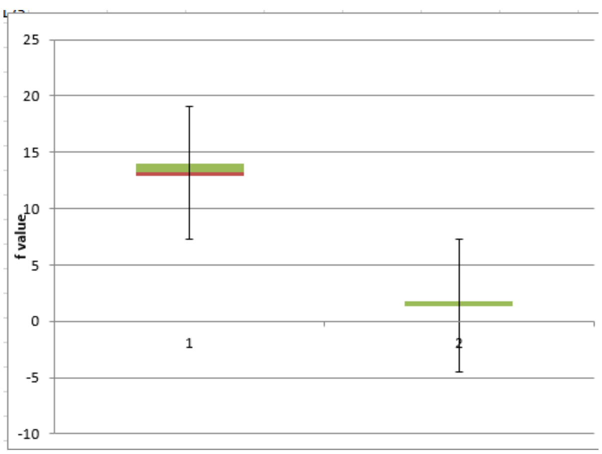
Statistical analysis were performed in Microsoft excel.from values derived from the ROI. ROI Values measured from the lesion and contralateral control areas of the brain parenchyma. Box plots were plotted from D* and f values.from this mean,median.min. and max.values were obtained as follows.

mean	54.209	16.895	13.75675	1.6635	q1	49.534	14.54175	13.18363	1.38575
median	53.971	16.3955	13.5015	1.462	q3	58.646	18.74875	14.26606	1.890875
min	45.334	14.472	12.23	1.157					
max	63.56	20.317	15.794	2.573					

Box plot of pseudodiffusion co efficient (D*)



Box plot of Perfusion Fraction (f)



DISCUSSION

The results presented in this report suggest that the sensitivity of IVIM to measure brain perfusion is sufficient in order to be used in the current clinical setting in multiple pathological conditions. In tumors with histologically proven pathological vascular proliferations,an increase in all three IVIM perfusions parameters,the perfusion fraction f, the pseudodiffusioncoefficient D*was observed.

There were many kinds of water molecule movements in brain tissue, including intracellular,intercellular, and transmembrane molecular diffusion, as well as microcirculation of blood in the capillary network. It has been confirmed that when applying a diffusion gradient field of high b values,signal attenuation of water molecule diffusion in brain tissue is following the way ofmultiexponential models,which (multiexponential models) can better reflect the actual diffusion information of brain parenchyma than monoexponential model.Compared to the multiexponential model, the biexponentialmodelmight be oversimplified, but in regard to the evaluation of two or more different proton diffusion pools in voxel, the biexponential model is more feasible.

Even allowing a wider application of the IVIM model, the best way to derive the diffusion coefficient, pseudodiffusion coefficient, and perfusion fraction from acquired data is still being explored. Because pseudodiffusion coefficient and perfusion fraction parameters are highly correlated, one approach would be to fix the pseudodiffusion coefficient value using a prior information.The situation is potentially even more complex because of heterogeneous patterns of signal attenuation on a voxelwise basis in normal tissues and tumors.a voxel within a tissue may exhibit signal attenuation best described by the IVIM model, but adjacent voxels may show signal loss best described by other models. The difficulty in generalizing such behaviour to a region of interest is indeed challenging, because choosing to fit all voxels in a region to one model can result in approximation. Clearly, future studies should aim to improve our understanding of the biologic relevance of a range of mathematic models and developing novel algorithms to describe complex DW-MRI tissue behavior.

CONCLUSION

Our initial experience shows brain perfusion imaging is feasible with IVIM in a 3tesla MRI Scanner

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