A Feasibility Study of MR Angiography Using a Silent Scan MRA

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AIM OF THE STUDY

A comparison study between silent MRA and 3D TOF MR Angiography. The purpose of this study was to determine whether Silent MRA could visualize flow in an intracranial stent, coiled aneurysms, DAVF, Moya Moya syndrome, AVMs etc.

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BASIC SCIENCE AND REVIEW OF LITERATURE

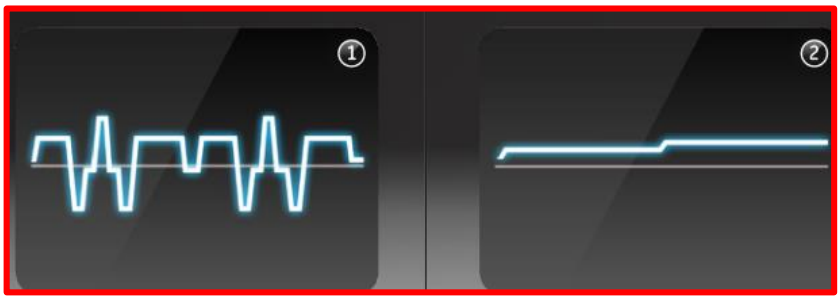
3D TOF MR Angio is widely used for the assessment of cerebral vasculature diseases and has also been examined as anon invasive substitute for DSA. TOF MR Angio is difficult to visualize the flow in stent because of magnetic susceptibility and radiofrequency shielding effect. After the stent assisted coil embolization, we can apply MR Angio by using Silent scan Algorithm, which contains an Ultra Short TE combined with an Arterial Spin Labeling technique.

The Arterial Spin Labeling Technique is used as a preparatory pulse and data acquisition is based on a 3D Radial scan. In this a control image is first scanned before the labeling pulse followed by a labelled image. The control and labelled images are subtracted to produce an angiographic image.

Silent MRI

The silent pulse sequences uses a 3D radial Centre – out sampling scheme, where end points of each spoke followed a spiral path in time. Isotropic voxels are acquired with zero TE. The gradient steps which are used in this sequence are relatively small in contrast to classic repeative gradient ramp up and down steps during gradient echo sequences

Conventional Silent MR

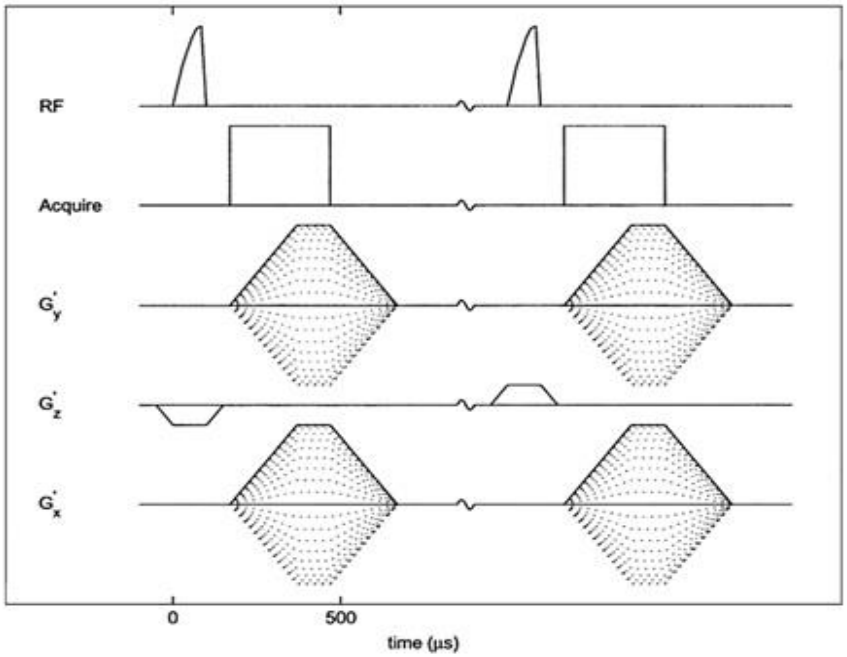


Ultra Short TE (UTE)

UTE pulse sequences are designed to deal with the difficulty of exciting short T2 components and the need to detect their signal rapidly before its decay.

The excitation is performed by a short half RF pulse coupled with a slice selective gradient. This provides a poorly selective slice, however when the excitation is then repeated with another half RF pulse with the gradient reversed a much better slice profile is obtained. When the data from these two half excitations are added it provides one line of K- space. The half pulse are switched off rapidly to allow prompt data acquisition. This is then performed begging with a zero gradient from the Centre of K - space and proceeds radially while the gradients are ramped up and continuing when they reach a plateau

This is done rapidly since it is necessary to detect the data quickly before it decays. The radial mapping of K – space is repeated through 360^0



Pulse sequence diagram for a basic UTE sequence. The half rf pulses are applied with the slice selection gradient G_z negative in the first half and with this gradient reversed in the second half. The rf pulse is truncated and followed rapidly by the acquisition during which G_x and G_y are applied to give the radial gradient. These gradients ramp up to a plateau during data acquisition.

