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

LOG BOOK

SUBMITTED IN FULFILLMENT FOR THE COURSE

(DAMIT)
DIPLOMA IN ADVANCED MEDICAL IMAGING TECHNOLOGY

PERIOD: JAN 2016 – DEC 2017

ALBIN V KURIAKOSE

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

CERTIFICATE

This is to certify that **ALBIN V KURIAKOSE** has participated in Interventional cases and Imaging Cases during the period Jan 2016 to Dec 2017 while working as an Technologist student in the Department of Imaging Sciences and Interventional Radiology, Sree Chitra Tirunal Institute for Medical Sciences and Technology, Trivandrum, Kerala (India).

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Department of Imaging Sciences and Interventional Radiology,
Sree Chitra Tirunal Institute for Medical Sciences and Technology,
Trivandrum, Kerala INIDA.

PREFACE

This work book, I have done as part of my training in the dept of radiology for diploma in Advanced Medical Imaging Technology (DAMIT) course includes brief details of the equipment used in the Dept, basic physics and working involved with the equipment's, 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 science and health care technology. It is a member of the Association of Indian Universities and the Association of Commonwealth Universities

ACKNOWLEDGEMENT

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

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

I extent my heartful thanks to all the Radiographers, other staffs of radiology, staff members of different 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 PG residents, senior and junior **DAMITS** for there co-operation at work place and in studies.

COURSE CURRICULUM

POSTING	NUMBER OF MONTHS
DSA	8
MRI	8
CT	7
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 - 3100
Chest - 200
Abdomen - 300
CT Angios - 1100
Cardiac CT - 70

D) CT Interventional Procedures.
CT Guided Biopsies : 10
Bone Biopsies : 10

F) Magnetic Resonance Imaging.
Equipment :
Magnetom Avanto Tim 76 x 18 1.5T / GE Discovery 750w 3T
No of Cases Done :
Brain - 2000

Cervical Thoracic,& Lumbar Spines - 1500
Stereotactic MRI(Pallidotomy & Biopsys) - 10
Musculo Skeletal System
(Pelvis, Hip joint, Knee, Sho
\ulder joint Etc.) - 50
Cardiac imaging - 110
Abdomen and Chest - 25
MR Angiograms - 250

H) D S A Lab.

Equipment : **GE innova 3131**. BiPlane System
No of Cases Assisted:

4Vessel Angios	:	500
Aortograms	:	50
IVDSA	:	4
Peripheral Angios	:	25
Spinal Angios	:	50
Coronary angio	:	6
Bronchograms	:	5
PTBD	:	60
WADA Test	:	20
BOT	:	4
Ba Studies	:	35

Interventional Procedures :

Angioplasty	:	150
PTCA	:	5
PDA Coiling	:	5
Embolization (Onyx,Glue& Particle)	:	180
GDC Embolization	:	60
Chemo. Embolization	:	40
Thrombolysis	:	25
Stenting	:	70
Tracheal Stenting	:	2
PLDD	:	6
Vertibroplasty	:	1
TESI	:	20
TGN laser ablation	:	9
Flow diverter	:	7
TEVAR	:	20
EVAR	:	10

SEMINARS PRESENTED

- Multi Detector Ct Technical Aspects & Clinical Application
- DSA instrumentation & 3d rotational angiography
- Interventional Procedures in dsa
- Imaging Parameters in MRI
- PACS & Tele radiology
- Radiation protection
- Spin Echo Pulse Sequences & Its Clinical Applications
- Gradient echo Pulse Sequences & clinial application
- SWI & clinial application
- EPI & clinial application
- fMRI & Bold
- Diffusion & Dti

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

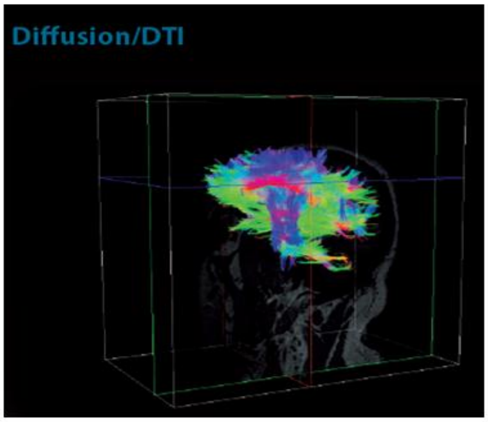
NEW POST PROCESSING SOFTWARE

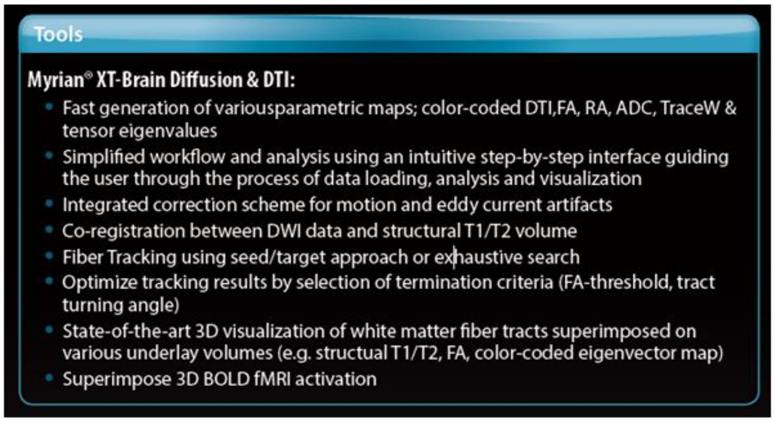
MYRIAN – INTRASENSE

- 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

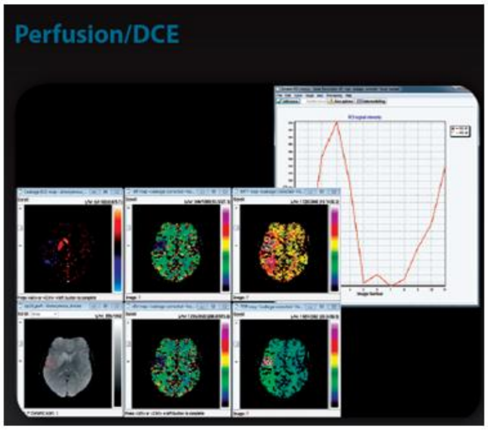
Provide flexibility for research oriented work

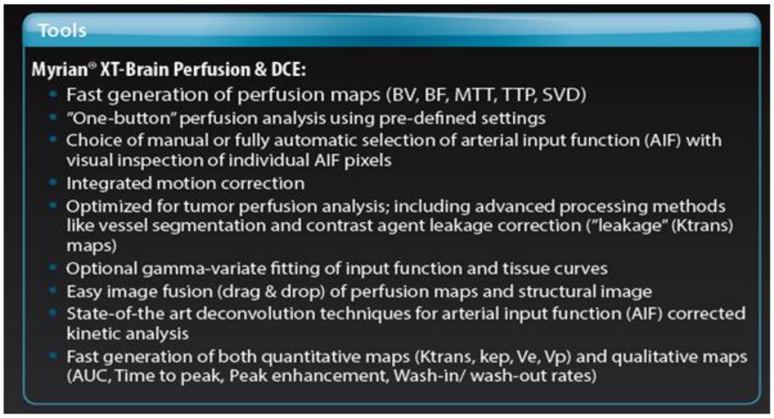




Myrian® XT-Brain Diffusion & DTI:

- Fast generation of variousparametric maps; color-coded DTI,FA, RA, ADC, TraceW & tensor eigenvalues
- Simplified workflow and analysis using an intuitive step-by-step interface guiding the user through the process of data loading, analysis and visualization
- Integrated correction scheme for motion and eddy current artifacts
- Co-registration between DWI data and structural T1/T2 volume
- Fiber Tracking using seed/target approach or exhaustive search
- Optimize tracking results by selection of termination criteria (FA-threshold, tract turning angle)
- State-of-the-art 3D visualization of white matter fiber tracts superimposed on various underlay volumes (e.g. structual T1/T2, FA, color-coded eigenvector map)
- Superimpose 3D BOLD fMRI activation





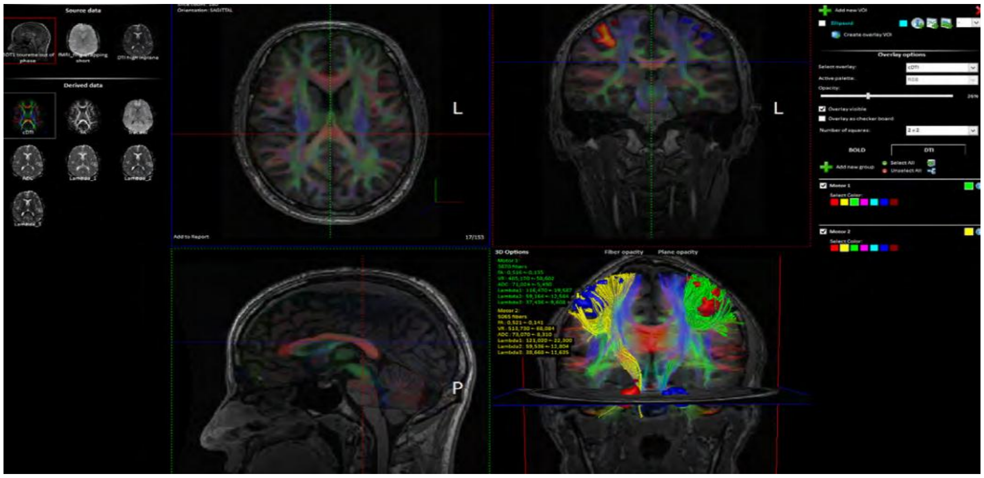
Myrian® XT-Brain Perfusion & DCE:

- Fast generation of perfusion maps (BV, BF, MTT, TTP, SVD)
- "One-button" perfusion analysis using pre-defined settings
- Choice of manual or fully automatic selection of arterial input function (AIF) with visual inspection of individual AIF pixels
- Integrated motion correction
- Optimized for tumor perfusion analysis; including advanced processing methods like vessel segmentation and contrast agent leakage correction ("leakage" (Ktrans) maps)
- Optional gamma-variate fitting of input function and tissue curves
- Easy image fusion (drag & drop) of perfusion maps and structural image
- State-of-the art deconvolution techniques for arterial input function (AIF) corrected kinetic analysis
- Fast generation of both quantitative maps (Ktrans, kep, Ve, Vp) and qualitative maps (AUC, Time to peak, Peak enhancement, Wash-in/ wash-out rates)

nordic Brain EX :

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

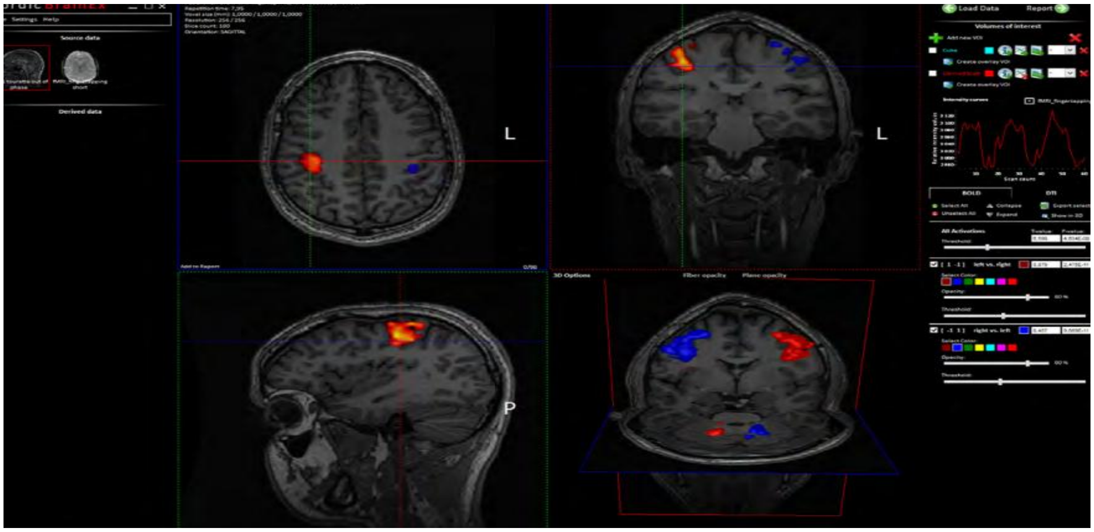
DTI Fiber tracking Module



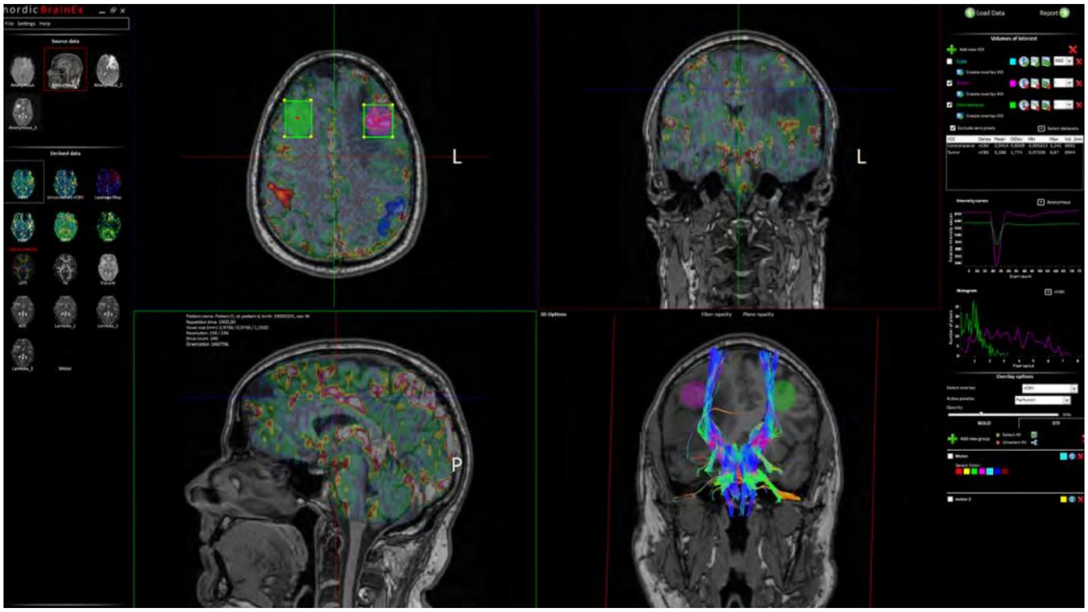
Preprocessing - Motion Correction, Eddy current correction , Smooth , Average ,Adjust noise level

Fibertracking – multiple VOI , AND OR & NOT option

BOLD fMRI module



- Perfusion/DSC module



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

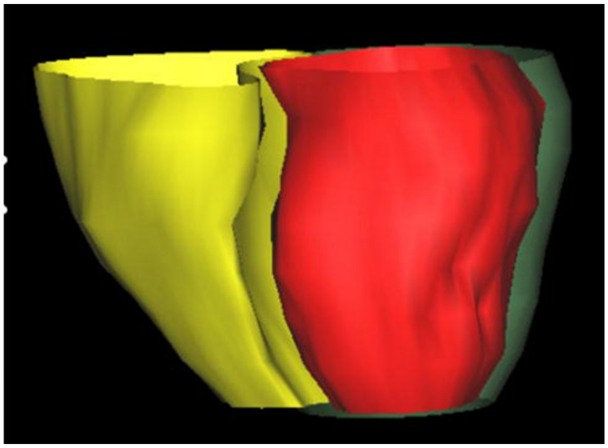
CIRCLE CARDIO VASCULAR IMAGING

LV/RV FUNCTION

SAX3D Stack LV Function

LAX corrected

EDV: 292.9 ml
ESV: 161.8 ml
SV: 131.1 ml
EF: 44.7 %
CO: 8911.5 ml/min
CI: 3.6 l/min/m²
HR: 68.0/min
Myo Mass (Diast): 210.4 g
Myo Mass (Syst): 244.1 g

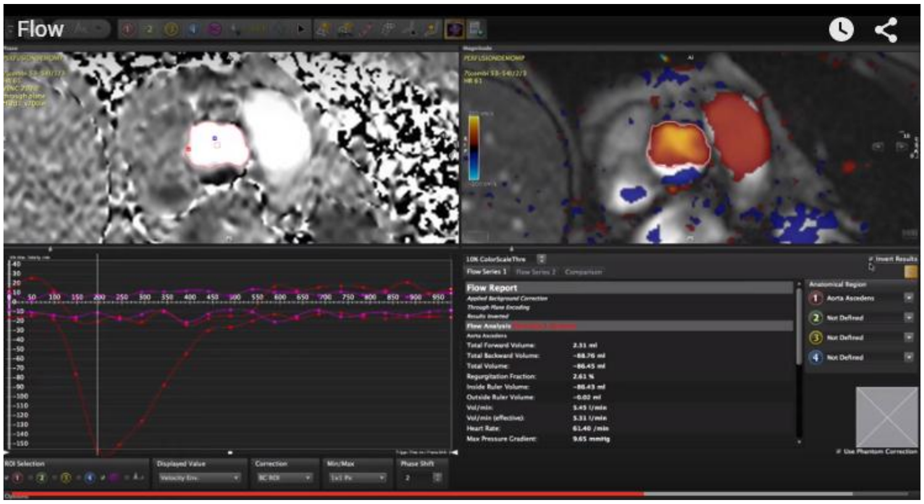


Left and right atrial volumetry [disk area summation & area length method]

- ➢ 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)

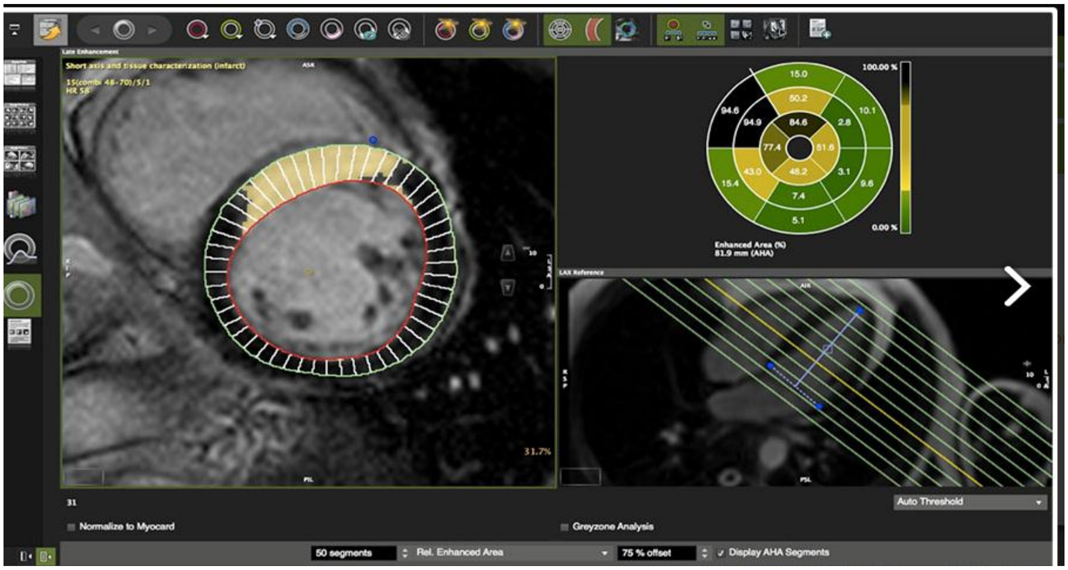
➢ FLOW



Flow Report
Applied Background Correction
Through Plane Encoding
Results Inverted
Flow Analysis
Aorta Ascedens
Total Forward Volume: 2.31 ml
Total Backward Volume: -88.76 ml
Total Volume: -86.45 ml
Regurgitation Fraction: 2.61 %
Inside Ruler Volume: -86.43 ml
Outside Ruler Volume: -0.02 ml
Vol/min: 5.45 l/min
Vol/min (effective): 5.31 l/min
Heart Rate: 61.40 /min
Max Pressure Gradient: 9.65 mmHg