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

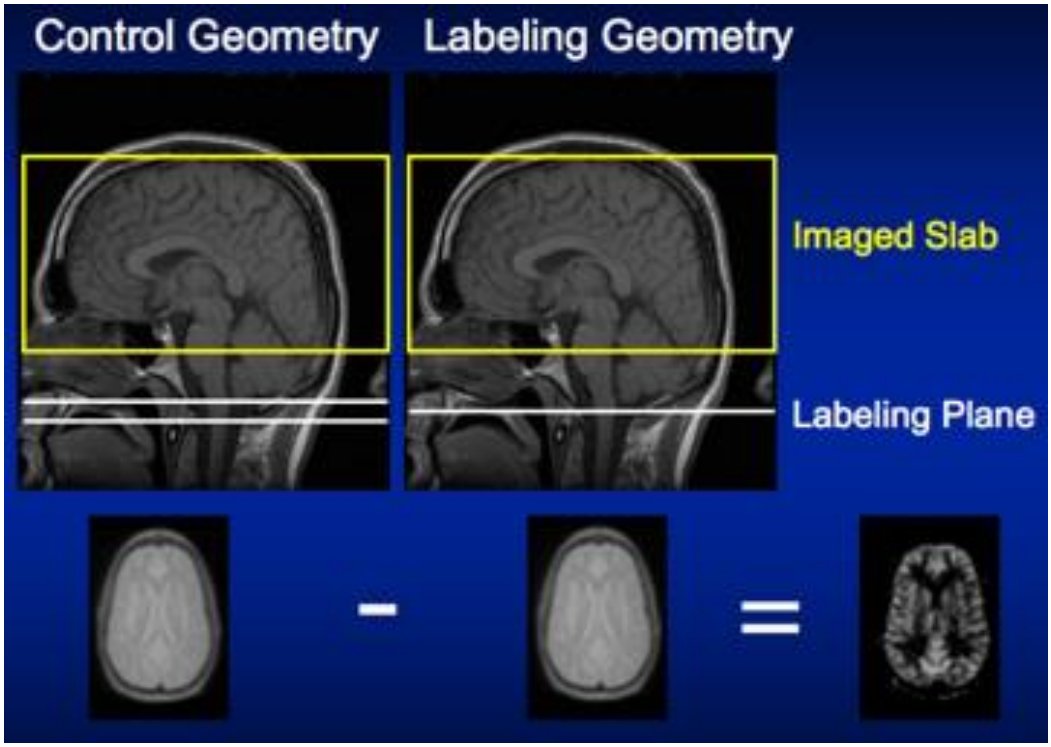
CASL uses long and continuous RF pulses (1-2seconds) along with a gradient field to induce a flow-driven adiabatic inversion in a narrow plane of spins, usually just below the imaging plane .

Pseudo Continuous ASL

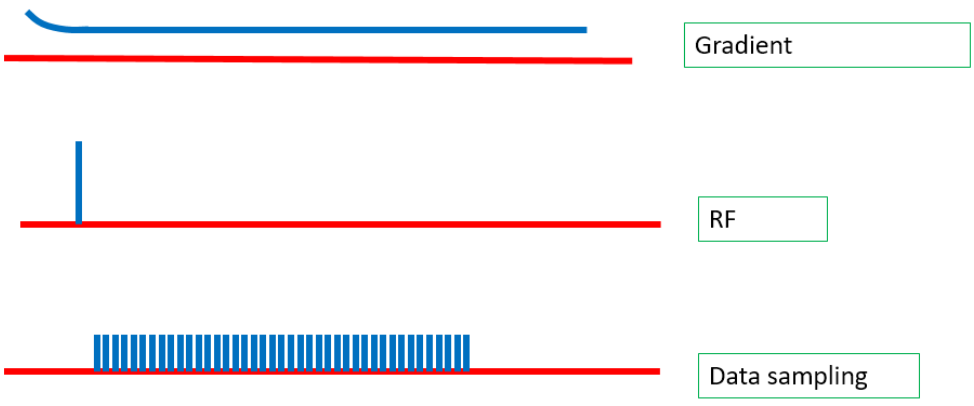
- Introduce to match the inversion efficiency of CASL with decreased transmission
- pCASL uses train of discrete RF pulses in conjuction with synchronous
- gradient field to mimic a flow-driven adiabatic inversion

VELOCITY SELECTIVE ASL

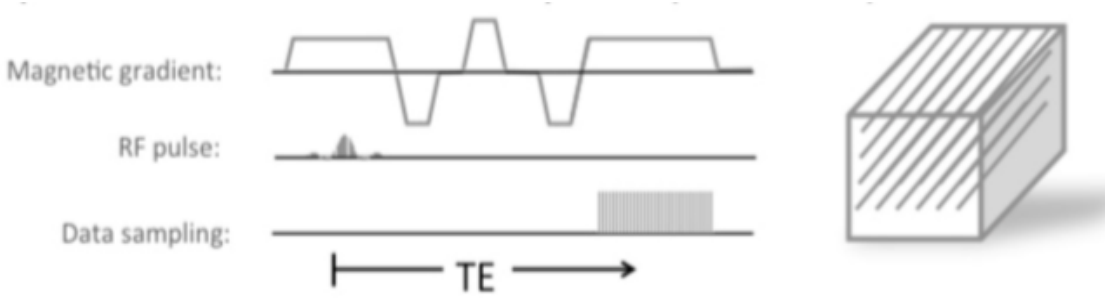
- Saturates the blood that is fast moving than the specific cut-off value.
- Measurement of CBF under slow and collateral flow like stroke.
- Difficulties in determining cut-off velocity.



Sequence chart of common 3D data acquisition



TR - 1116 TE-0.016 ms; flip angle- 5°



SCAN detail,

- The blood within the carotid arteries is "tagged" using a long RF inversion pulse commonly referred to as a "Labeling " pulse. Once the blood is tagged, it is allowed to flow into the vasculature and captured by the Silenz acquisition.
- This is followed by the collection of a control dataset where a "Labeling" pulse is applied above the head to minimize magnetization transfer effects and to control artifacts.
- These two datasets are subtracted to eliminate the background, leaving a depiction of the entire vascular tree

TOF MR Angiographic Techniques

The most commonly used nonenhanced MR angiographic technique has been TOF imaging , developed in the late 1980s. TOF angiography relies on the differences in exposure to radiofrequency excitation between in-plane or in-slab stationary protons and the blood protons flowing into the section or slab. Stationary protons in the imaging section become relatively saturated with repeated excitation pulses and produce low signal intensity. Inflowing blood protons in arteries and veins have not experienced the excitation pulses, are not saturated, and therefore generate high signal intensity. For selective imaging of arteries, saturation bands are applied on the venous side of imaging sections to null signal from the venous flow. Flow-compensation gradients, consisting of additional positive and negative-lobed gradients applied in one or more directions, reduce flow related dephasing.

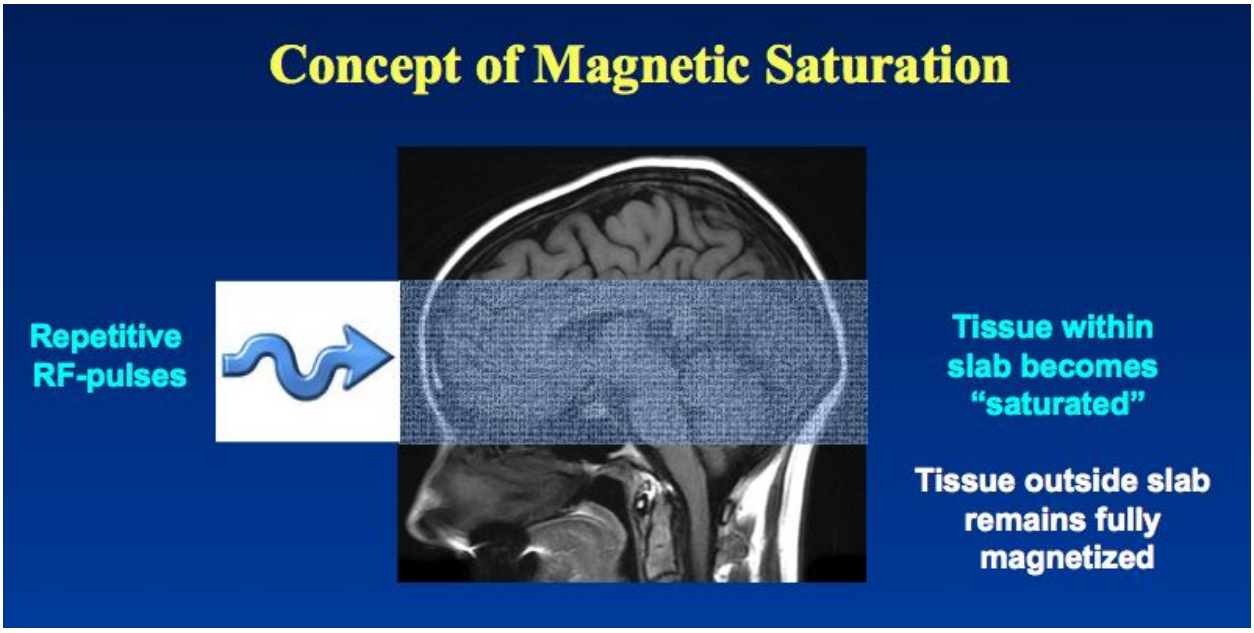
The contrast between inflowing arteries and background tissue in TOF MR angiography depends on certain imaging parameters. Longer repetition times allow for inflow of arterial protons, but at the expense of increased imaging times. With thinner sections, shorter

repetition times can be used, although the gain in time with shorter repetition time is offset by the need to image more sections for the same anatomic coverage; typically repetition times for 2D imaging range from 25 to 50 msec. The higher the flip angle the greater the suppression of background tissue and the greater the signal from the fully magnetized inflowing arterial protons, provided flow is sufficiently fast for all spins to be completely replaced in a section with each excitation. Flip angles can vary from 25° to 60°, depending on the application. Acquisitions can be performed by using 2D or 3D methods, depending on the spatial resolution and the extent of the vascular territory to be imaged. Today, the most common clinical application of TOF angiography is the examination of intracranial vessels , for which 3D methods are preferable to achieve high-spatial resolution isotropic imaging . Improvements to enhance inflow effects in intracranial 3D TOF include tilted optimized non saturating excitation or TONE which uses progressively increasing flip angles through the slab to compensate for saturation of blood flowing in the slab , and multiple overlapping thin slab acquisition, or MOTSA, which represents a hybrid of 2D and 3D methods . Application of magnetization transfer pulses improves depiction of intracranial vessels by further suppressing the brain parenchyma signal on the basis of differences in T2 relaxation times between free unbound water protons (blood) and protons bound to macromolecules (brain). It should also be noted that with TOF methods, the focus is on flow-dependent luminal imaging. Visualization of the vessel wall is limited, as compared, for example, to gated FSE images.

MOTSA, which stands for Multiple Overlapping Thin Slab Acquisition, is a hybrid between 2D and 3D TOF techniques. MOTSA involves the sequential acquisition of a several overlapping 3D volumes (or "slabs"). Each slab is typically less than 5 cm in thickness, so the number of contained slices is small . Because of this restricted slab thickness, loss of

signal due to saturation effects is relatively limited, even at the exit slices. MOTSA thus offers a method to cover a relatively large anatomic area using 3D TOF with preserved intravascular signal intensity.

Some variation in signal still occurs at the end slices, so MOTSA extracts only the central portions for each of the overlapping acquisitions to make up the final data set for processing into the MRA projections. The end slices are typically discarded, but may be averaged with those in the adjacent MOTSA section.



MATERIALS AND METHODS

10 Silent MRA and 3D TOF MRA datas are collected retrospectively from our institute . out of this 5 were stent assisted coil embolization and rest of the cases are other vascular anomalies ,with in different age groups . all patients are undergone silent MRA and TOF MRA.

Data acquisition by 3T MR System ,GE Discovery 750w using a 24 channel head and neck phased array coil