- ➢ 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



☐ Normalize to Myocard

☐ Greyzone Analysis

Auto Threshold

50 segments

Rel. Enhanced Area

75 % offset

☑ Display AHA Segments

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

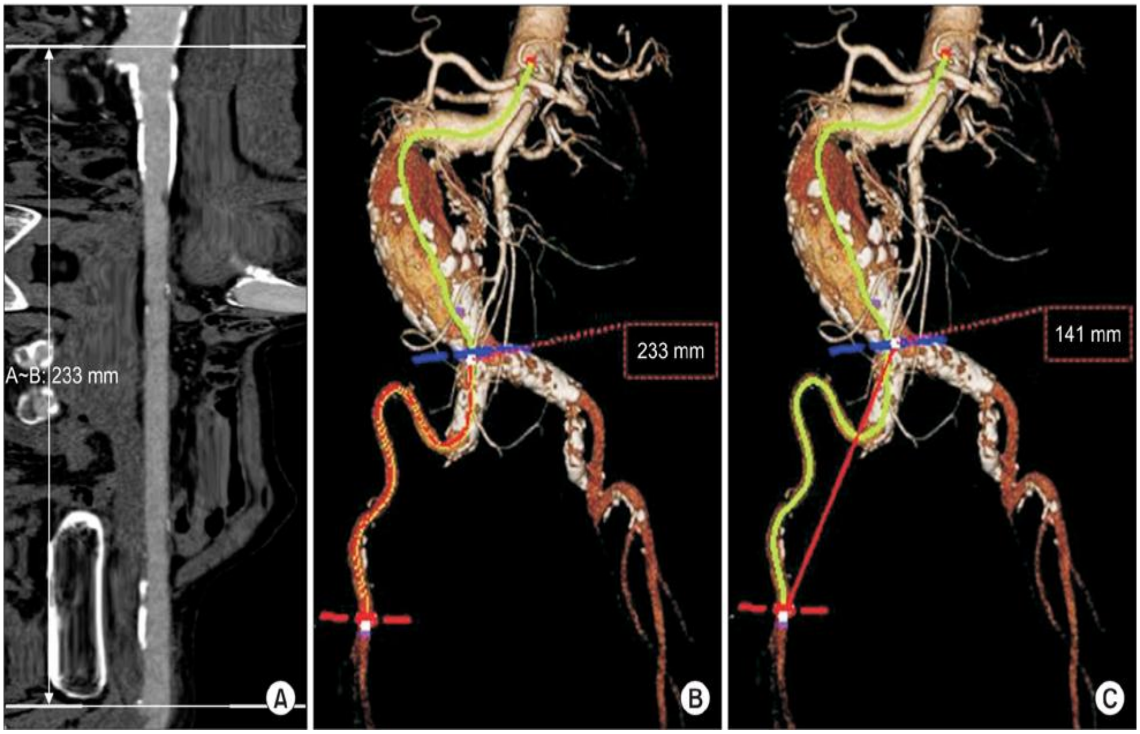
Early Gadolinium Enhancement

- 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



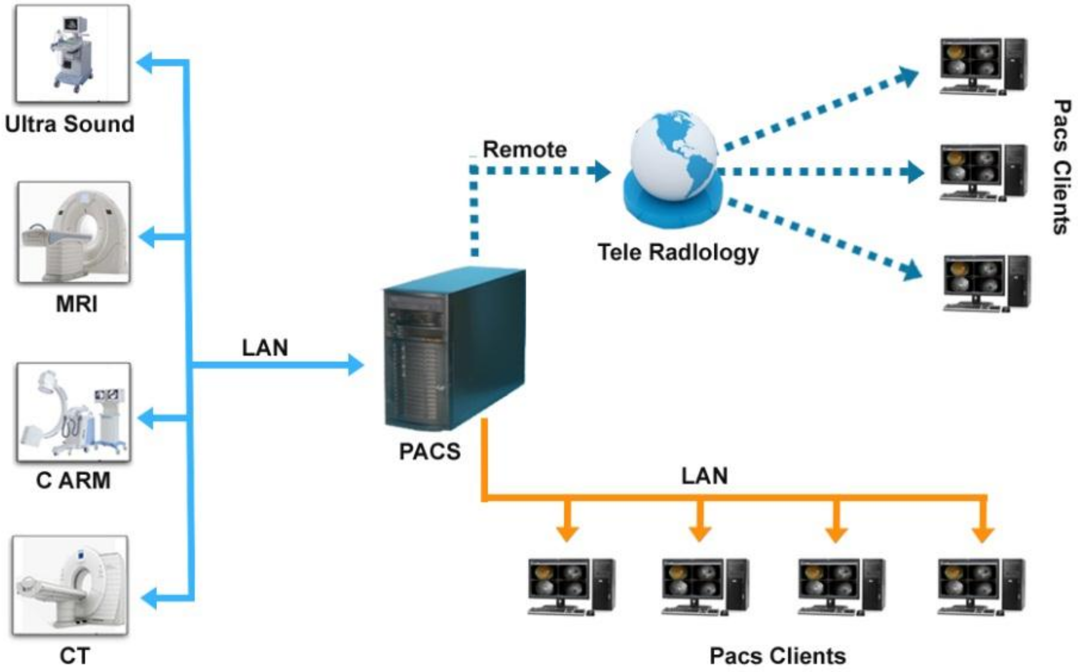
PACS

A **picture archiving and communication system** (**PACS**) is a medical imaging technology which provides economical storage and convenient access to images from multiple modalities (source machine types).[1] Electronic images and reports are transmitted digitally via PACS; this eliminates the need to manually file, retrieve, or transport film jackets, the folders used to store and protect X-ray film. The universal format for PACS image storage and transfer is DICOM (Digital Imaging and Communications in Medicine). Non-image data, such as scanned documents, may be incorporated using consumer industry standard formats like PDF (Portable Document Format), once encapsulated in DICOM.

A PACS consists of four major components: The imaging modalities such as X-ray plain film (PF), computed tomography (CT) and magnetic resonance imaging (MRI), a secured network for the transmission of patient information, workstations for interpreting and reviewing images, and archives for the storage and retrieval of images and reports. Combined with available and emerging web technology, PACS has the ability to deliver timely and efficient access to images, interpretations, and related data. PACS reduces the physical and time barriers associated with traditional film-based image retrieval, distribution, and display.

SCTIMST AGFA IMPAX

- AGFA IMPAX 6.5.3
- Online storage- 8.5TB
- Archive server- 16.5TB
- DLT Library- 12 tapes (6 + 6)
- One DLT tape stores 3TB compressed data.



Advances in MRI

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

ADVANCES IN MRA

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

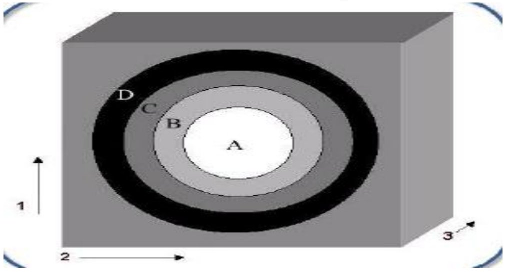
TRICKS / TWIST

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

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

Background:

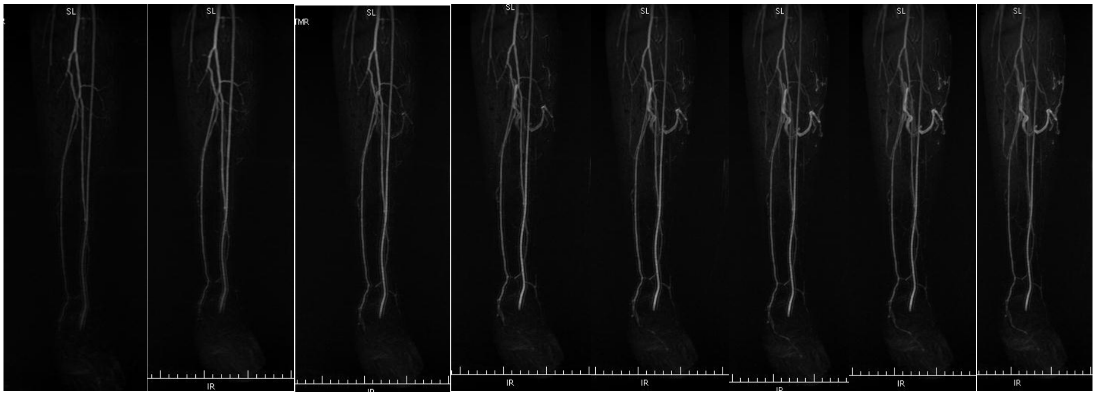
Elliptic Centric-TRICKS is a modified 3D Fast GRE pulse sequence that produces. CE MRA high spatial and temporal resolution images. A mask acquisition used to produce automatically subtracted source images. Collapsed images from each temporal output phase. TRICKS high temporal resolution is achieved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



K – SPACE SCHEME

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

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



TRICKS image of RT Leg

Clinical Applications

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

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

INHANCE / NATIVE - NON CONTRAST ANGIOGRAPHY

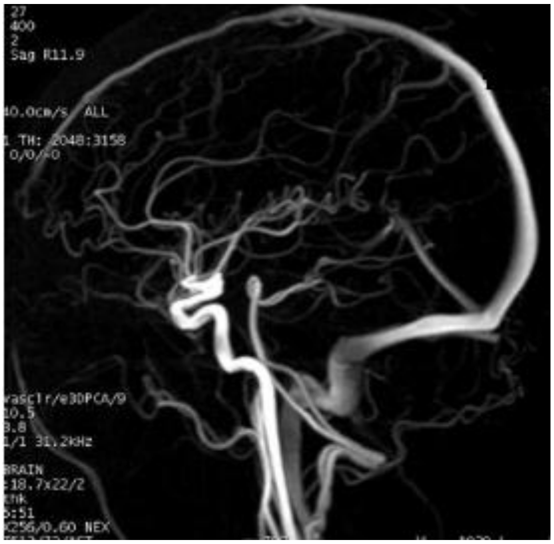
Advances in MRI is help full to provide non contrast MRA in abdominal and peripheral application. The early techniques of NON CONTRAST MRA include 2D &3D TOF IMAGING , GATED 2D TOF , PHASE CONTRAST ANGIOGRAPY

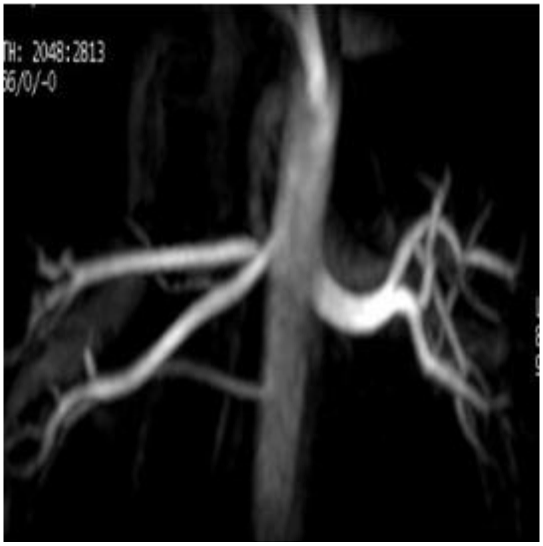
INHANCE include newer non contrast angiography technique for imaging patient's without contrast medium

INHANCE 3D VELOCITY:

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

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

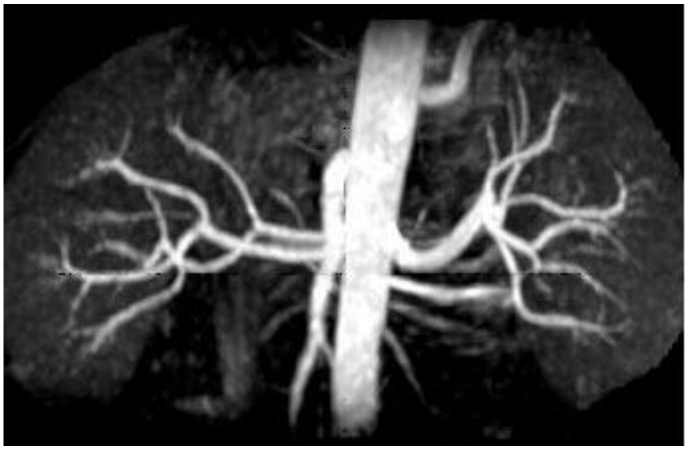




INHANCE INFLOW IR [NATIVE TRUEFISP]

Inhance 3D Inflow IR1 is a contrast-free angiographic (non-CEMRA) method based on the inherent in-flow effects of blood. This sequence is based on 3D FIESTA, which improves SNR and produces bright blood images. Selective inversion pulses are applied over the region of interest to invert arterial, venous, and static tissue. At the null point of the background tissue, an excitation pulse is applied to generate signal. The net result is an angiographic image with excellent background suppression and free of venous contamination. Inhance Inflow IR can also be used to image venous vasculature. This can be achieved by setting inversion recovery pulses to suppress upstream arterial flow. Respiratory trigger is used to reduce motion artifacts and **SPECIAL** (a chemical saturation technique) is implemented to produce good fat saturation.

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



<u>INHANCE 3D DELTA FLOW</u> [NATIVE SPACE]

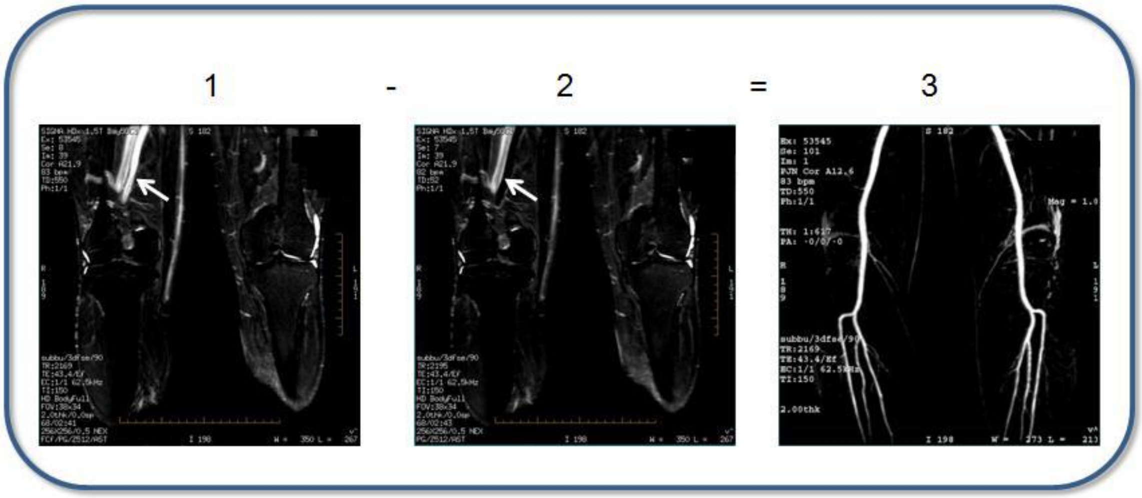
Inhance Deltaflow is a non-contrast agent MRA1 method that is typically used to image peripheral arteries in a run-off exam. Inhance Deltaflow acquires two 3D slabs: one during systolic phase and one during diastolic phase.
A multi-phase SSFSE scan is acquired to determine the diastolic trigger delay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

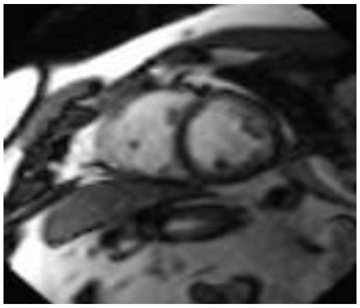
The ***MR-Echo*** application is for cardiac real-time prescription and acquisition. Real time acquisition is particularly useful in patients with irregular heart beats and with patients who cannot perform a breathhold acquisition. Using real-time images as localizers, the following batch scans can be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

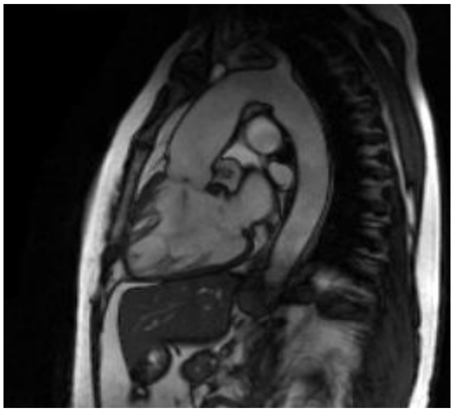
Background

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

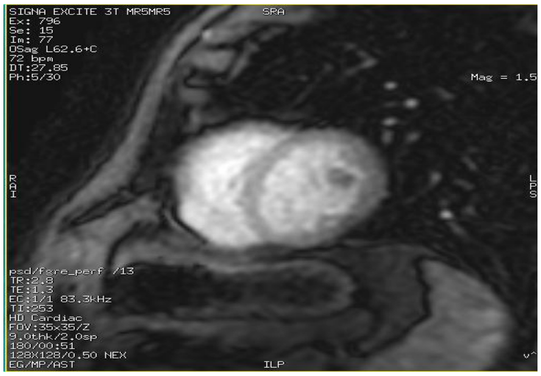
Realtime uses a non-gated 2DFIESTA PSD for acquiring real-time images of the heart using a FIESTA (bright blood) pulse sequence. The PSD acquires images at a high-frame rate for localization and qualitative ventricular function assessment.



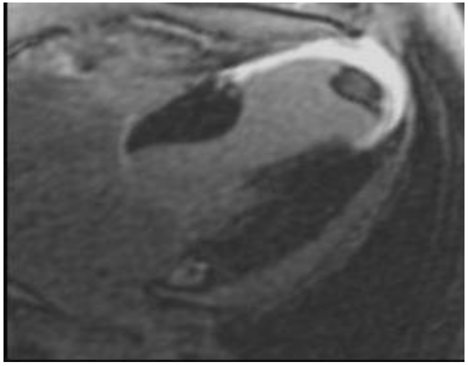
Function uses a gated 2D FIESTA PSD. It provides a multi-phase CINE high-frame rate acquisition mode for high-image quality breath-hold cardiac images that are added to the image database. This mode functions with both ECG2 or peripheral gating.



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, cardiac-triggered Fast GRE with an IR1-Prep pulse.

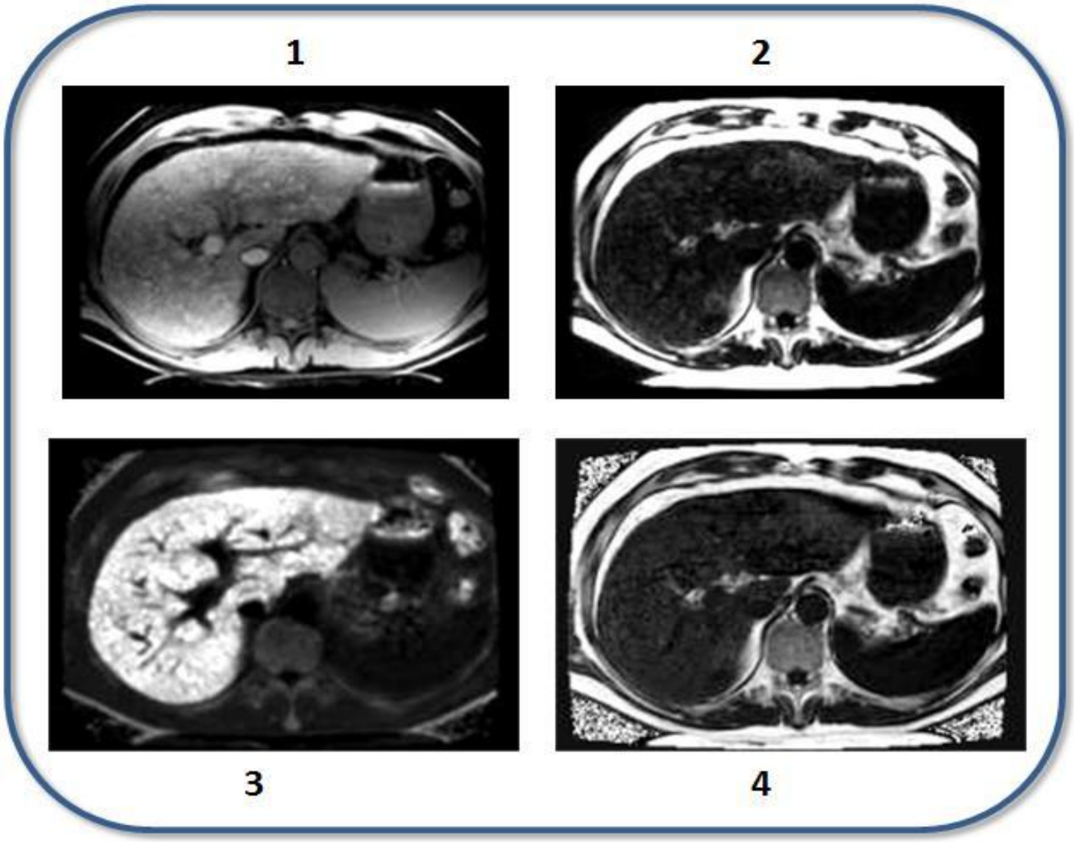


IDEAL IQ

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

The combination of the R2* map with the triglyceride fat-signal fraction map enables IDEAL IQ to improve the accuracy of tissue characterization parameters (R2* or triglyceride fat) by removing contamination from multiple chemical components.