Imaging Parameters

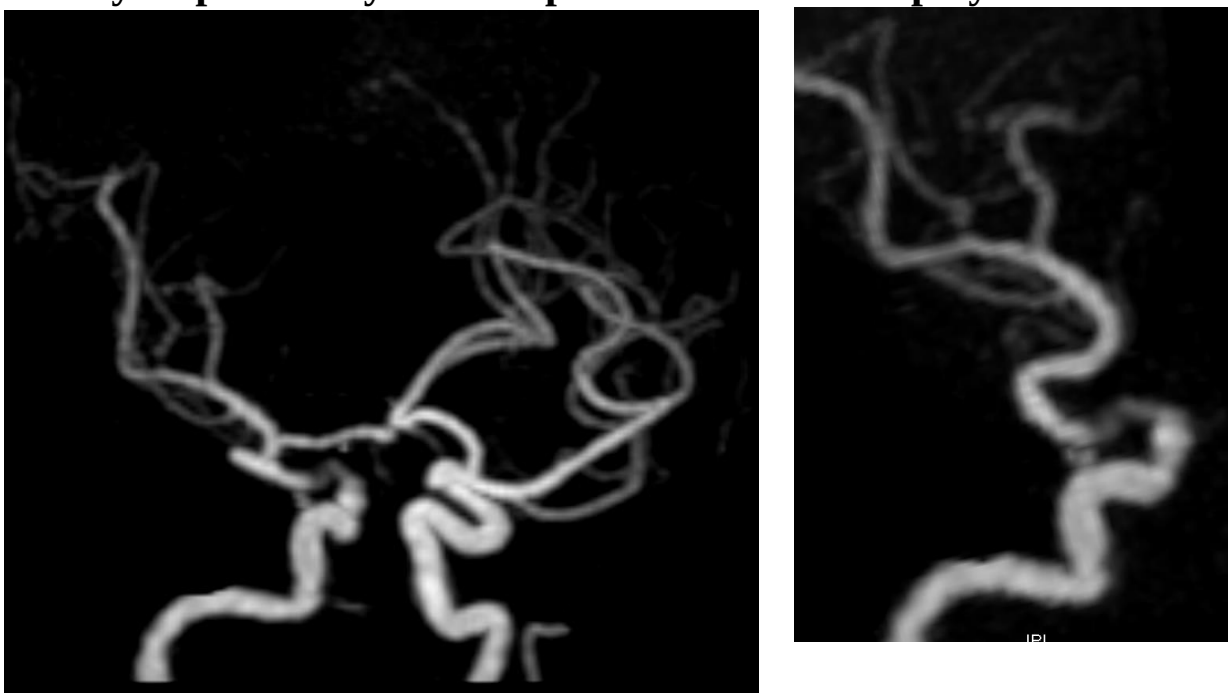
Parameters	Silent MRA	3D TOF MRA
TR	1116.4 ms	19 ms
TE	0.016 ms	2.9 ms
FA	5^{o}	15^{0}
FOV	180 x 180 mm	200 x 200 mm
Matrix	150 x 150 mm	416 x 192 mm
Slice Thickness	1.2 mm	1.2 mm
NEX	1.5	1
Band Width	+-- 20 KHz	+-- 41.7 KHz
Time of Acquisition	7.40 Minute	7.30 Minute

The details of the Silent MRA algorithm were undisclosed . ASL technique is used as a preparation pulse and data acquisition is based on a 3D Radial scan . In this Silent MRA a control image is first scanned before the labeling pulse followed by a labelled image . The control and and labelled images are subtracted to yield an angiographic image . Neuro Radiologists are independently reviewed the MRAs and rated the visual conditions around the flow in stents.

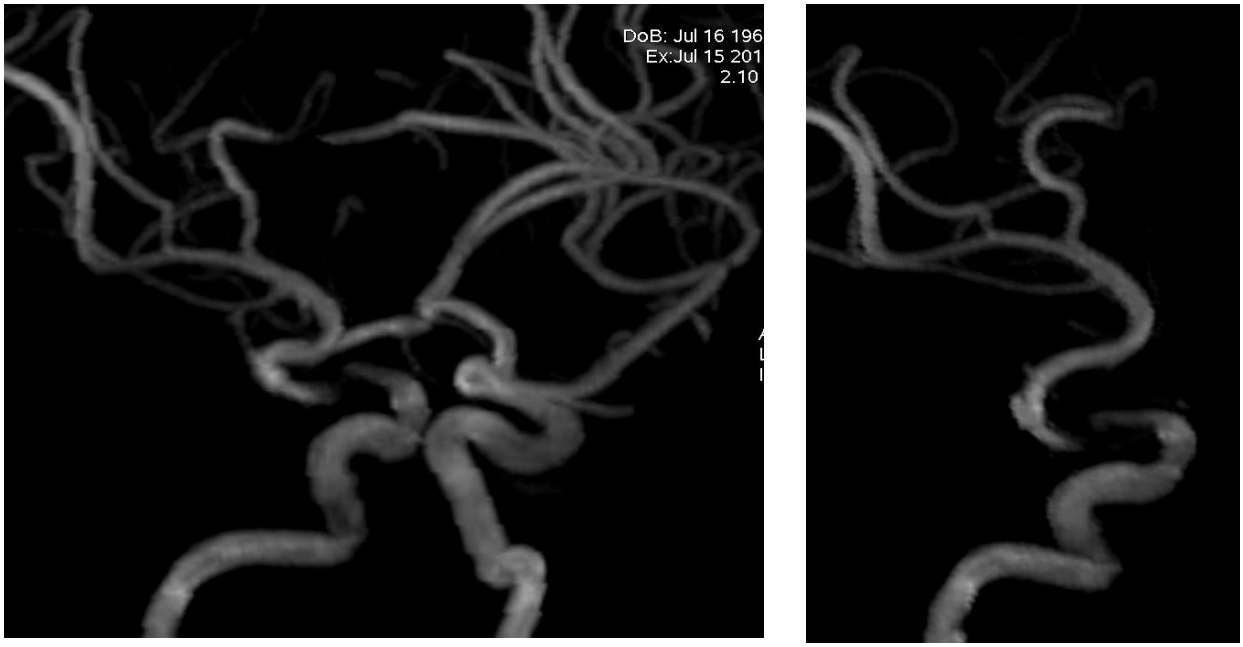
The post processing of both Silent MRA and 3D TOF MRA was done on the multi-modality work station "Advantage Window v4.6" provided by GE Health care .