IDEAL IQ uses ARC, which allows for acceleration in both phase and slice directions for supported coils

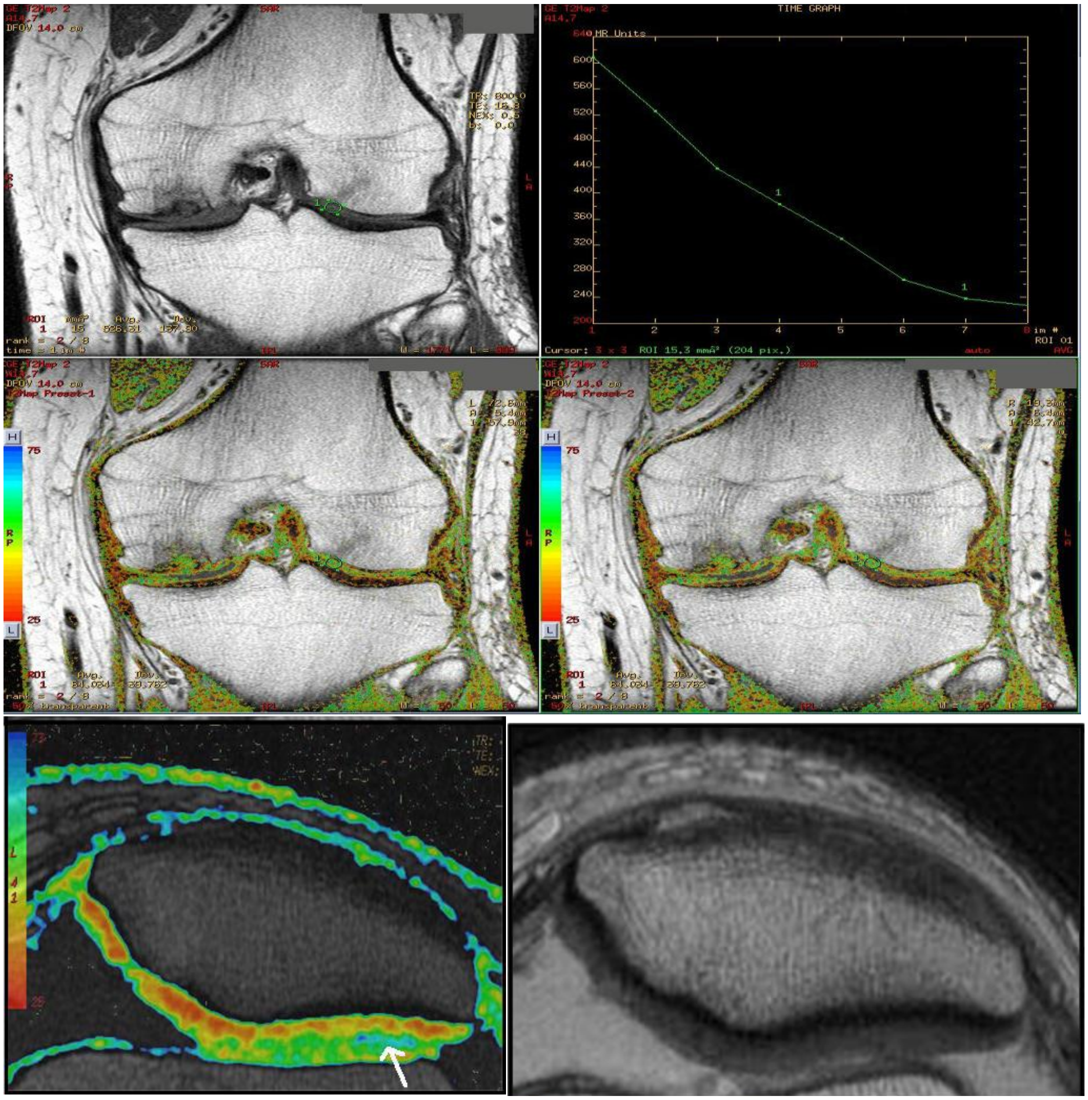


1= T2* corrected waterIDEAL IQ image ,2 T2* corrected triglyceride fat IDEAL IQ image ,3 R2* map IDEAL IQ image , 4 Triglyceride fat-fraction IDEAL IQ image

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.



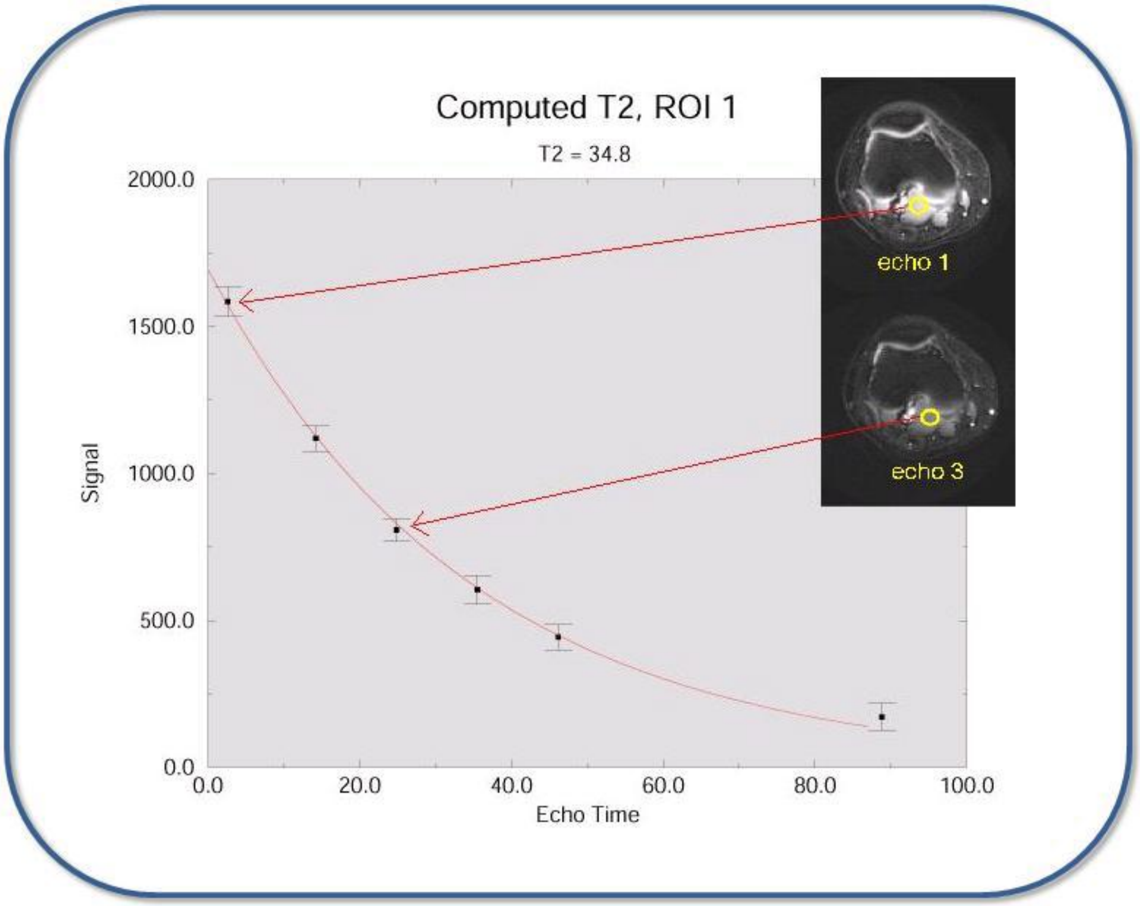
T2 Map

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.

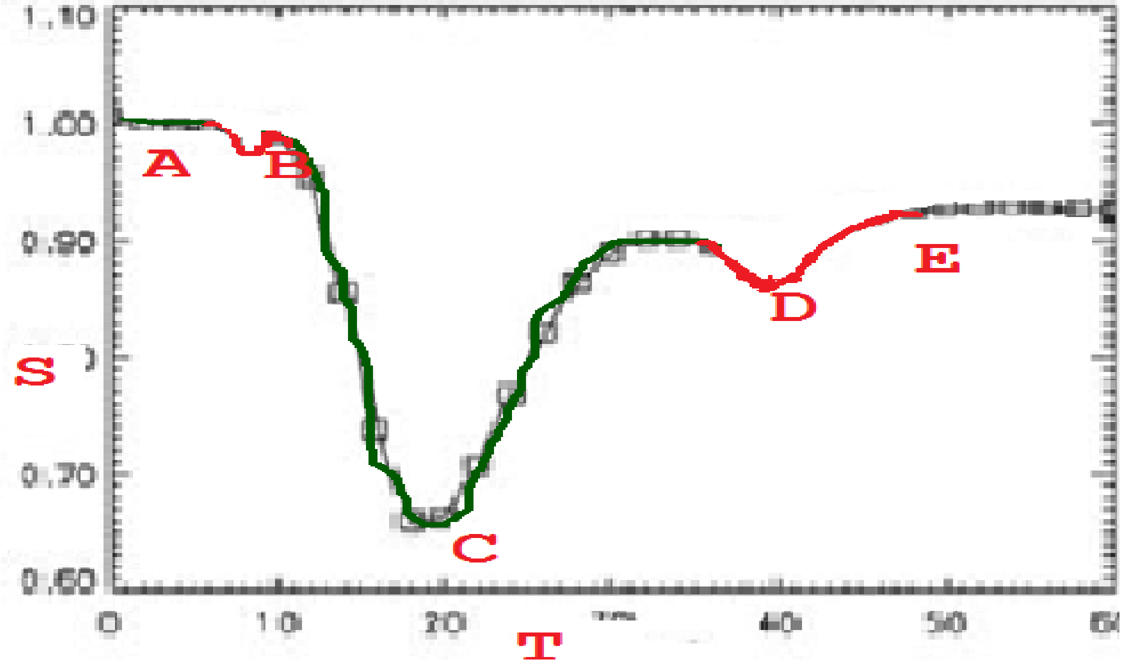
The susceptibility contrast generated by the passage of a paramagnetic contrast agent through the microvasculature is imaged using T2- or T2*-weighted sequences (see step 6). Fast acquisition imaging techniques, such as echo planar imaging (EPI), are required to characterize the transient MR signal drop (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)

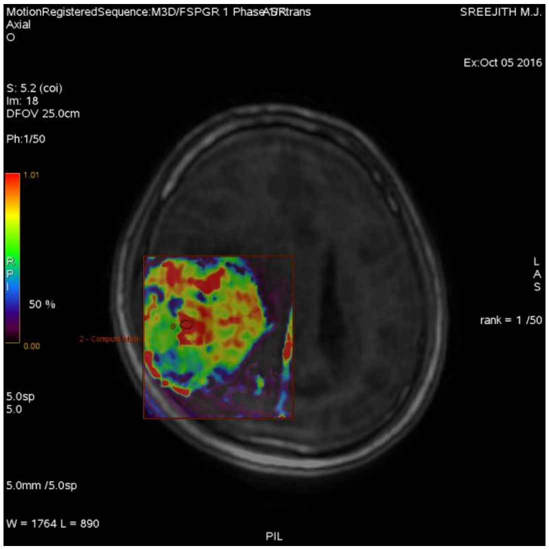
- Mean Transit Time (MTT)
- Average time to flow through capillaries (artery → vein)
- MTT=CBV/CBF
- Units: seconds
- 5 S

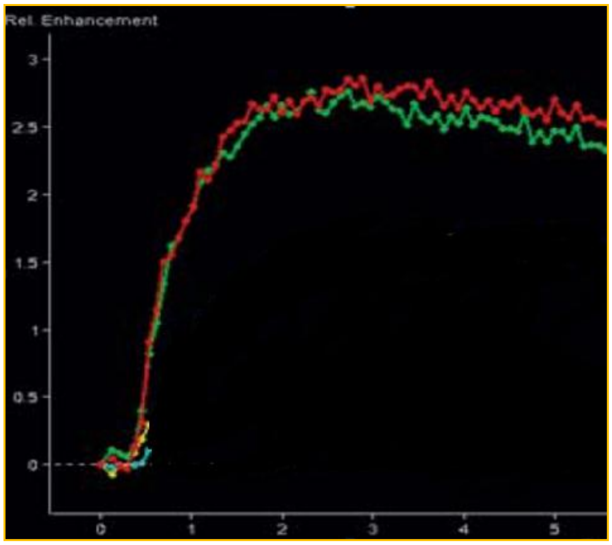
Time to maximum (Tmax)

- 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

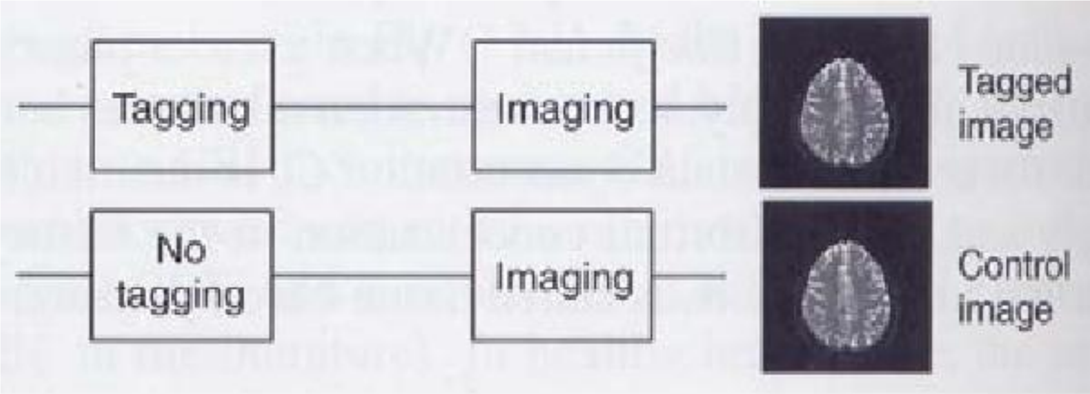
- Evaluation of ischemic penumbra in stroke.
- Classification of brain tumor.
- Grading of brain tumor.
- Cerebral infarction risk assessment
- Selection of patients for extracranial to intracranial bypass surgery
- Moyamoya evaluation
- Assessing risk of hyperperfusion syndrome
- Balloon test occlusion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

ASL

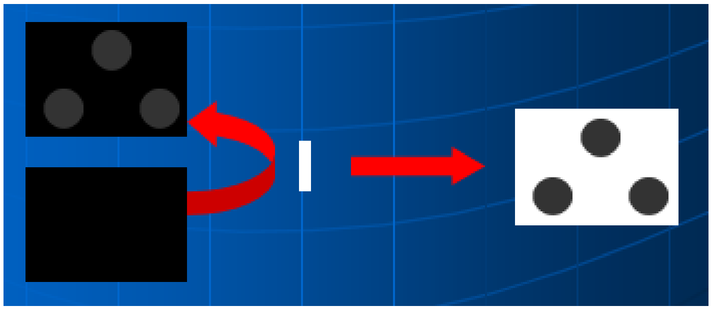
- ASL technique was conceived more than 15yrs ago.

- No exogenous contrast bolus required.

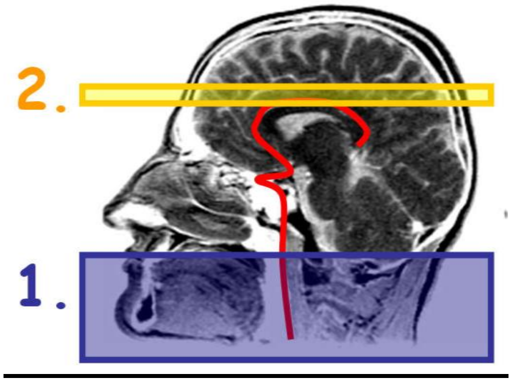
- ASL is based on labeling protons in the blood in supplying vessels outside the imaging plane and waiting for a period called post delay period for reaching the parenchyma.



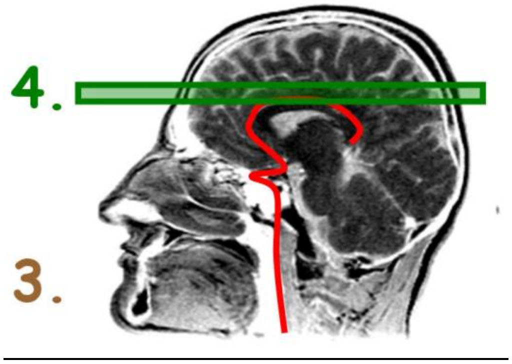
- Images are obtained from the parenchyma in labeled and controlled state.
- Subtracting these two type of images eliminates the static tissue signal will give CBF images.



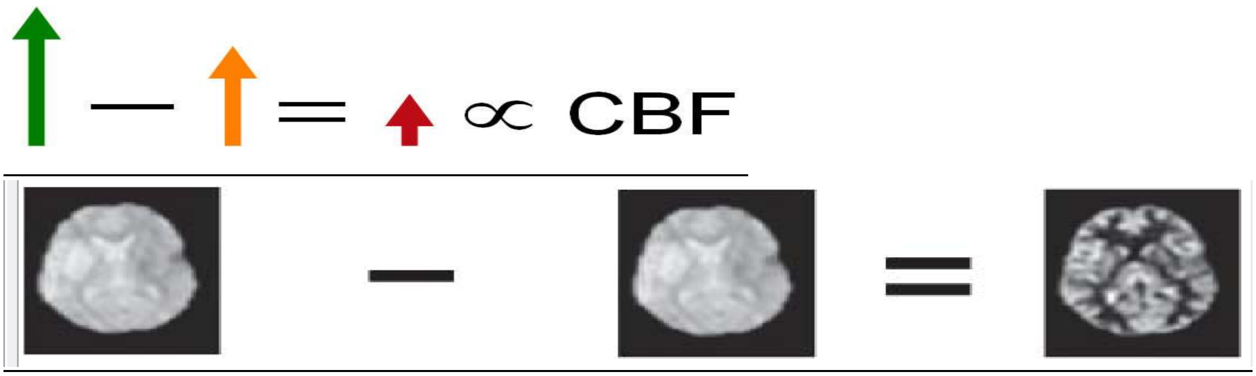
Principle of ASL



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



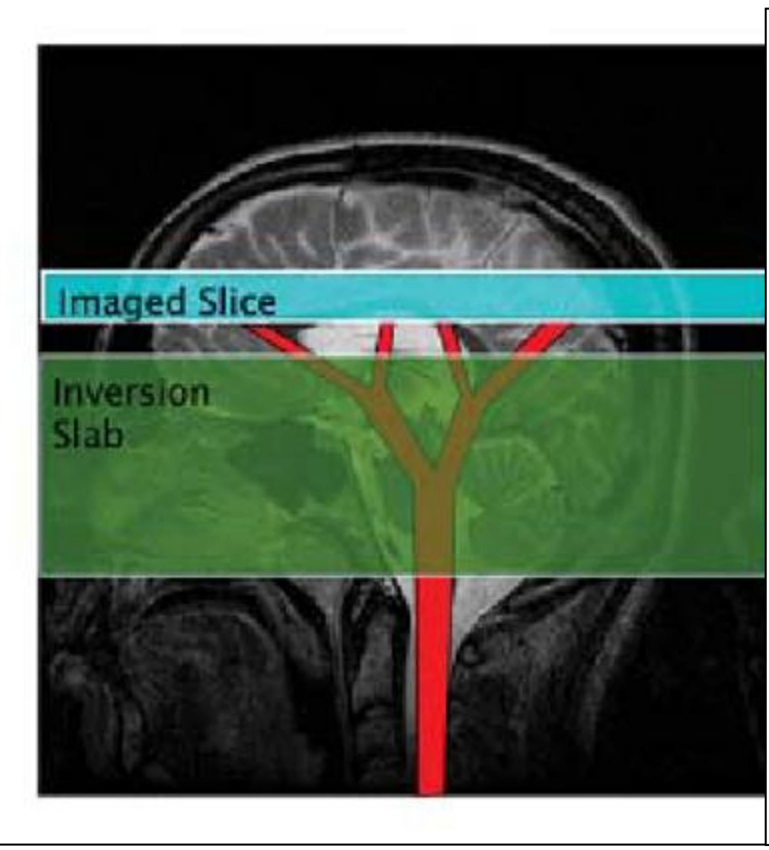
3. Repeat experiment without **tag**
4. Acquire the **control image**



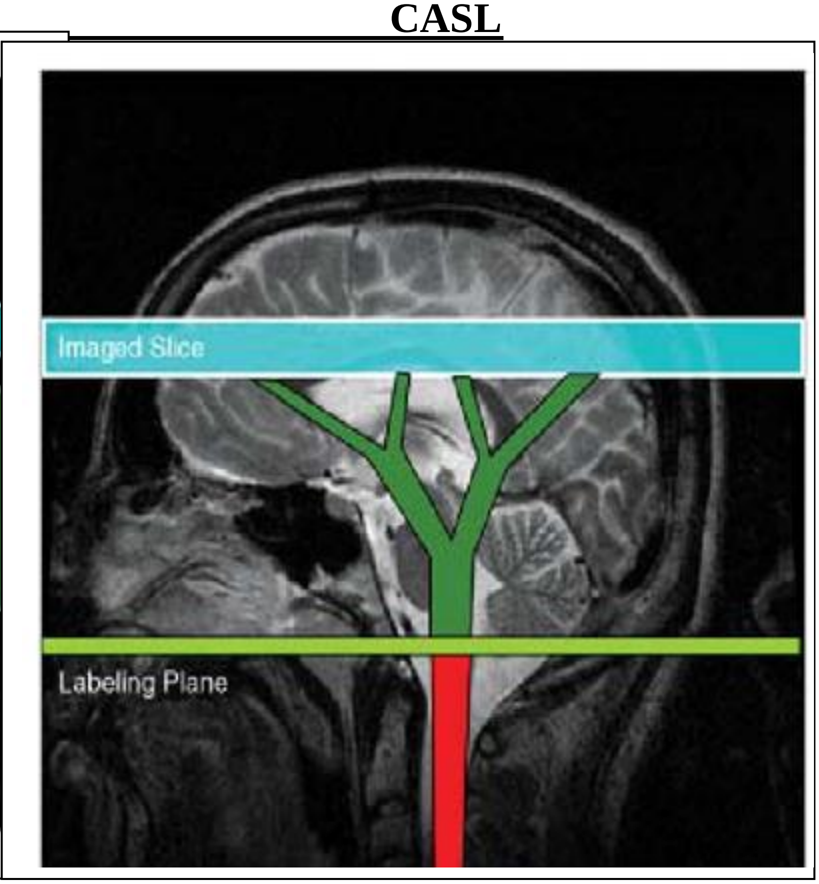
TYPES OF ASL

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

PASL



CASL

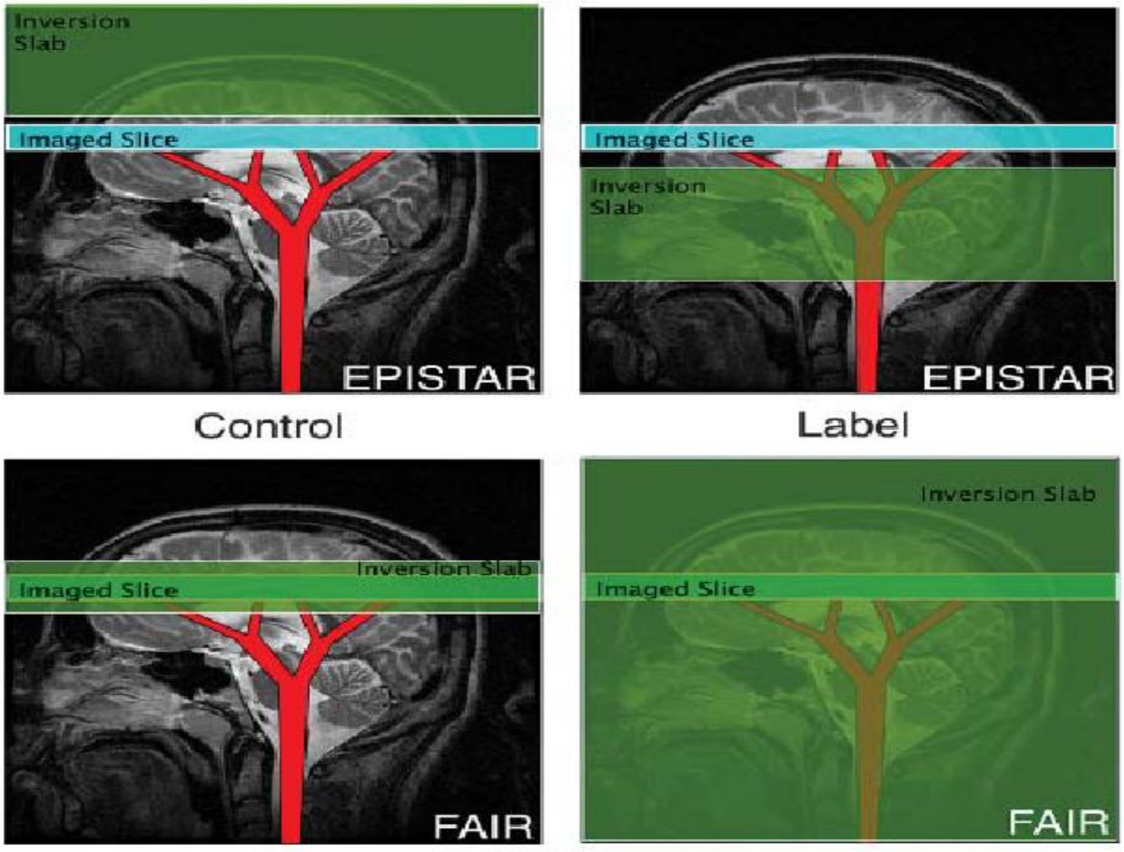


ASL Types	**Advantages**	**Disadanatges**
PASL	Higher tagging efficiency Lower SAR	Lower SNR
CASL	Higher SNR than PASL	Lower tagging efficiency Continuous RF transmit hardware required Higher SAR Magnetization Transfer effects
pCASL	Higher SNR than PASL Higher tagging efficiency than CASL	Higher SAR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

Sequence for ASL

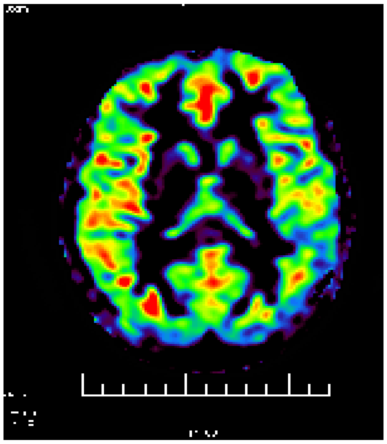
- EPISTAR-Echo planar imaging and signal targeting with all radiofrequency.
- PICORE-proximal imaging with a control for off resonance effect.
- TILT-transfer insensitive labeling technique.
- FAIR-flow sensitive alternating inversion recovery.
- FAIRER-FAIR with extra radiofrequency pulse.

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.

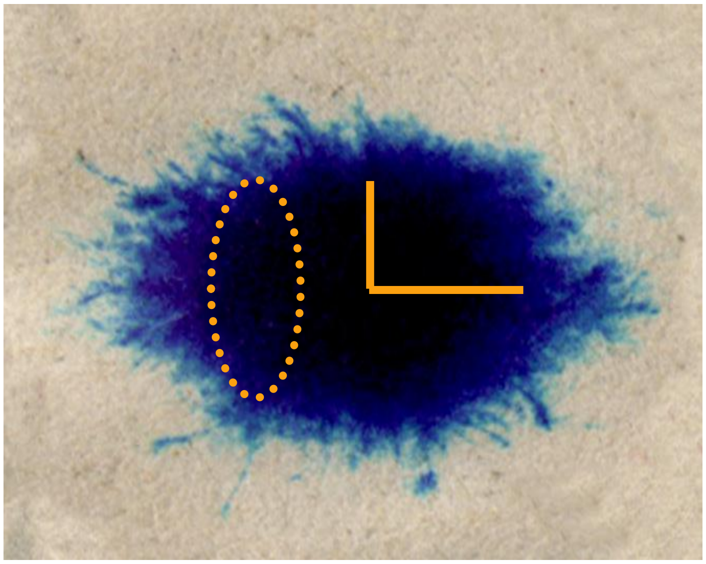
Observed in 1827, by Robert brown.

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.

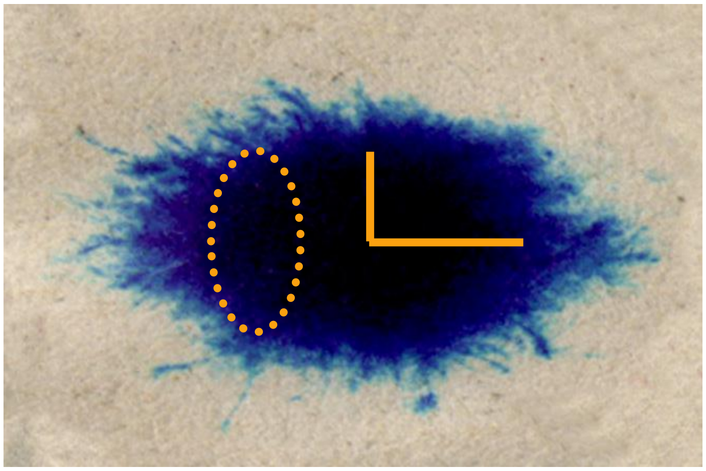
Isotropy and anisotropy

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

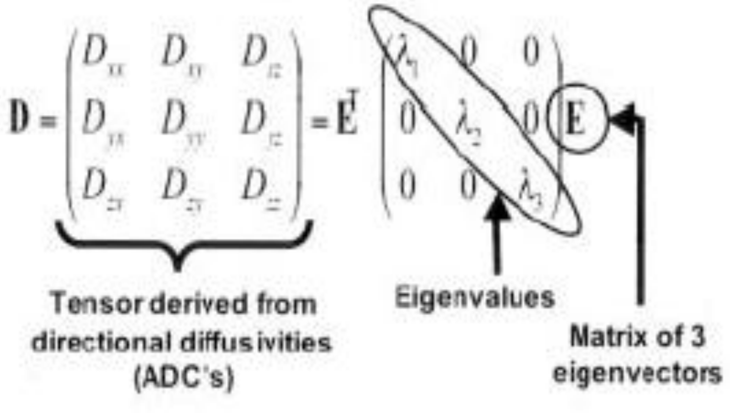
Diffusion-Weighted Imaging

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

b-Value

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

ADC maps

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

FA

- Degree of anisotropy

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

Clinical application

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

SWI / SWAN

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

Phase mask is created from the MR phase images, and multiplying these with the magnitude images increases the conspicuity of the smaller veins and other sources of susceptibility effects, which is depicted using minimal intensity projection (minIP).

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

Imaging acquisition and image processing

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

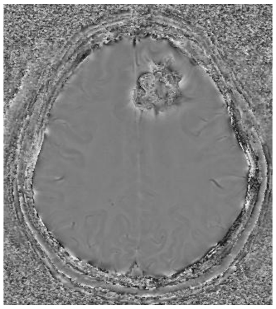
Usefulness of SWI phase imaging

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.

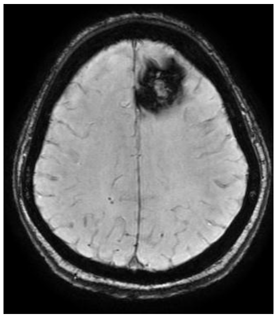
Blood oxygen level-dependent MR Venography / small vessel imaging

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.

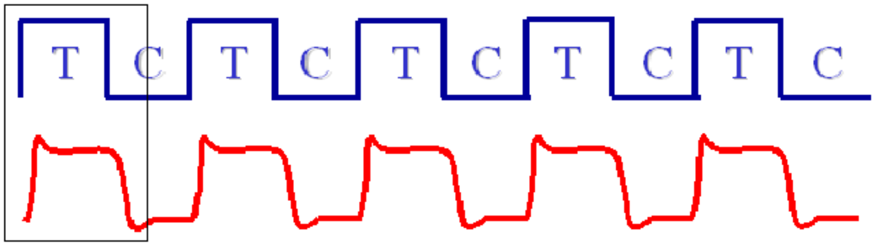
Hence there has been a push for larger field scanners to both improve localization and increase the signal

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

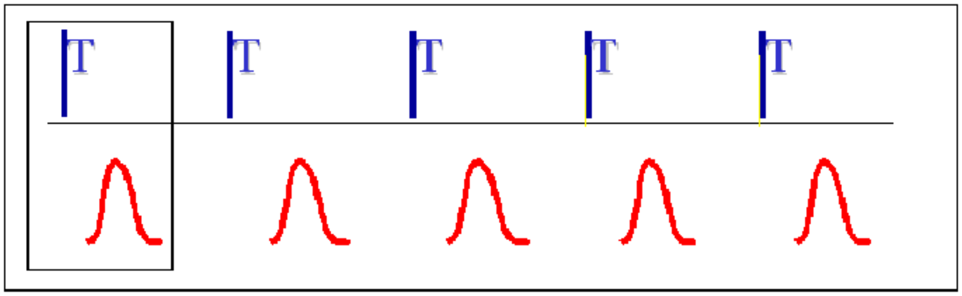
- First used in f MRI and still and the most useful in prevalent neurosurgery.
- It involves subject performs a task, alternated for a similar time with one or multiple control tasks.



Event related f MRI

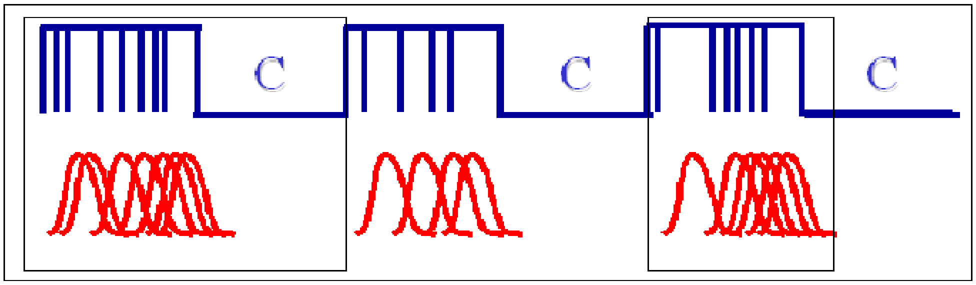
- The individual trials are randomized.

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

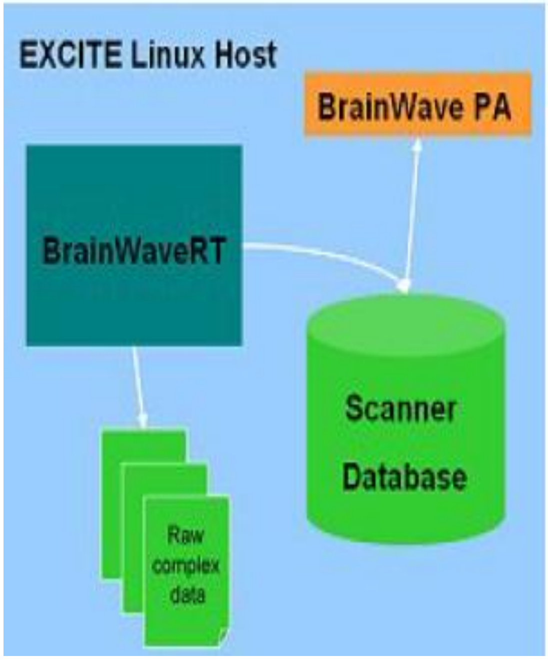
1. Motor paradigms
2. Bilateral finger tapping Vs Rest
3. Lip Pouting vs rest
4. Bilateral leg motor vs Rest
5. Language paradigms
6. Verb generation
7. Word pair
8. Syntax
9. Sematics

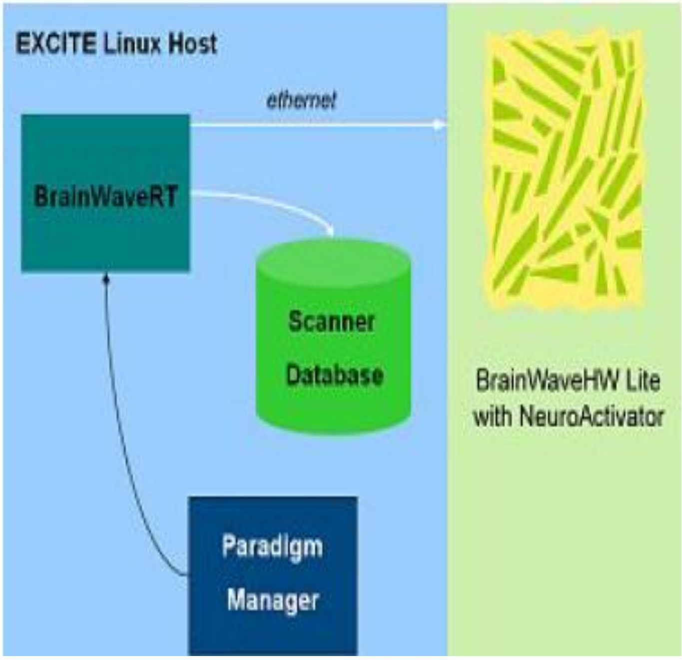
Clinical application

- 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



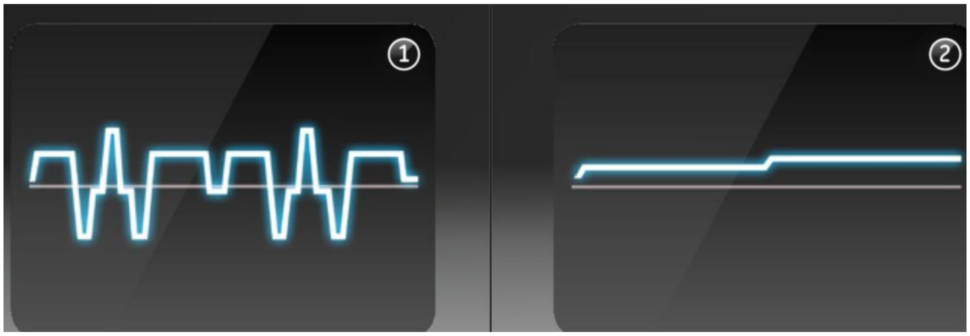


BrainWaveHW Lite comprises equipment used to create custom audio, visual, language and motor paradigms and play them out into the patient environment when used with BrainWaveRT. This equipment consists of a stimulus computer mounted in a rack in the MR equipment room. Paradigm Studio software on the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

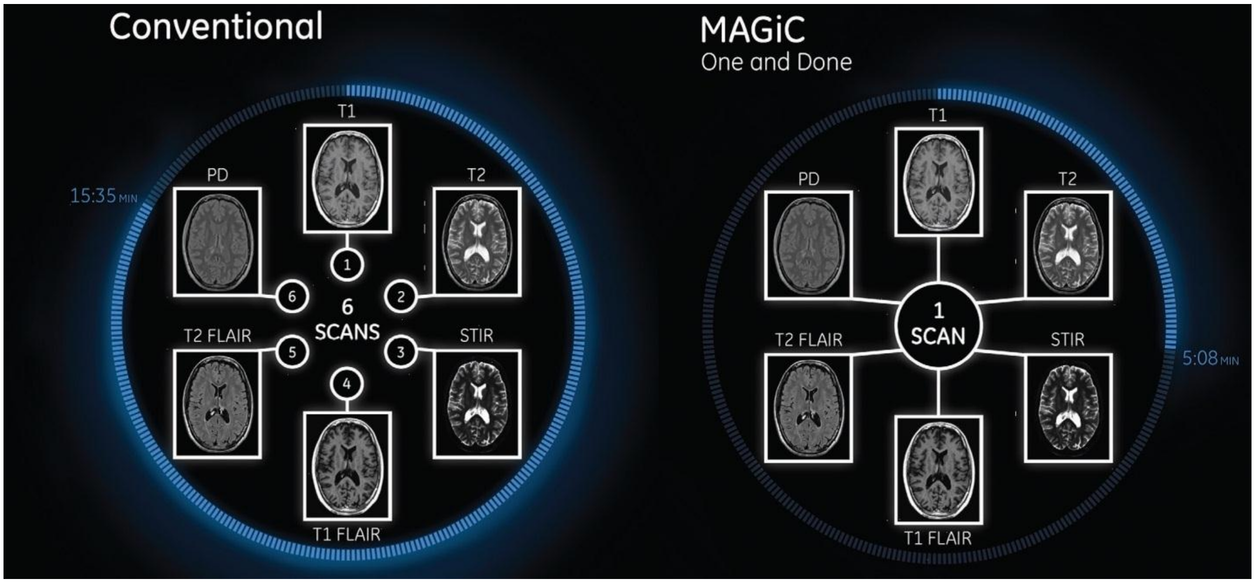


1. High Fidelity Power Electronics Our High Fidelity Power Electronics platform helps maintain the extremely stable gradients and radio frequency (RF) required to avoid generating image artifacts during reconstruction.
2. Ultra-fast RF switching capabilities Since Silent Scan technology avoids switching 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

SYNTHETIC MRI

Synthetic MRI is a quantitative MR imaging method in which a multiple-spin-echo saturation recovery sequence (QMAP sequence) is used with 4 saturation delays and 5 echoes to measure absolute R1 relaxivity (1/T1), R2 relaxivity (1/T2), and proton density (PD) values. Fully automated synthetic MR imaging visualization software loads the raw DICOM data, performs relaxivity curve fitting to the Bloch equations, and calculates whole brain R1, R2, and PD maps used to synthesize MR images with standard contrast. Additionally, the R1, R2, and PD maps are used as input to calculate an intracranial mask that determines the intracranial volume (ICV). A look-up table is used to convert R1, R2, and PD values of each voxel into tissue volume fractions with no atlas, manual tracing, or a priori assumptions of tissue distribution or anatomy.

Whole intracranial volumes of CSF, GM, WM, nonassignable tissues, and myelin (MY) are calculated by summing the partial volume fraction of each voxel within the ICV.The partial volume method accounts for voxels containing multiple tissue types and decreases dependence on the acquired resolution of the dataset.A key advantage of this segmentation method is that unlike voxel intensity in standard MR images, R1, R2, and PD values are inherent physical properties of a given tissue/voxel at a given field strength and are otherwise independent of the acquisition strategy or hardware.



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.

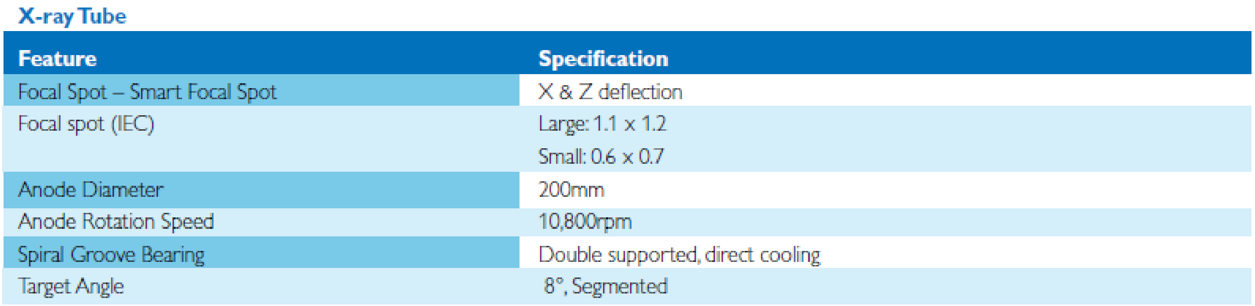
Today, an advanced multislice unit is priced less than a single-slice CT was several years ago. Moreover, with the accelerated exam throughput and a growing repertoire of procedures, many small hospitals have found that a multislice CT can pay for itself in a short time and go on to turn a significant 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.