RESULT

Recurrent giant partially thrombosed right supra clinoid ICA aneurysm previously coiled – p64 flow diverter deployed

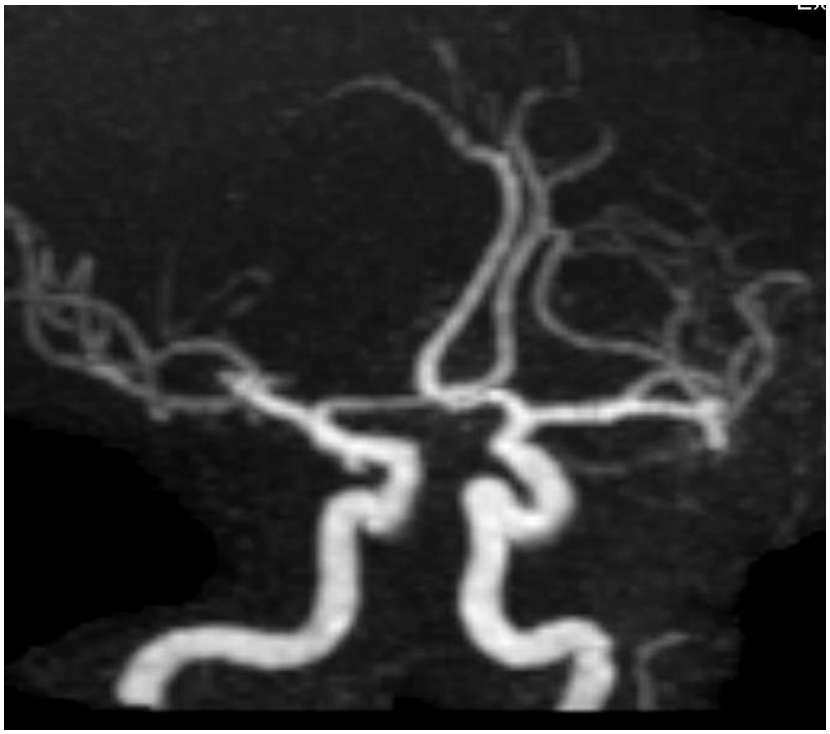


Silent MRA

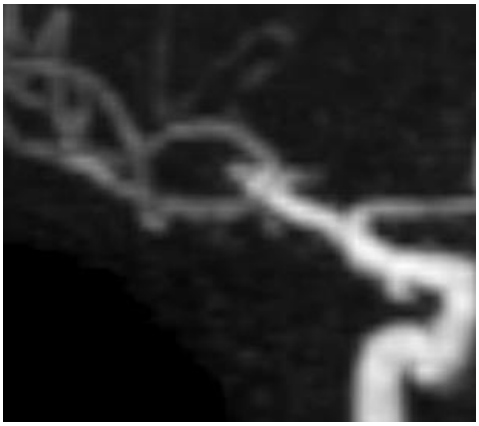


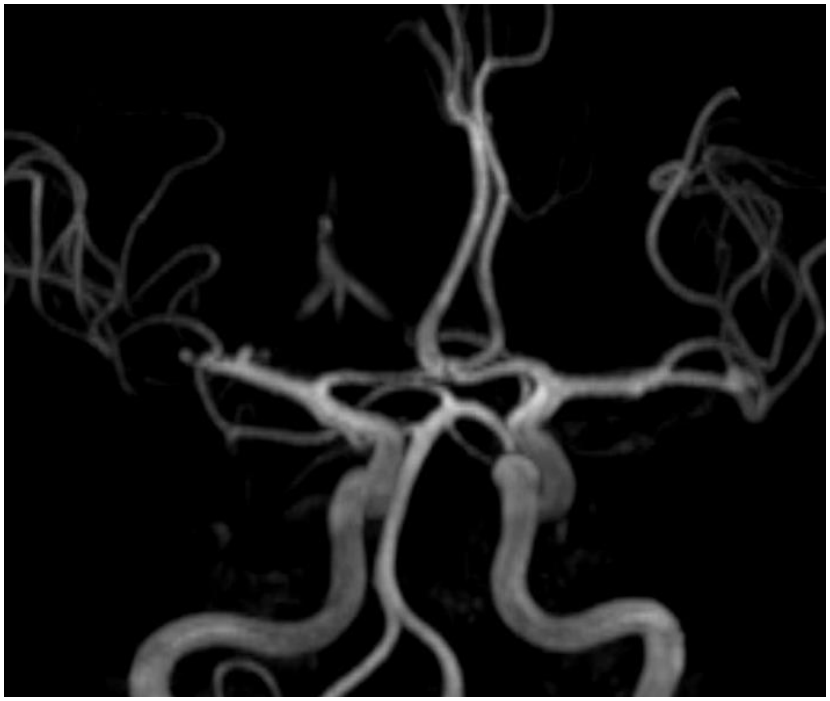
3D TOF MRA

Recanalized flow between the coil mass and stent is difficult to demonstrate. Though TOF showed signal loss at the region, Silent showed the flow.



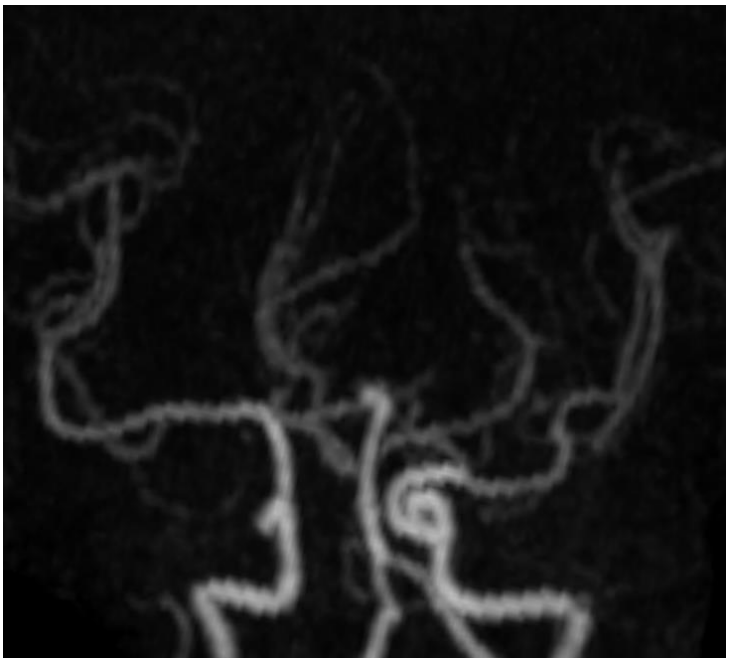
Silent MRA



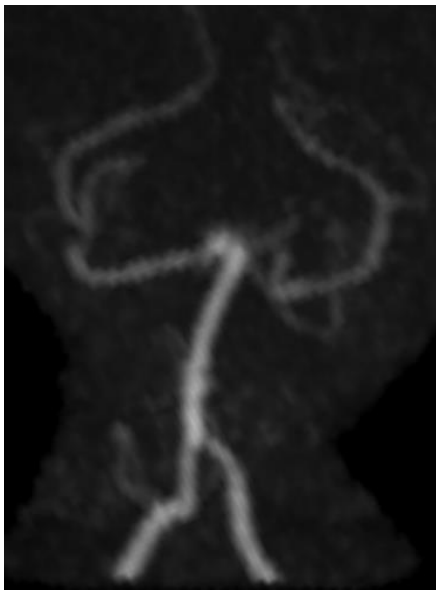


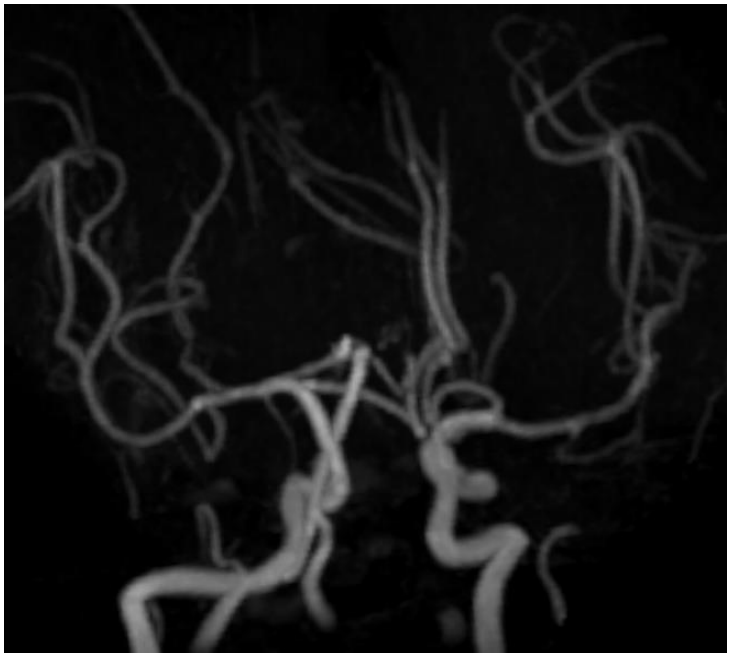
3D TOF MRA

Post coiling case of basilar top aneurysm SILENT MRA showed an in-stent flow and residual flow inside the aneurysm.On the other hand, TOF-MRA could not depict neither in-stent flow, nor residual flow