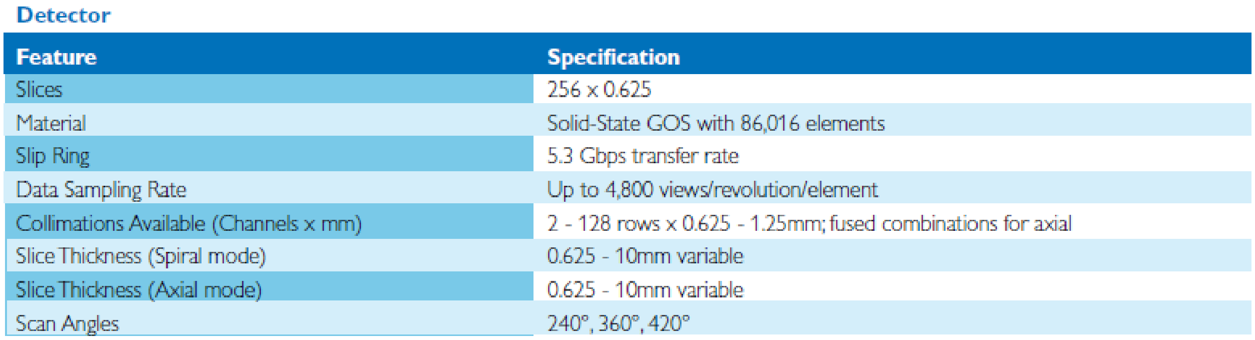
X-ray tube



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

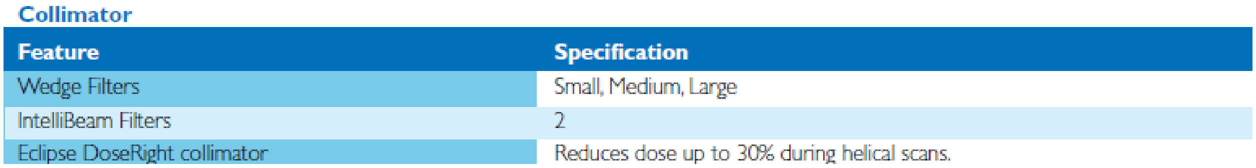
Detectors



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

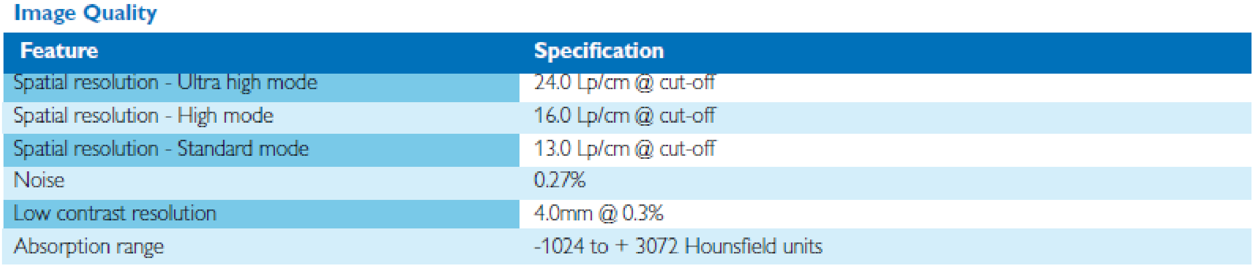


Image Quality

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.

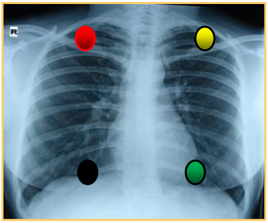
To acquire data over several heart cycles, scanning has to be done in relation to the heart beat. Retrospective ECG gating is therefore useful.

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.



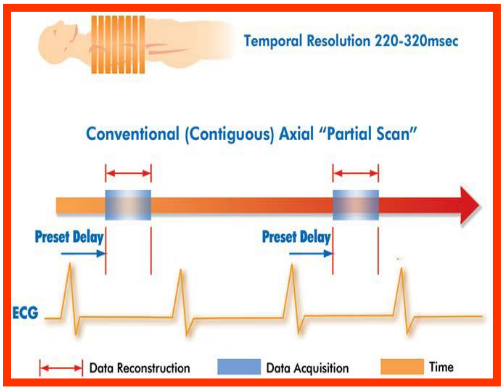
- Red electrode: on the right mid-clavicular line, directly below the clavicle
- Yellow electrode: on the left mid-clavicular line, directly below the clavicle
- Black electrode: right mid-clavicular line, 6 or 7 intercostal space
- Green electrode : on the left mid-clavicular line, 6 or 7 intercostal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

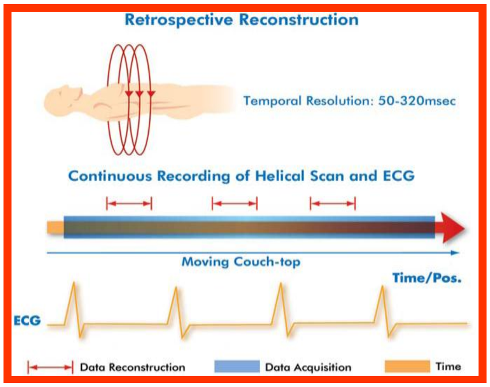
TWO MODES OF ACQUISITION

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.

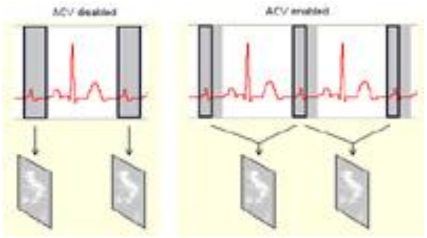
Because the acquisition time spans several heart cycles, the spiral is measured in parallel with the patient`s ECG signals. Acquired volume data is later reconstructed according to these ECG signals (retrospective ECG gating). See the illustration below for a schema of retrospective gated multi-slice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

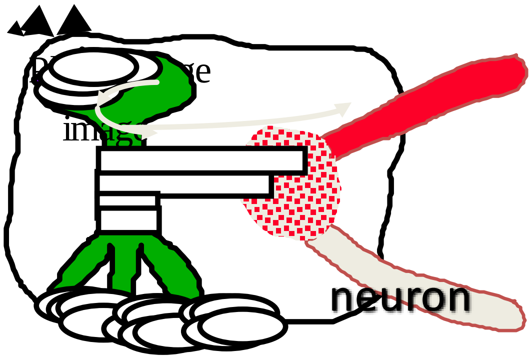


With the collimated slice width used (0.625 mm), images of nominal slice width of 0.625, 1, 2 and 3 mm can be reconstructed. We recommend to use slice widths of 1 mm to increase image quality by reducing artifacts.

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

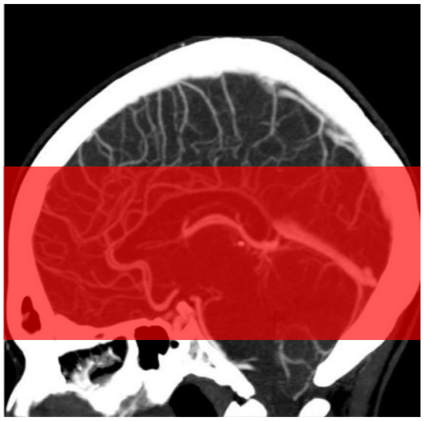
Steps of CT Perfusion Scan

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

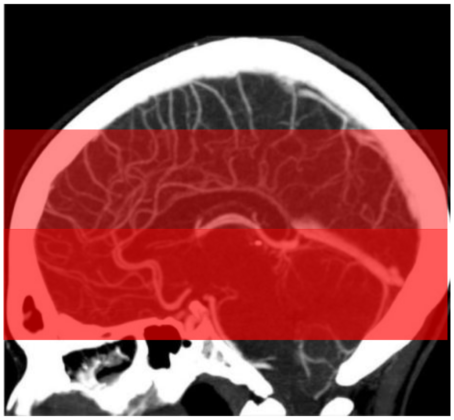
NON JOG SCAN



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



80 mm
+
80mm

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

“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

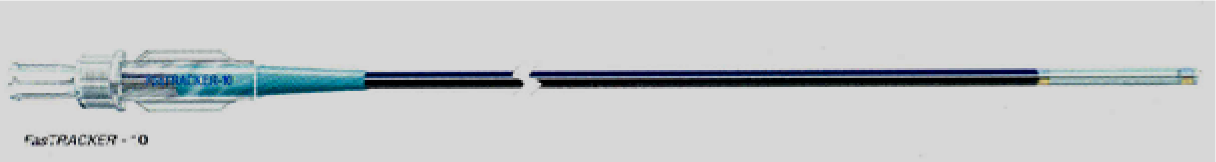
Rotational angiography features	A fast rotational 200 rotation at a 40sec spin speed, using a frame rate of30 FPS provides approximately 150 views in a 5 second acquisition

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.

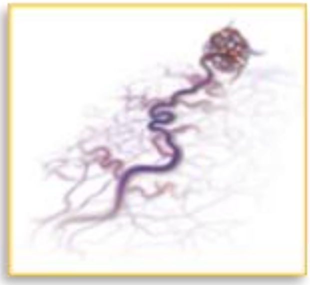
FLOW GUIDED MICROCATHETERS

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



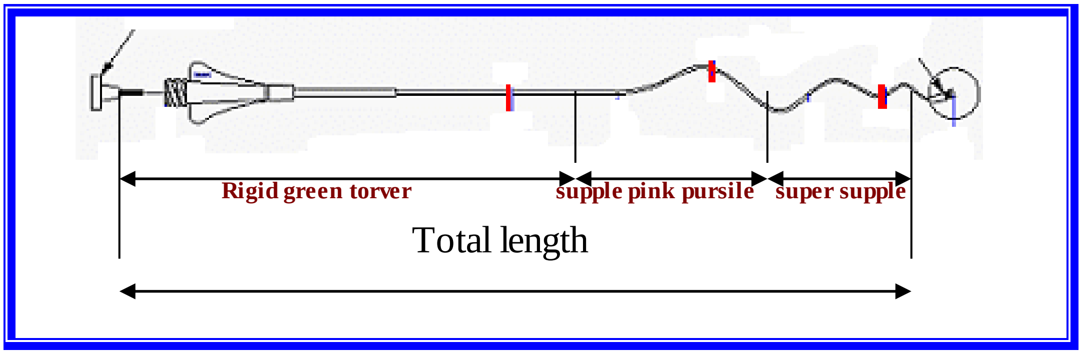
Developed as an Onyx Delivery Catheter, the Marathon offers the user the lowest available tip profile while providing unmatched burst and tensile strength, making it the ideal catheter for the treatment of Brain AVMs.It has proximal pushability due to the stainless steel coil reinforcement in proximal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



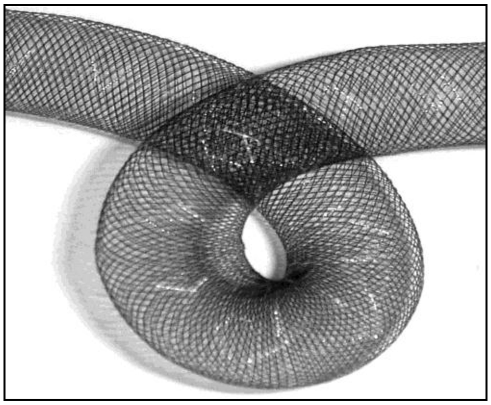
OBLITERATION PROCEDURE

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.

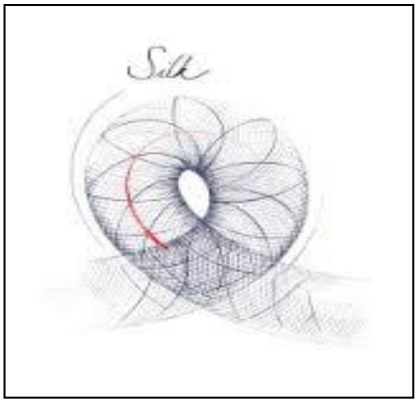
Flow Diverter:

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

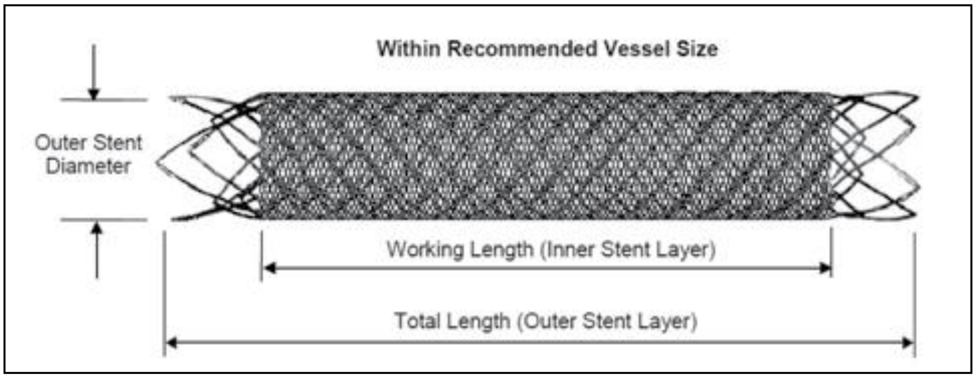
- **Pipeline embolization device** (PED ev3/ Covidien, Irvine, California)
- **Silk flow diverter (**SILK; Balt Extrusion, Montmorency, France)
- **Fred flow diverter(**FRED, Microvention, Terumo,P64)
- **Surpass flow diverter(**SURPASS; Stryker Neurovascular, Fremont)
- **phenox64 (p64)**



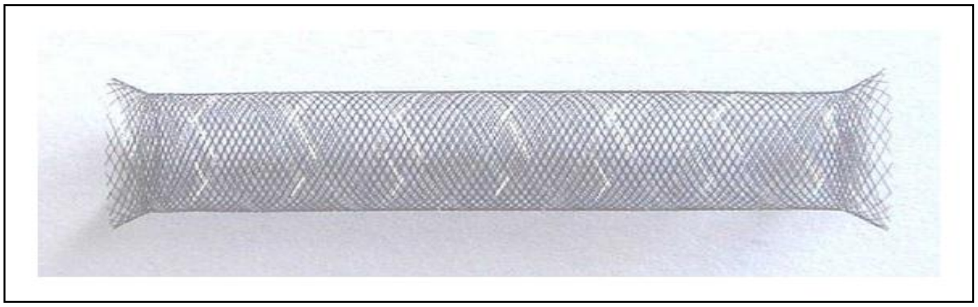
Pipeline flow diverter



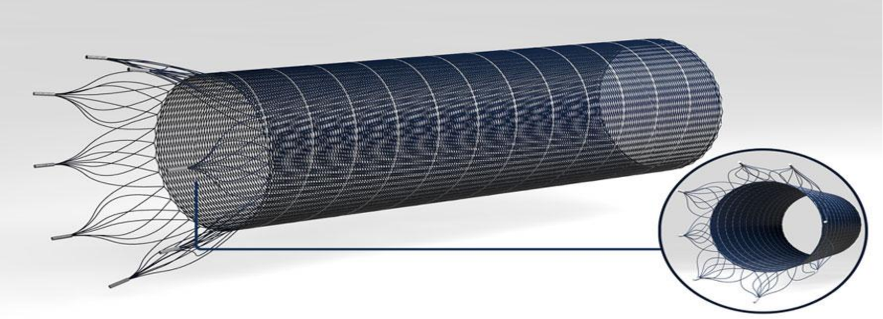
Silk flow diverter



Fred system



Surpass flow diverter

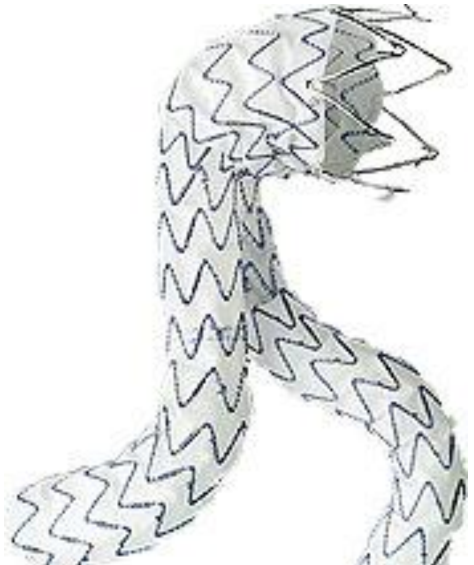


P64 by phenox

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

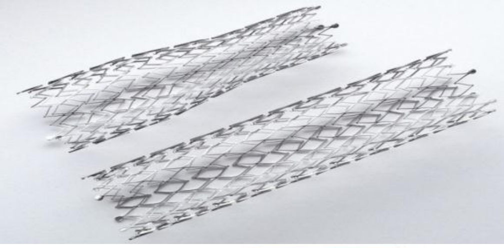
THORACIC COVERED STENT GRAFT

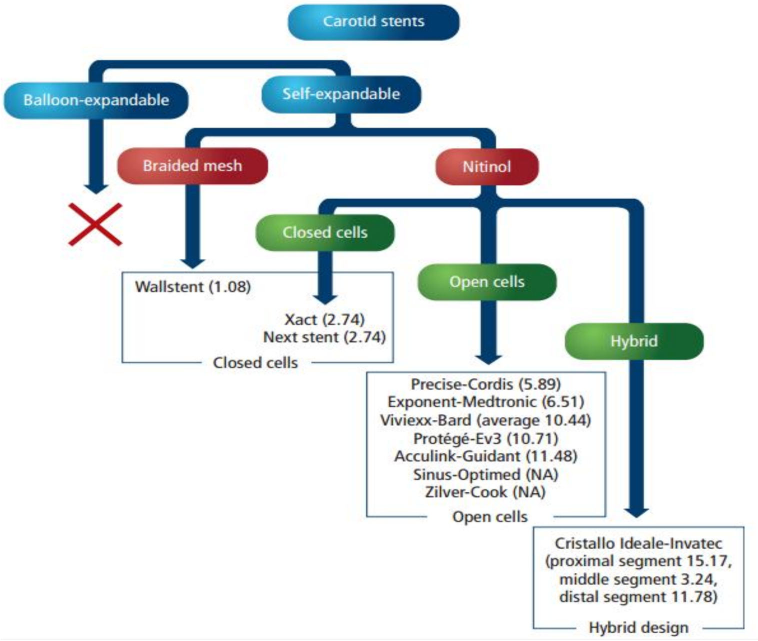


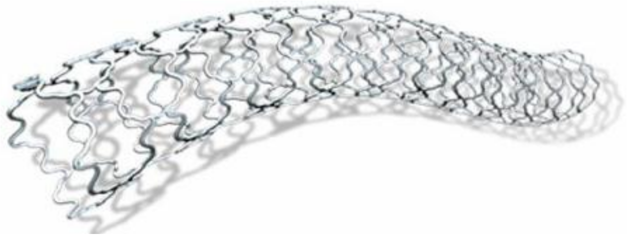
Carotid stent

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 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

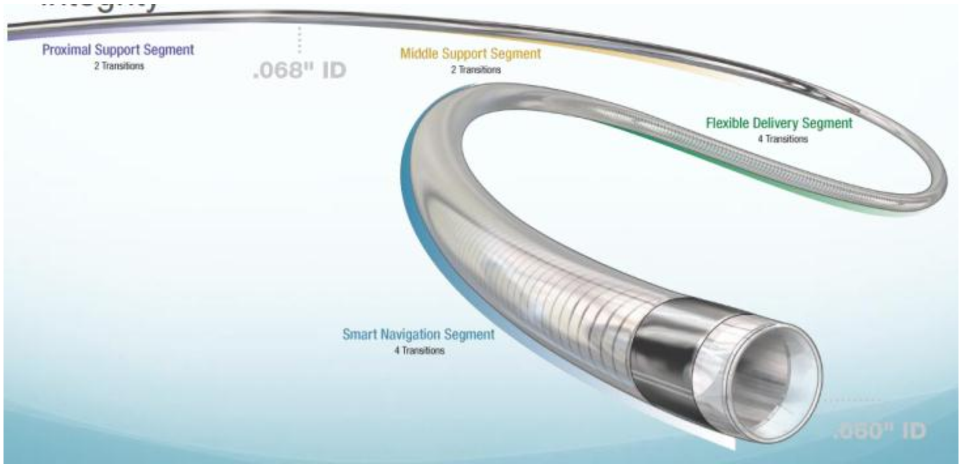
It is a non-adhesive liquid embolic agent comprised of a biocompatible polymer dissolved in dimethyl sulfoxide (DMSO) solvent. An Iodine component is covalently bonded to the polymer to provide homogenous fluoroscopic visualization.

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

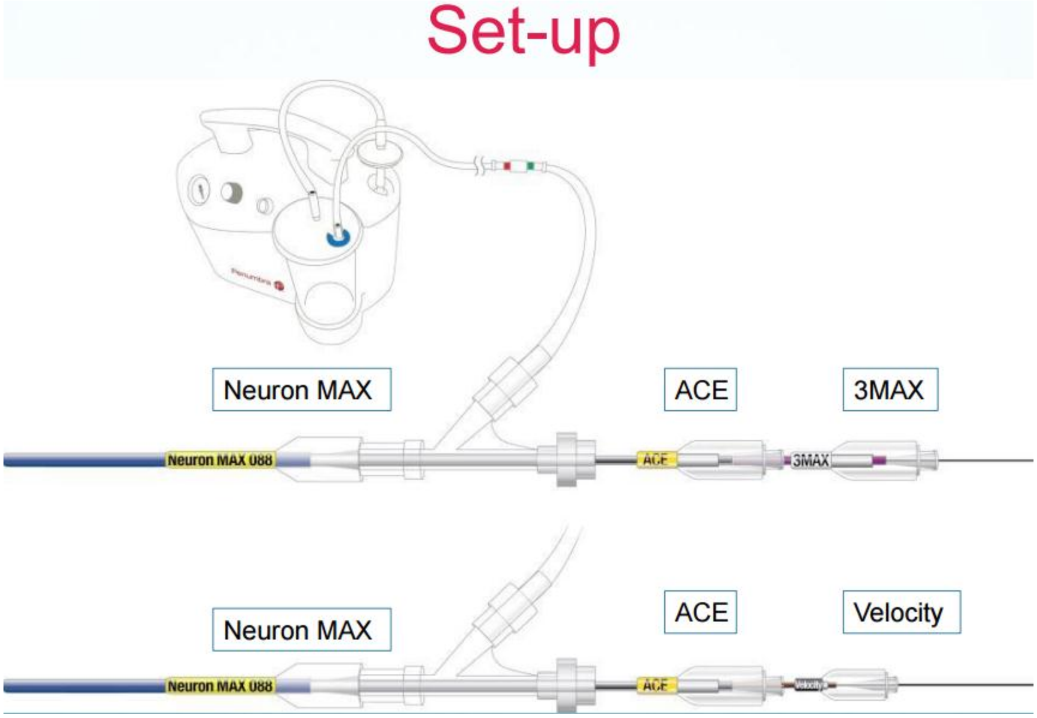
PENUMBRA–ACE

- 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

UTILITY OF MULTI - DELAY ASL IN NEUROVASCULAR DISEASES

SUBMITTED IN FULLFILLMENT OF THE COURSE OF

(DAMIT)

DIPLOMA IN ADVANCED MEDICAL IMAGING TECHNOLOGY

PERIOD: JAN 2016-DEC 2017

ALBIN V KURIAKOSE

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1. AIM
2. SCIENCE & REVIEW OF LITERATURE
3. MATERIALS AND METHODS
4. RESULT AND OBSERVATION
5. DISCUSSION
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AIM OF THE STUDY

To study the feasibility of Multi delay ASL in neurovascular diseases such as ICA Stenosis/occlusion, stroke, vasospasm, Moya Moya, Dural Arteriovenous Fistula , Arteriovenous Malformtion etc

SCIENCE AND LITERATURE

ARTERIAL SPIN LABELLING (ASL)

Arterial spin labeling (ASL) is an alternative approach to measuring blood flow with MRI that does not require the injection of a contrast agent. ASL can be thought of as a natural extension of magnetic resonance angiography (MRA). In MRA, spatially selective excitation pulses or flow encoding gradient pulses are used to create a difference between the signal in flowing blood and the signal in the surrounding tissue. Imaging is performed during or very quickly after the selective pulses are applied so the flowing blood signal is still within the vessels. ASL methods are quite similar except that after the pulses which differentiate between static tissue and flowing blood, time is allowed for the blood to move out of the vessels and into the perfused tissue. The signal change in tissue caused by the selective labeling of the arterial blood is closely related to the blood flow into that tissue.

ASL uses a slab selective inversion prior to imaging to label the blood in the arteries within that slab. Time is allowed after the inversion for the labeled arterial blood to enter the imaged slice. Since the signal from inverted magnetization is negative, the inflowing labeled blood decreases the signal in the slice. Because the decrease is very small, the image must be subtracted from another image without the inversion pulse. The difference between the control image and the labeled image reflects blood flow into the slice.

Types of ASL

- Pulsed ASL
- Continuous ASL
- Pseudo continuous ASL
- Velocity selective ASL

PULSED ASL

Single perturbing RF pulse applied for 2-5ms to invert a thick slab of spins in the tagging plane.

CONTINUOUS ASL

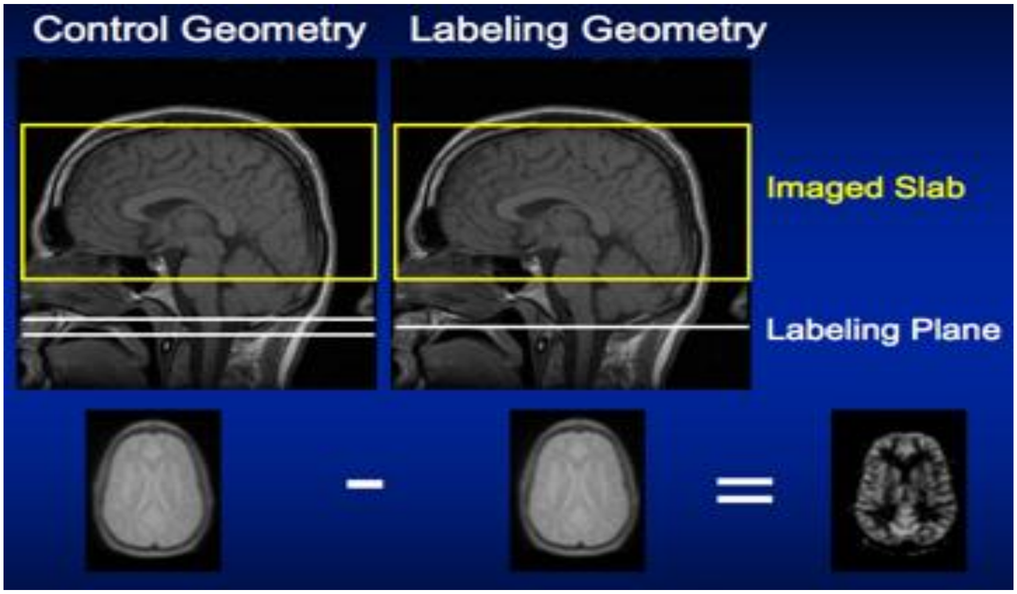
CASL uses long and continuous RF pulses (1-2seconds) along with a gradient field to induce a flow-driven adiabatic inversion in a narrow plane of spins, usually just below the imaging plane.

PSEUDO CONTINUOUS ASL

Introduce to match the inversion efficiency of CASL with decreased transmission
pCASL uses train of discrete RF pulses in conjuction with synchronous
gradient field to mimic a flow-driven adiabatic inversion

VELOCITY SELECTIVE ASL

Saturates the blood that is fast moving than the specific cut-off value.Measurement of CBF under slow and collateral flow like stroke. Difficulties in determining cut-off velocity.



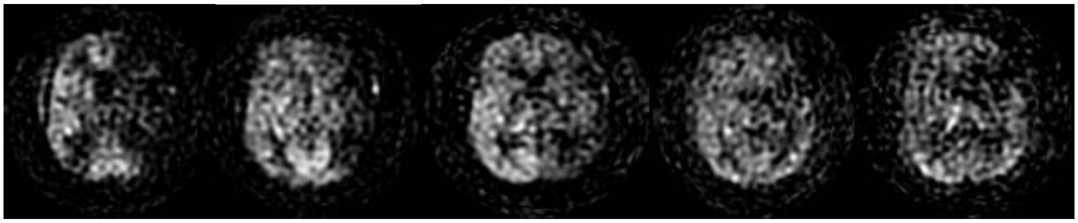
However, a disadvantage of ASL-MRI is that in patients with cerebrovascular disease, the quantification of CBF is hampered by the recruitment of additional blood flow through collateral pathways leads to a delayed arrival of the labeled blood bolus to the brain .As most ASL-MRI techniques acquire the labeled images at a fixed time after the initial labeling of arterial blood, it is possible that the magnetic label may not have reached the imaging plane, leading to underestimation of CBF.

ASL-MRI with acquisition of a series of images at increasing delay times after the initial labeling has been introduced as a method to compensate for such blood transit delays.

Multi Delay ASL

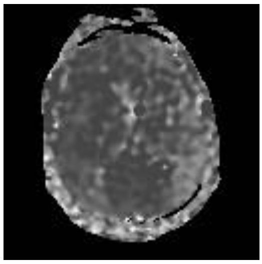
Existing ASL studies having only a single post-labeling delay (PLD) between 1.2 s and 3.2 s for the estimation of CBF.

Prolonged ATT greater than the PLD may result in intravascular labeled signals as well as underestimation of perfusion in brain tissue,so it is ideal to acquire serial ASL images at multiple PLDs, so that both ATT and CBF can be estimated simultaneously

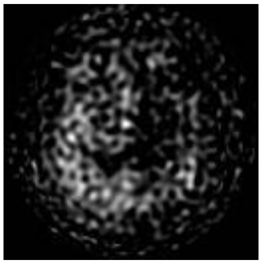


RAW MULTI-DELAY ASL-

WD



AVERAGE



TRANSIT DELAY (ATT)

TRANSIT DELAY

aCBV

WD - Weighted Delay

aCBV -Absolute arterial cerebral blood volume

REVIEW OF LITERATURE

Arterial spin labeling (ASL) techniques are MR imaging methods designed to highlight the signal coming from arterial blood by manipulation of its magnetization. These techniques have been used mostly for measuring perfusion , although historically, they were developed as MR angiography methods. All of these methods are based on the subtraction of two consecutively acquired images. The first image usually is acquired after saturation or inversion of the arterial blood magnetization upstream to the area of interest. The second image is acquired without any manipulation of the arterial magnetization, and the subtraction of both images provides information related to the amount of labeled arterial magnetization**(9)** A tagging plane for PCASL is typically located below the circle of Willis, and tagging RF pulses invert flowing arterial spins in the internal carotid arteries and the vertebral arteries(10)

Arterial spin labeling (ASL) offers a non-invasive method for quantifying cerebral blood flow (CBF) by using magnetically labelled arterial blood water as an endogenous tracer. Owing to its completely non-invasive nature, perfusion measurement using ASL has been increasingly applied to imaging studies on neurologic and psychiatric diseases. The ASL perfusion technique offers information similar to that provided by conventional dynamic susceptibility sequences, but it does not require the use of an intravenous contrast agent, and the data can be quantified. The appearance of pathology is affected significantly by the ASL techniques used. Familiarity with the available sequence parameter options and the common appearances of pathology facilitates perfusion interpretation.**(8)**

However, clinical evaluation studies have demonstrated the challenges of optimizing ASL acquisitions for subjects across a wide range of vascular and perfusion characteristics.The main limitation of ASL is that the time delay between labeling in the feeding arteries and the arrival of labelled blood in tissue (i.e. arterial transit time or ATT) can have a large effect on the ASL signal**.(1)**

In moyamoya diseases, ATT is generally prolonged leading to focal intravascular signals, as well as underestimation of tissue perfusion a phenomenon termed arterial transit effects .
By incorporating delayed ATT in the calculation of CBF, multi delay ASL is able to improve CBF quantification that is consistent with CT perfusion in moyamoya disease. ASL as part of standard neuroimaging protocols in the management of moya moya disease**.(1)** Arterial transit times correction by multidelay acquisitions led to improved consistency with PET, but still underestimated CBF in the presence of long transit delays . Long-label long-delay ASL scans showed the strongest correlation relative to PET, and there was no difference in mean relative CBF between the modalities, even in areas of severe delays.(5)

Patients with ischemic stroke or transient ischemic attacks and an occlusion of the internal carotid artery.CBF values obtained with ASL-MRI at multiple delay times correlated significantly with $H2^{15}O$ PET, although there was a systematic overestimation of CBF by ASL-MRI. This overestimation shows that for quantitative use, ASL perfusion images should be interpreted with caution(2)

ASL is largely consistent with DSC for detecting delineating hypoperfused brain regions, although ASL may miss small lesions and may overestimate perfusion/diffusion mismatch due to prolonged arterial transit time (ATT) in stroke. Among the multiple hemodynamic parameters generated by DSC PWI, ASL estimate of cerebral blood flow (CBF) was found to best match temporal parameters of a contrast bolus such as the mean transit time (MTT) and time to the maximum of tissue residual function (Tmax). **(3)**

Existing ASL studies on stroke generally employed a single postlabeling delay (PLD) time typically between 1.5 and 2 s for the estimation of CBF. Consequently, prolonged ATT greater than the PLD may result in intravascular labeled signals as well as underestimation of perfusion in brain tissue. It would be ideal to acquire serial ASL images at multiple PLDs so that both ATT and CBF can be estimated simultaneously .Such a multi-delay ASL approach has several potential advantages over existing single delay ASL scans (3) including improved accuracy of CBF quantification, imaging of multiple hemodynamic parameters (ATT, CBF and arterial cerebral blood volume or aCBV).

There were highly significant correlations between pCASL and DSC CBF measurements and moderately significant correlations between pCASL and DSC CBV measurements. ASL ATT showed correlations with DSC Tmax and MTT. (3) The technique has been employed successfully in cerebrovascular diseases, such as acute ischemic stroke and moyamoya disease , which demonstrates significant correlations between multi-delay ASL and dynamic susceptibility contrast (DSC) as well as computed tomography (CT) perfusion CBF measurements.(6)

Quantitative measurement of CBF by ASL depends on a number of parameters including T1 of brain tissue, T1 of arterial blood and arterial transit time (ATT), which denotes the duration for the labeled blood to travel from the labeling region to the imaged tissue. Transit time considerations are crucial in measuring absolute CBF by ASL, especially in patients with occlusive cerebrovascular disease, where heterogeneously prolonged ATTs due to the drop in perfusion pressure and consequent development of collateral pathways result in inaccurate measurements of regional CBF .To compensate for such delays in blood transit, ASL methods using multiple post-label delay acquisitions have been developed and introduced (4)

CBF measurements using pCASL with multiple post-label delay acquisitions were correlated well with quantitative CBF values derived from 15O-H2O PET in patients with chronic occlusive cerebrovascular disease. Second, arterial transit times (ATTs) in affected sides were significantly longer than those in contralateral sides. Recent evidence indicates that perfusion and territorial perfusion imaging of the brain feeding arteries with ASL can help to assess the extent of hemodynamic compromise and to customize medicinal and surgical treatment, both in patients with acute and with chronic cerebrovascular disease.(7)

Arterial transit times correction by multidelay acquisitions led to improved consistency with PET, but still underestimated CBF in the presence of long transit delays . Long-label long-delay ASL scans showed the strongest correlation relative to PET, and there was no difference in mean relative CBF between the modalities, even in areas of severe delays. (4)

MATERIALS AND METHOD

Multidelay ASL was conducted with a 24 channel head coil on GE scanner. EASL With 7 delay acquisitions were obtained from twenty neurovascular disease patients,The data were acquired with a 3T GE MR750 scanner at the Sree Chitra Tirunal Institute of Medical Sciences & Technology Trivandrum Kerala,

7 DELAYS

- This protocol encodes 7 different post label delay times into a single acquisition.
- With parameters tabulated below, images with post label delay times of [1.00, 1.22, 1.48, 1.78, 2.15, 2.63, 3.32] seconds and effective label durations of [0.22, 0.26, 0.30, 0.37, 0.48, 0.68, 1.18]seconds will be reconstructed.
- These post label delay times are intended to probe bolus arrival time**.**

Patient position	Supine , head first
Plane Name	Axial
NEX	1
Bandwidth	62.5
Fov	22
Slice Thickness	4
Locs per slab	32
Series Description	7 Delays
Scan time	3.48 min

Data Processing

After processing, we can get various maps such as:-

1. Raw PW images
2. CBF map (ml/100g/min)
3. Transit delay corrected CBF map (ml/100g/min)
4. Transit delay map (ms)

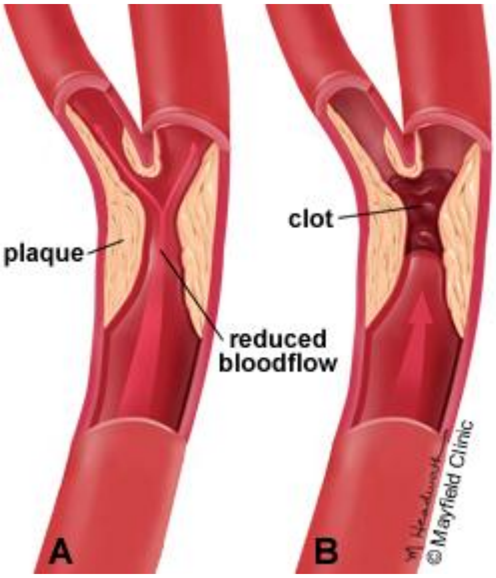
Loading of grey scale PW images , Transit delay corrected CBF map in READYVIEW Tool of multi-modality work station "Advantage Window v4.6" provided by GE Health care will provide corresponding colour maps .Quantification of Data also can be done in Advantage workstation.

RESULT AND OBSERVATION

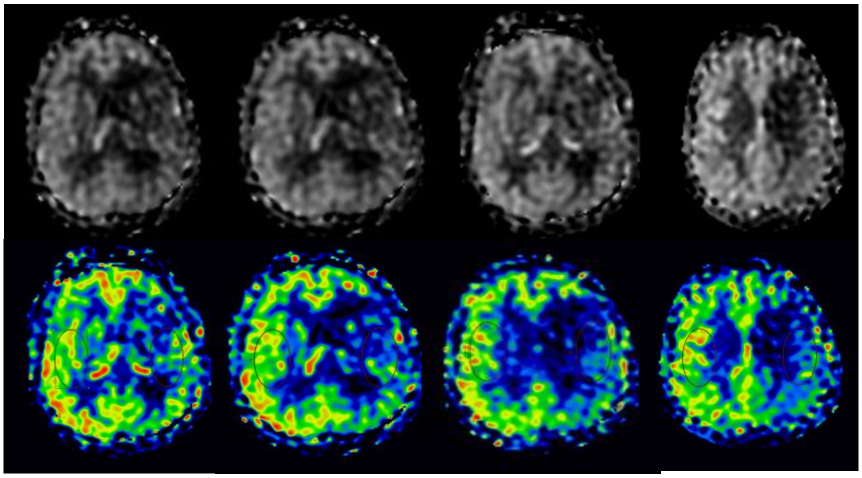
ICA STENOSIS/OCCLUSION WITH RECURRENT TIA

Carotid stenosis is a narrowing of the carotid arteries, the two major arteries that carry oxygen-rich blood from the heart to the brain. Also called carotid artery disease, carotid stenosis is caused by a buildup of plaque (atherosclerosis) inside the artery wall that reduces blood flow to the brain.

The plaque can be stable and asymptomatic, or it can be a source of embolization. Emboli break off from the plaque and travel through the circulation to blood vessels in the brain. As the vessel gets smaller, they can lodge in the vessel wall and restrict blood flow to parts of the brain which that vessel supplies. This ischemia can either be temporary, yielding a transient ischemic attack, or permanent resulting in a thromboembolic stroke.