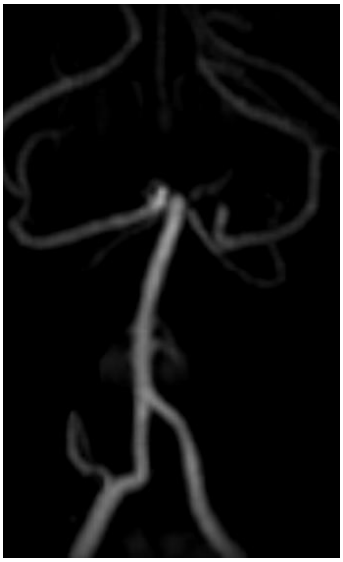


Silent MRA

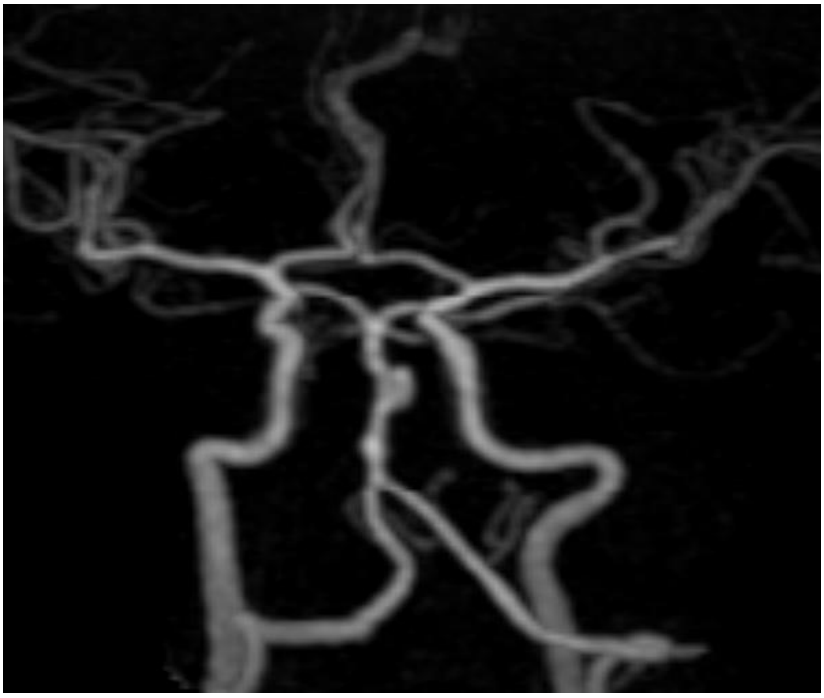




3D TOF

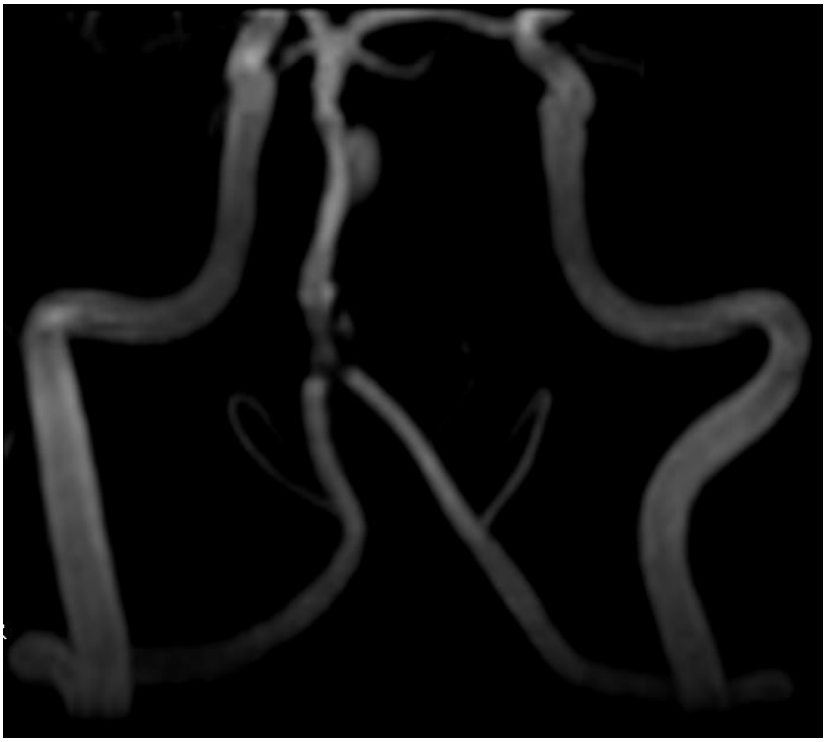


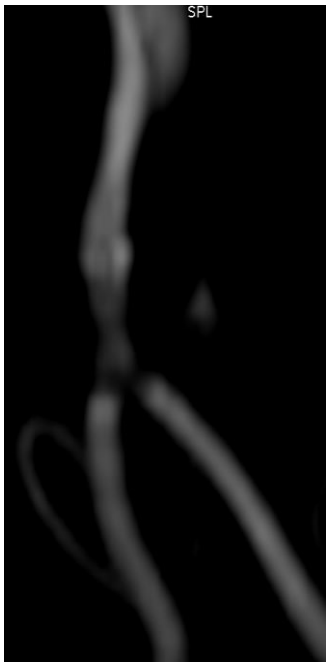
Basilar artery aneurysm post coiling and post flow diverter placement
Silent MRA