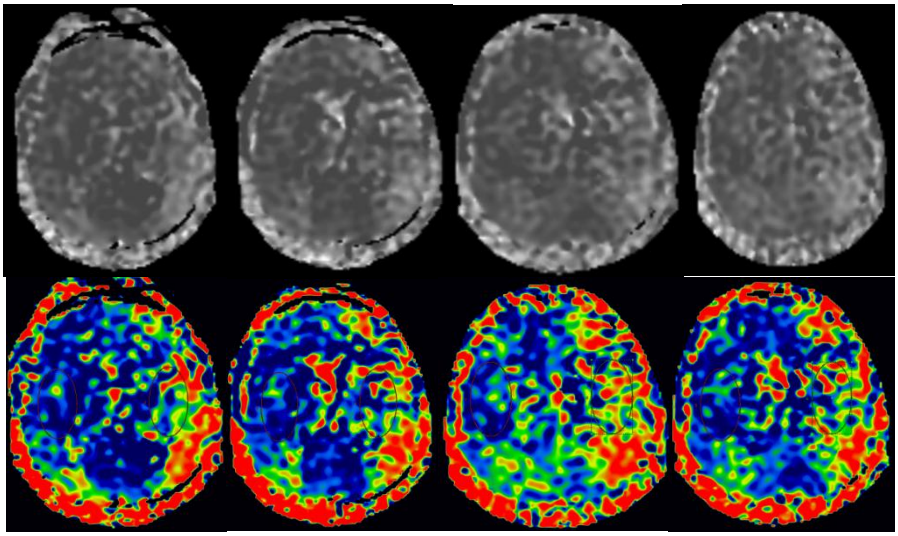
TRANSIT DELAY CORRECTED CBF



ROI 1 2 3,4 5,6 7,8

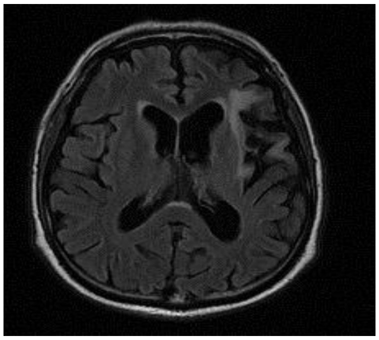
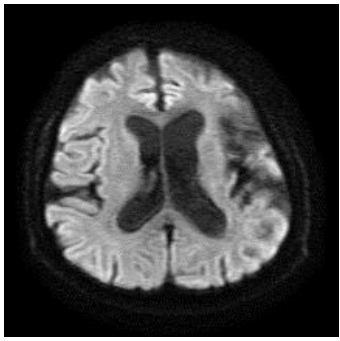
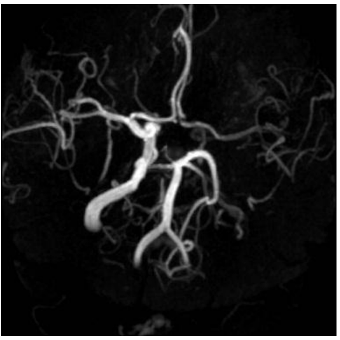
Finding 1	ROI 1 Ave : 61.9 ROI 2 Ave : 45.0
Finding 2	ROI 3 Ave : 62.4 ROI 4 Ave : 41.5
Finding 3	ROI 5 Ave : 59.2 ROI 6 Ave : 37.6
Finding 4	ROI 7 Ave : 60.6 ROI 8 Ave : 38.5

ATT



ROI 1 2 3,4 5,6 7,8

Finding 1	ROI 1 Ave :1135.2 ROI 2 Ave :1383.8
Finding 2	ROI 3 Ave :1142.4 ROI 4 Ave :1374.0
Finding 3	ROI 5 Ave :1165.9 ROI 6 Ave :1447.5
Finding 4	ROI 7 Ave :1192.6 ROI 8 Ave :1538.4

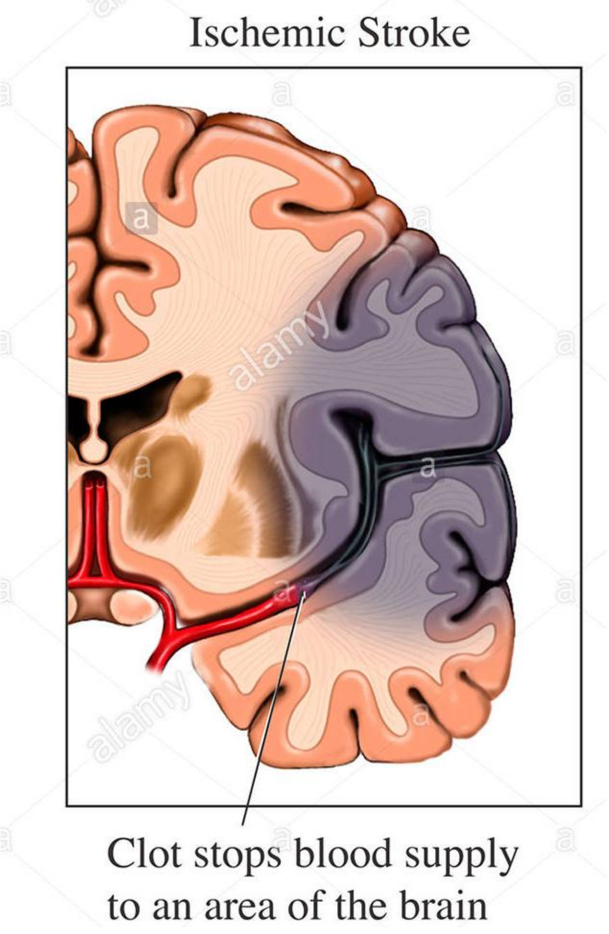
T2 FLAIR DIFUSSION 3D TOF

Case of Left MCA stroke in 2013. Now with recurrent left hemispheric TIAs.

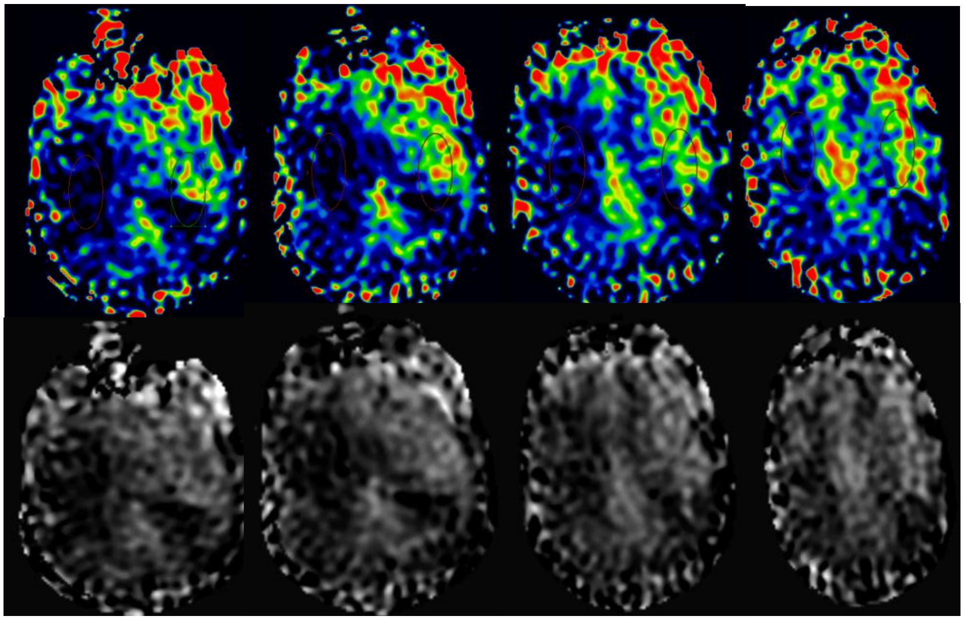
Transit Delay Corrected CBF maps shows reduction of CBF & Arterial Transit Time maps shows correspondingly increased arterial Transit time in the left MCA region. Due to this patient is having recurrent left hemispheric Transient Ischemic Attacks.

STROKE

Ischemic stroke is characterized by the sudden loss of blood circulation to an area of the brain, resulting in a corresponding loss of neurologic function. Acute ischemic stroke is caused by thrombotic or embolic occlusion of a cerebral artery occurs when a blood clot blocks an artery that carries blood to the brain. Deprived of oxygen, brain cells die at a rate of two million cells per minute, increasing the risk of permanent brain damage, disability or death



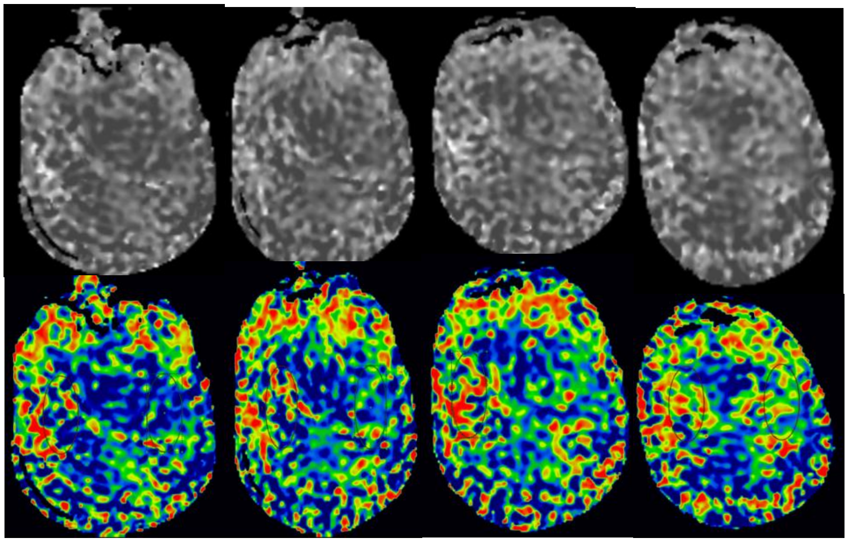
TD CORRECTED CBF



ROI 1 2 3,4 5,6 7,8

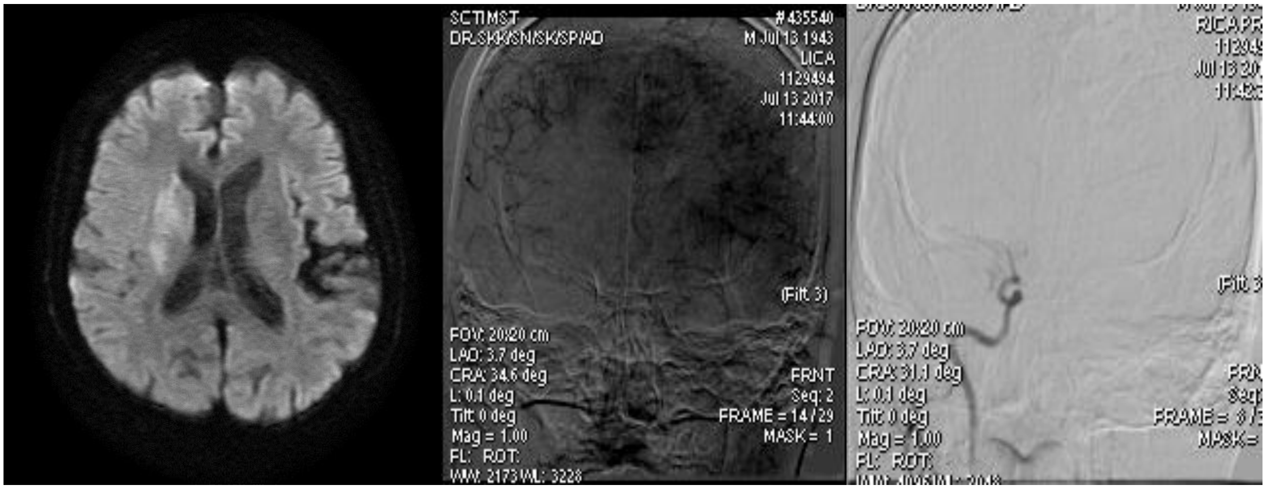
Finding 1	ROI 1 Ave : 5 ROI 2 Ave : 26.7
Finding 2	ROI 3 Ave : 6.7 ROI 4 Ave : 32.8
Finding 3	ROI 5 Ave : 9.2 ROI 6 Ave : 29.4
Finding 4	ROI 7 Ave : 14.1 ROI 8 Ave : 35.9

ATT



ROI 1 2 3,4 5,6 7,8

Finding 1	ROI 1 Ave :1531.0 ROI 2 Ave :1377.1
Finding 2	ROI 3 Ave :1624.1 ROI 4 Ave :1507.9
Finding 3	ROI 5 Ave :1892.1 ROI 6 Ave :1621.7
Finding 4	ROI 7 Ave :1747.8 ROI 8 Ave : 1693.0



DIFFUSION DSA

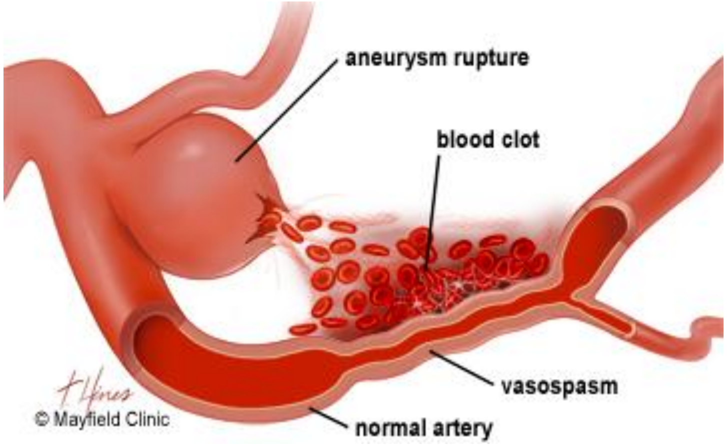
CASE OF RT MCA STROKE WITH M1 OCCLUSION

Decreased CBF and increased ATT can calculate easily at affected region by depicting ROI in corresponding maps
The CORE area can seen in DIFFUSION or CBV maps and PENUMBRA can see from ATT or CBF maps. With this Perfusion/diffusion mismatch can calculate easily .
The multidelay pCASL protocol also offered the capability for the evaluation of collateral flow through dynamic perfusion image series.

VASOSPASM

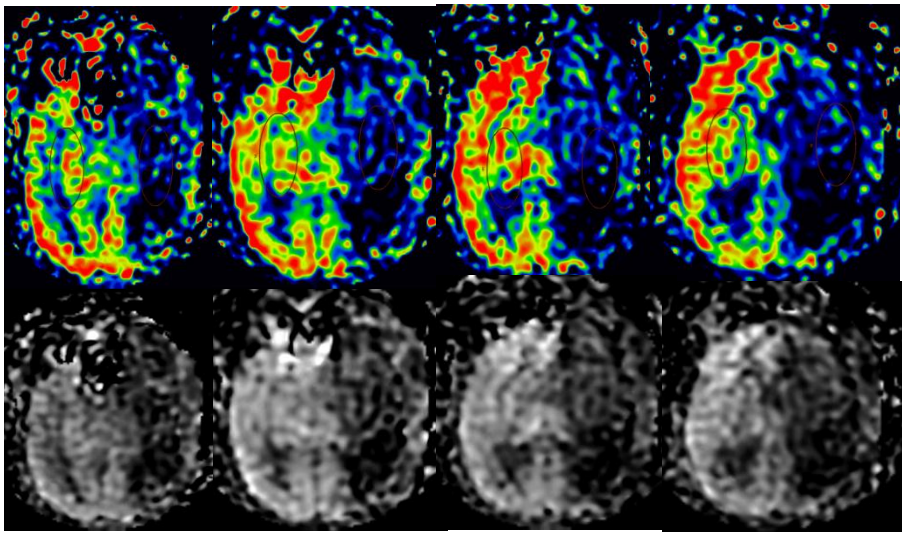
A vasospasm is the narrowing of the arteries caused by a persistent contraction of the blood vessels, which is known as vasoconstriction. This narrowing can reduce blood flow.When the vasospasm occurs in the brain, it is often due to a subarachnoid hemorrhage after a cerebral aneurysm has ruptured.

Cerebral vasospasm leading to delayed cerebral ischemia (DCI) continues to be a major complication and source of morbidity in cases of a SAH.



When red blood cells break down, toxins can cause the walls of arteries nearby to contract and spasm. The larger the SAH, the higher the risk of vasospasm

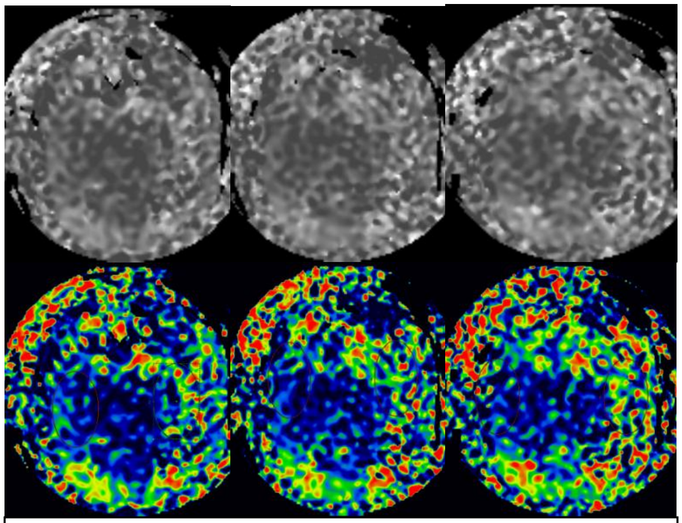
TD corrected CBF



ROI 1 2 3,4 5,6 7,8

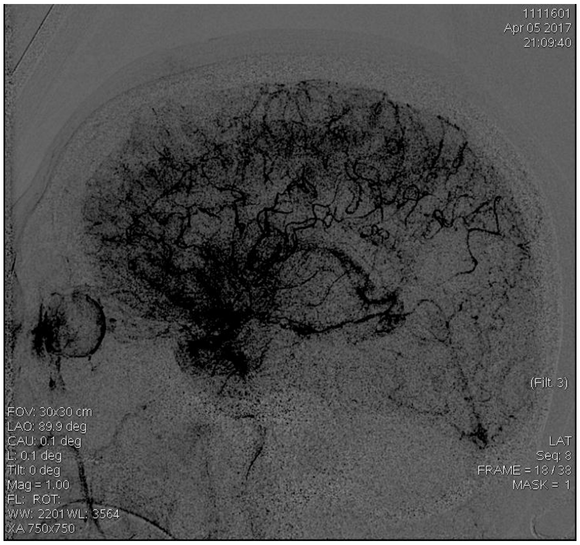
Finding 1	ROI 1 Ave : 40.0 ROI 2 Ave : 14.0
Finding 2	ROI 3 Ave : 44.2 ROI 4 Ave : 15.4
Finding 3	ROI 5 Ave : 43.6 ROI 6 Ave : 13.1
Finding 4	ROI 7 Ave : 45.7 ROI 8 Ave : 15.7

ATT



ROI 1 2 3,4 5,6

Finding 1	ROI 1 Ave :1333.2 ROI 2 Ave :1625.9
Finding 2	ROI 3 Ave :1332.5 ROI 4 Ave :1626.7
Finding 3	ROI 5 Ave :1367.6
	ROI 6 Ave : 1710.8



DSA

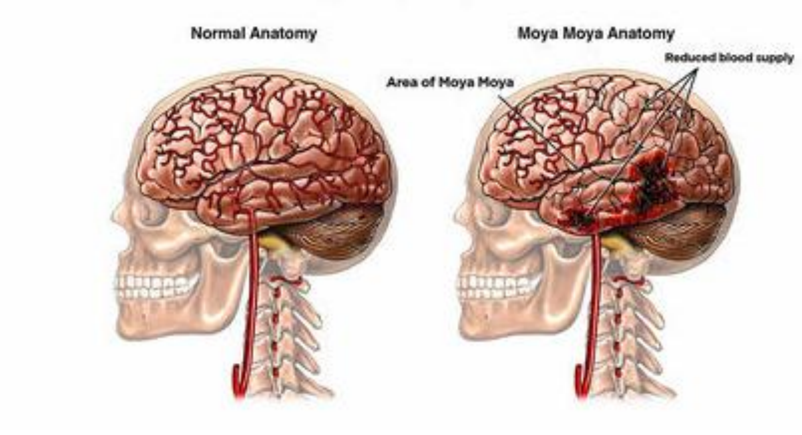
Case of operated Acom aneurysm followed by vasospasm. TD corrected CBF maps shows reduced CBF values in left hemisphere with corresponding DSA image showing hypoperfusion. ATT maps shows increased transit time values. EASL helps to locate the areas which are affected.

MOYA MOYA

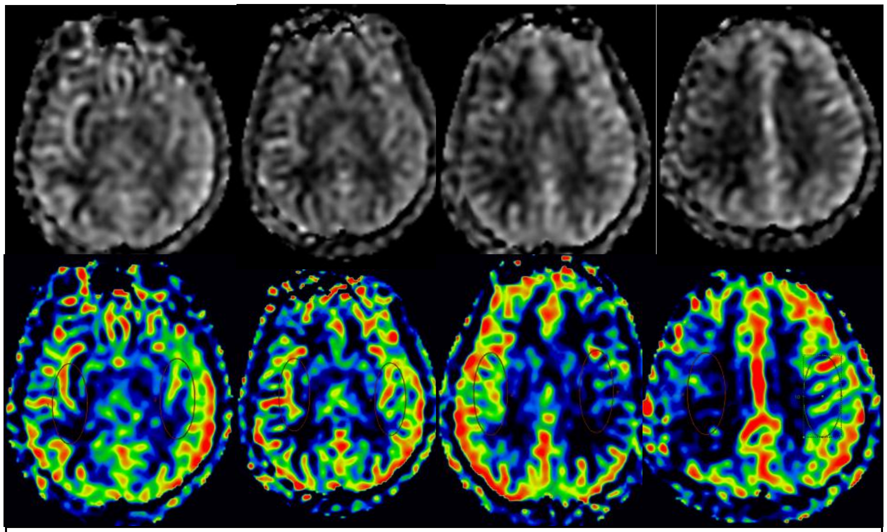
Moyamoya disease is a chronic and progressive narrowing of the internal carotid arteries at the base of the brain where they divide into middle and anterior cerebral arteries. The walls of the arteries become thickened, which narrows the inside diameter of the vessel. The narrowing can eventually result in complete blockage and stroke.

To compensate for the narrowing arteries, the brain creates collateral blood vessels in an attempt to deliver oxygen-rich blood to deprived areas of the brain. These tiny collateral vessels, when seen on an angiogram, have a hazy, filmy appearance. The Japanese were the first to describe the condition, and they named it "moyamoya," the Japanese term for "puff of smoke."

More fragile than normal blood vessels, the tiny moyamoya collaterals can break and bleed into the brain, causing hemorrhages. Moyamoya usually affects both sides of the brain and is often accompanied by aneurysms.



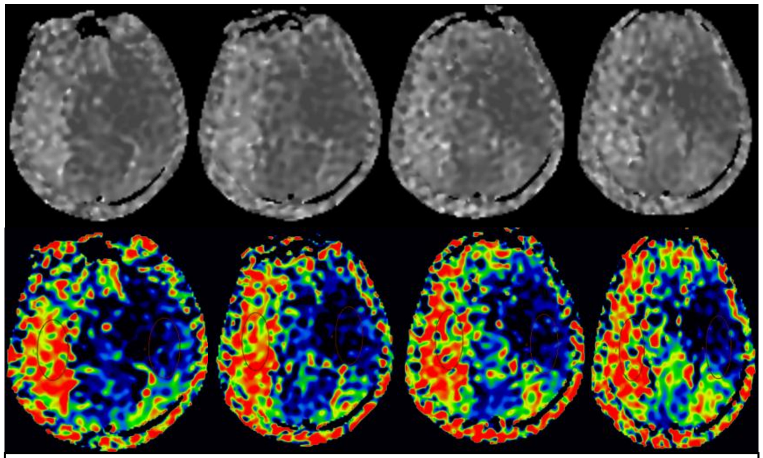
TD CORRECTD CBF



ROI 1 2 3,4 5,6 7,8

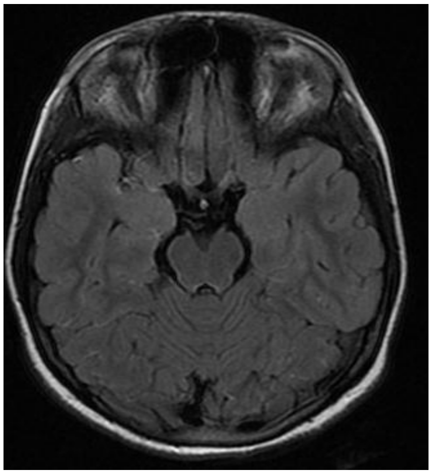
Finding 1	ROI 1 Ave :37 ROI 2 Ave : 46.5
Finding 2	ROI 3 Ave : 43.0 ROI 4 Ave : 54.5
Finding 3	ROI 5 Ave : 30.3 ROI 6 Ave : 57.7
Finding 4	ROI 7 Ave : 22.8 ROI 8 Ave : 45.0

ATT

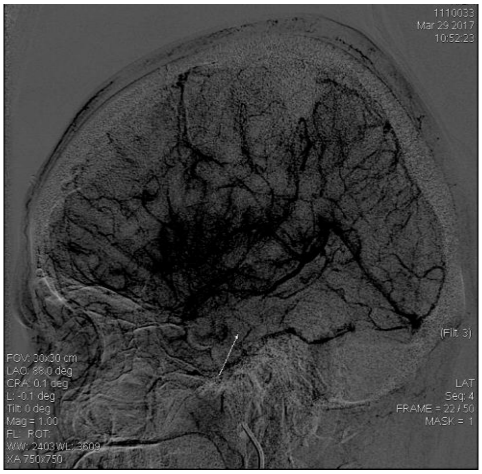


ROI 1 2 3,4 5,6 7,8

Finding 1	ROI 1 Ave :1919 ROI 2 Ave :1197
Finding 2	ROI 3 Ave : 1902 ROI 4 Ave : 1847
Finding 3	ROI 5 Ave : 1847 ROI 6 Ave : 1189
Finding 4	ROI 7 Ave : 1869 ROI 8 Ave : 1216



T2 FLAIR



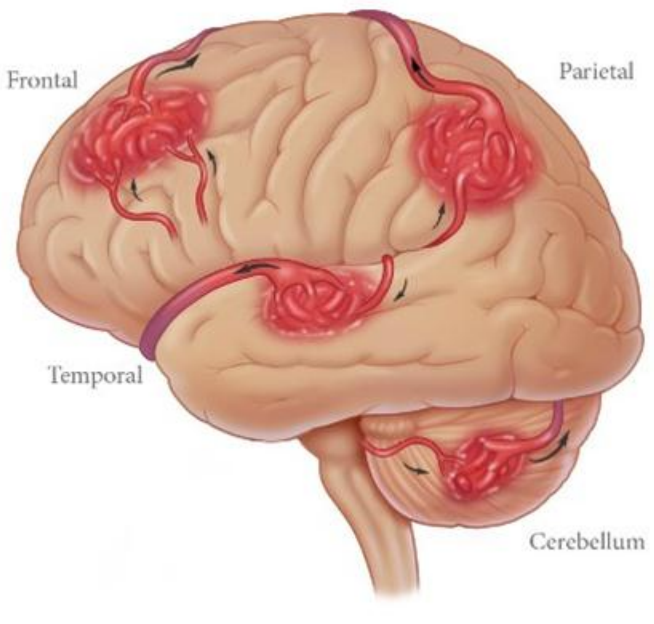
DSA

In Moya moya TD corrected CBF map shows hypoperfusion in the right anterior temporal region corresponding DSA image shows the same. While ATT map shows increased transit time due to the collateral circulation.

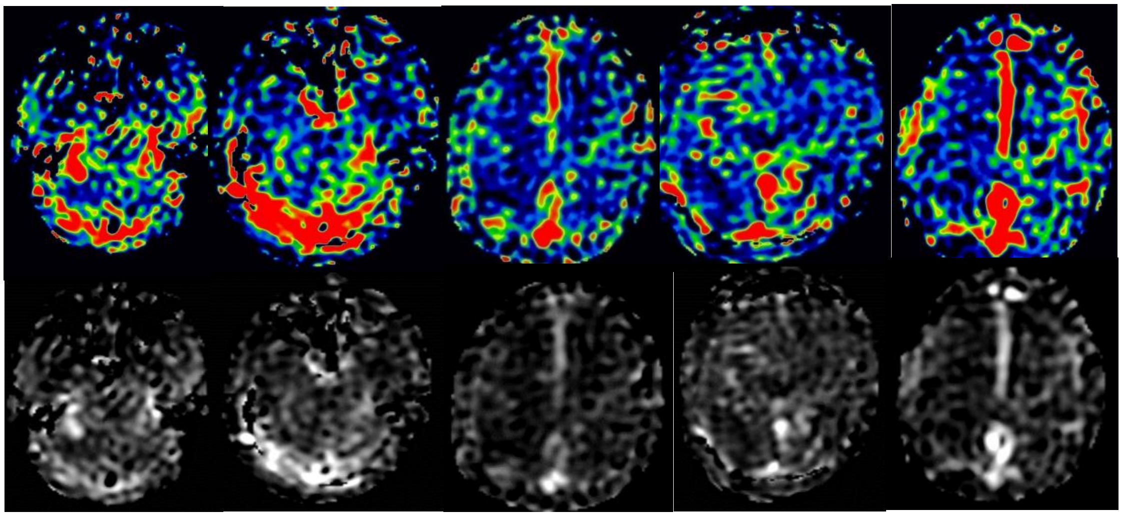
DAVF

Dural arteriovenous fistulae (DAVF) are rare, abnormal connections between arteries and veins in a protective membrane on the outer layer of the brain and spine, called the dura. These abnormal blood vessels divert blood from the normal paths. In a DAVF, there is a direct connection between one or more arteries and veins or sinuses which gives rise to many problems. If the volume of diverted blood flow is large, tissue downstream may not receive an adequate blood and oxygen supply.

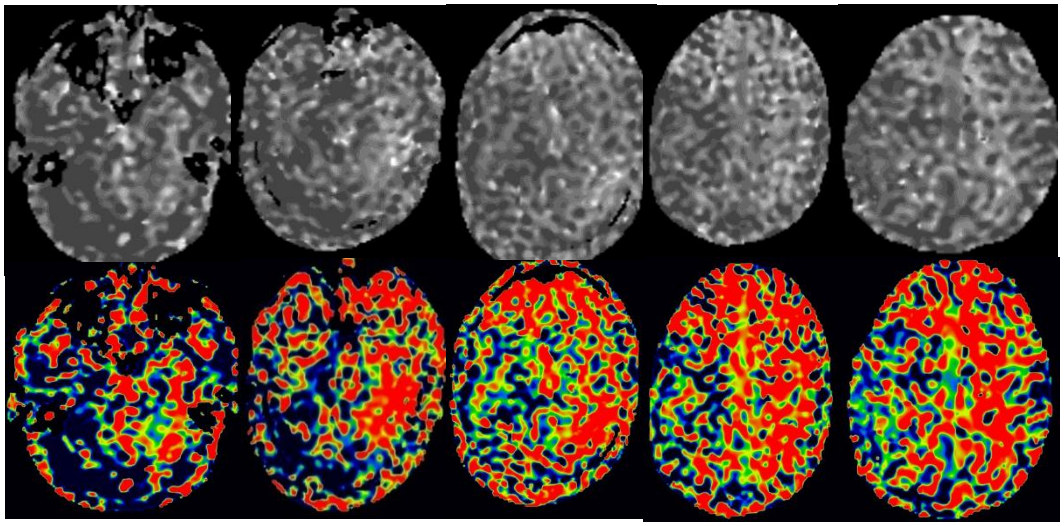
An unusually heavy blood flow also can lead to aneurysms or ruptures in the veins.

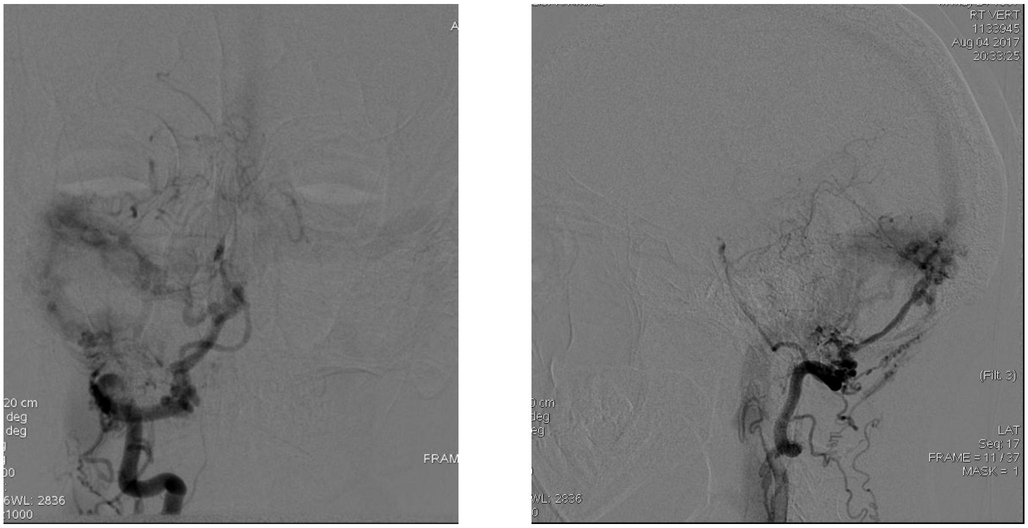


TD CORRECTED CBF



ATT





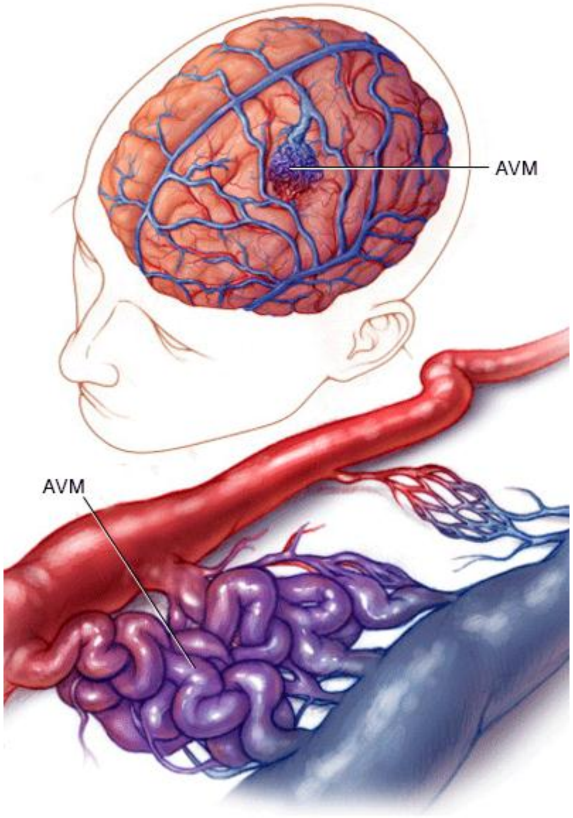
DSA

Case of Rt TS-SS DAVF, dsa shows the fistula well. Corresponding TD corrected CBF will show the hyper signal intensity in the site of fistula . ATT map shows the decreased transit time.

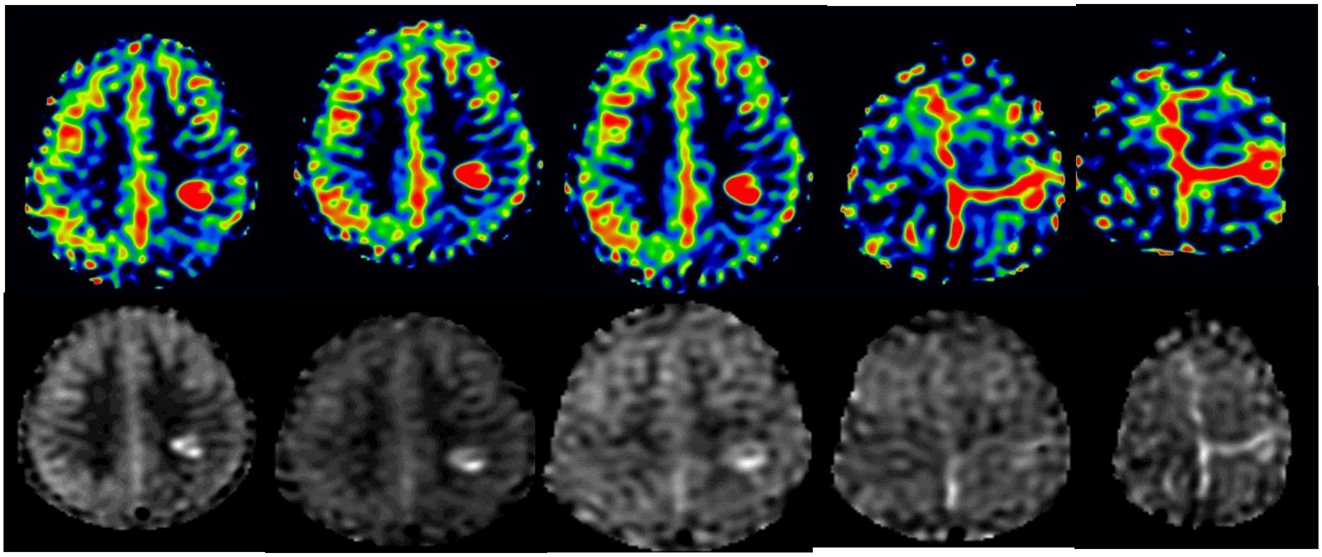
AVM

A brain arteriovenous malformation (AVM) is a tangle of abnormal blood vessels connecting arteries and veins in the brain.

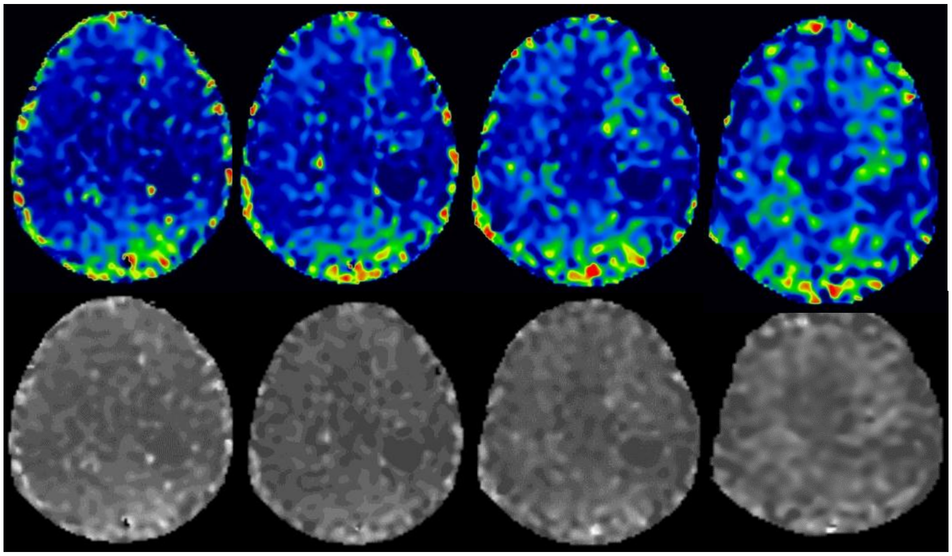
The arteries are responsible for taking oxygen-rich blood from the heart to the brain. Veins carry the oxygen-depleted blood back to the lungs and heart. A brain AVM disrupts this vital process.

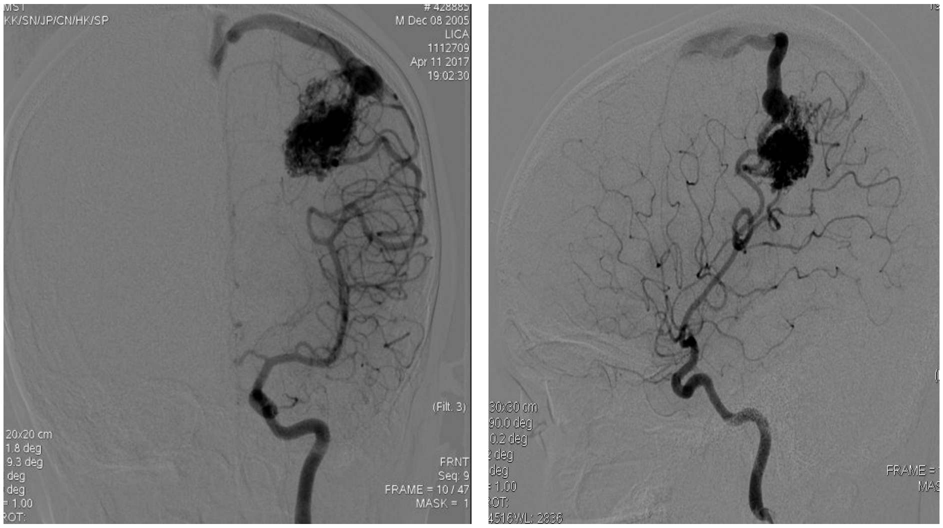


TD corrected CBF



ATT





DSA

Case of left parietal avm , DSA images and TD corrected CBF shows site of AV shunt. ATT maps shows decreased transit time due to the malformation.

DISCUSSION

In this study,we found that EASL has superior quality for visualizing CBF,ATT,and aCBV in neurovascular diseases like ICA Stenosis/occlusion, stroke, vasospasm, Moya Moya, Davf , Avm. CBF may be underestimated in regions with delayed arterial arrival times, especially in cerebrovascular diseases in traditional single delay ASL. Limited by the relatively long scan time required, prolonged ATT greater than the PLD may result in intravascular labeled signals as well as underestimation of perfusion in brain tissue. The most important characteristic of EASL is its multiple post Labeling Delay times (7 different delay time in our case) will help to calculate the mean CBF and ATT together, avoiding the problems faced in single delay ASL.

Another potential use of the multi-delay pCASL protocol is the evaluation of collateral flow through dynamic perfusion images. Delayed arterial transit effects characterized by focal intravascular signals and low tissue perfusion in ASL images may indicate the status of collateral perfusion.

Wang Rui et al,used 4 post label delays in moyamoya disease . He founds that By incorporating delayed ATT in the calculation of CBF, multi delay ASL is able to improve CBF quantification. In our study we have used 7 delays and founds that In Moya moya TD corrected CBF map shows decreased mean CBF While ATT map shows increased transit time due to the collateral circulation.

In carotid artery occlusion. Bokkers, Reinoud PH, et al. showed that there was a overestimation of CBF. He used delay times from 200 to 2600ms and with a scan time of 5 minute.
But in our study we found that Transit Delay Corrected CBF maps shows reduction of CBF & Arterial Transit Time maps shows correspondingly increased arterial Transit time.Here we used delay times between 1200 to 3200 ms with a scan time of 3.48minute.
In acute ischemic stroke Wang, Danny JJ, et al used a protocol of 4 post-labeling delay times acquired within 4.5 minute.In that ASL ATT Showed correlations with DSC Tmax and MTT.CBF ,CBV values are also correlates with DSC values.Our 7 delay protocol shows Decreased CBF and increased ATT at affected region by depicting ROI in corresponding maps.The CORE area can seen in DIFFUSION or CBV maps and PENUMBRA can see from ATT or CBF maps. With this Perfusion/diffusion mismatch can calculate easily .

In a vasospasm case Multidelay ASL TD corrected CBF maps shows reduced CBF values with corresponding DSA image showing hypoperfusion. ATT maps shows increased transit time values. Our 7 delay asl helps to locate the areas which are affected

In DAVF, dsa will shows the fistula well. Corresponding TD corrected CBF maps get in multidelay asl will show hyper signal intensity in the site of fistula, And In AVM , DSA images and TD corrected CBF shows site of AV shunt clearly. ATT maps shows decreased transit time due to the malformation.
Multidelay ASL not showed a much big difference in Both of these cerebrovascular diseases .

CONCLUSION

Multidelay ASL have shown better **accuracy of CBF** quantification than traditional single delay ASL.Imaging of multiple hemodynamic parameters (**ATT, CBF and arterial cerebral blood volume or aCBV**) is possible with in a limited scan duration. As only limited studies are available regarding multidelay asl, Further studies involving large number of subjects is needed to evaluate its potential applications

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