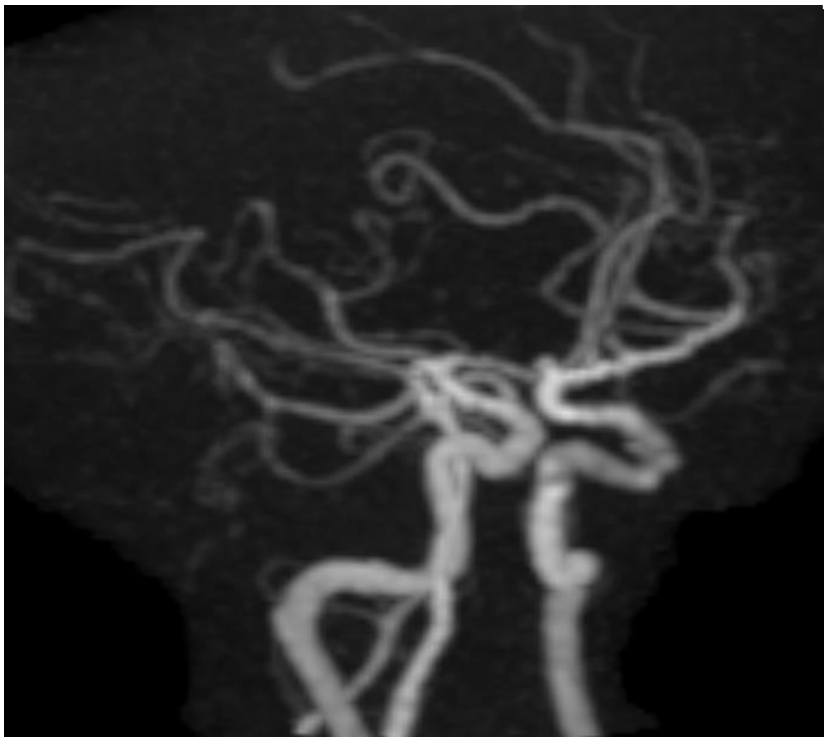
Silent MRA

3D TOF

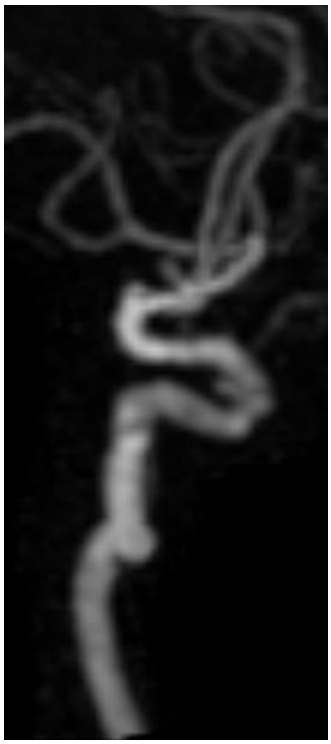


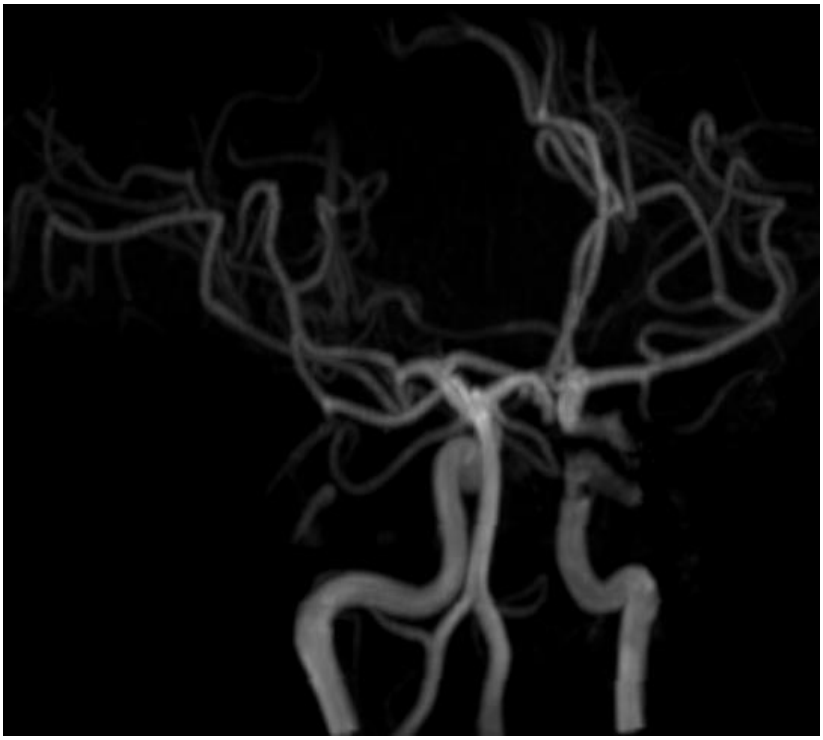


Lt cavernous ICA aneurysm post stent assisted coil embolization . silent MRA shows good intent flow

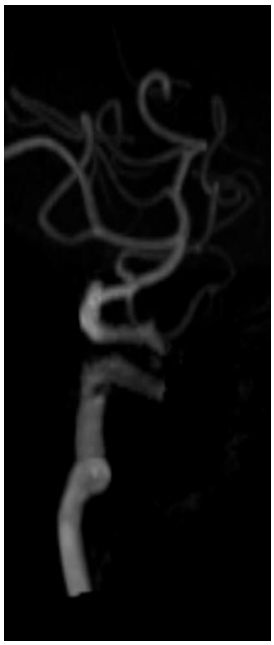


Silent MRA



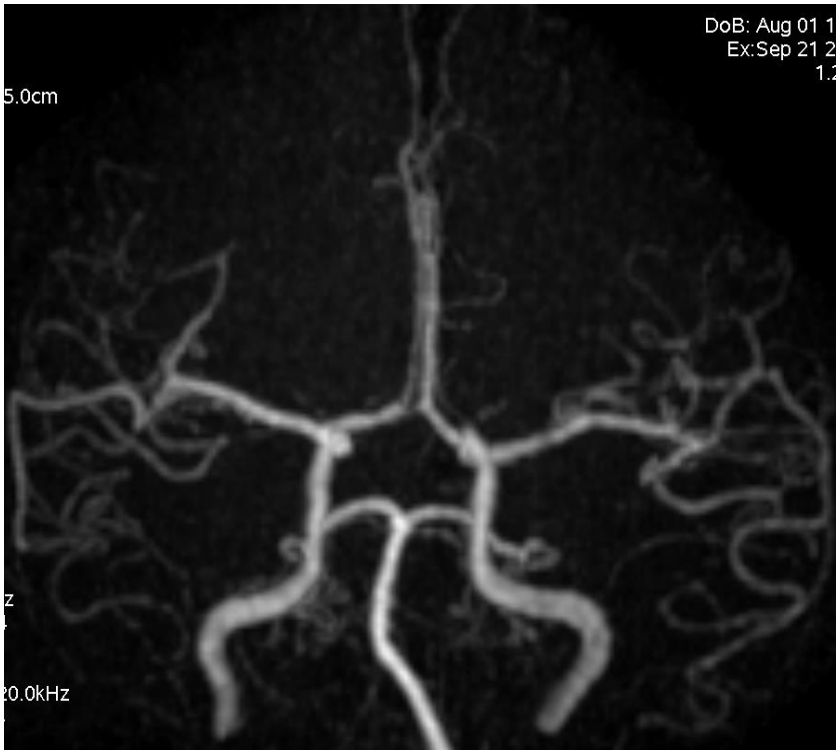


3D TOF

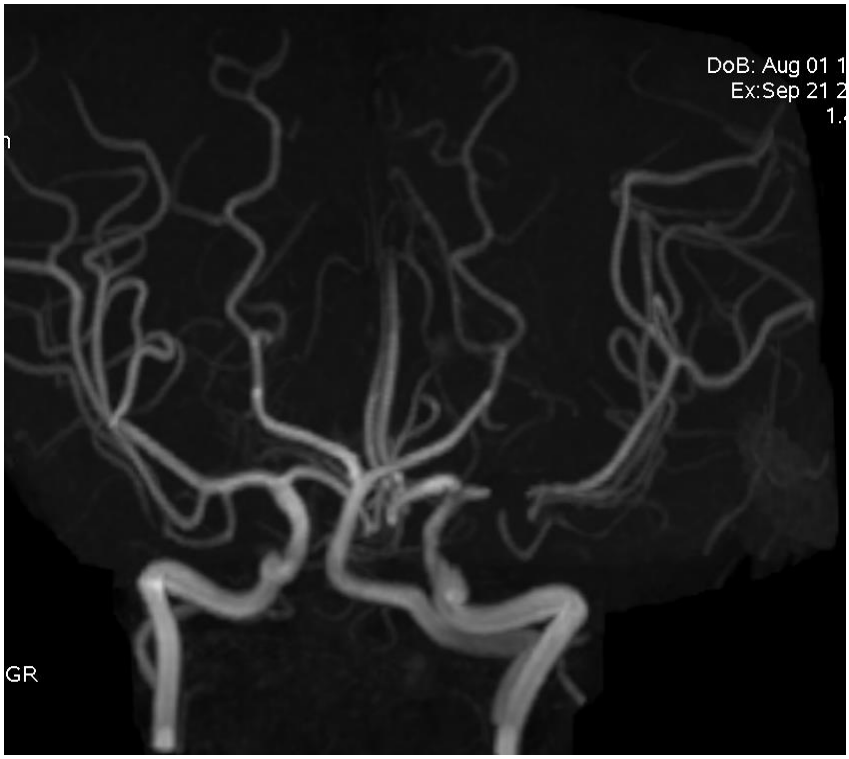


Left ICA bifurcation aneurysm post stent assisted coiling

Silent MRA

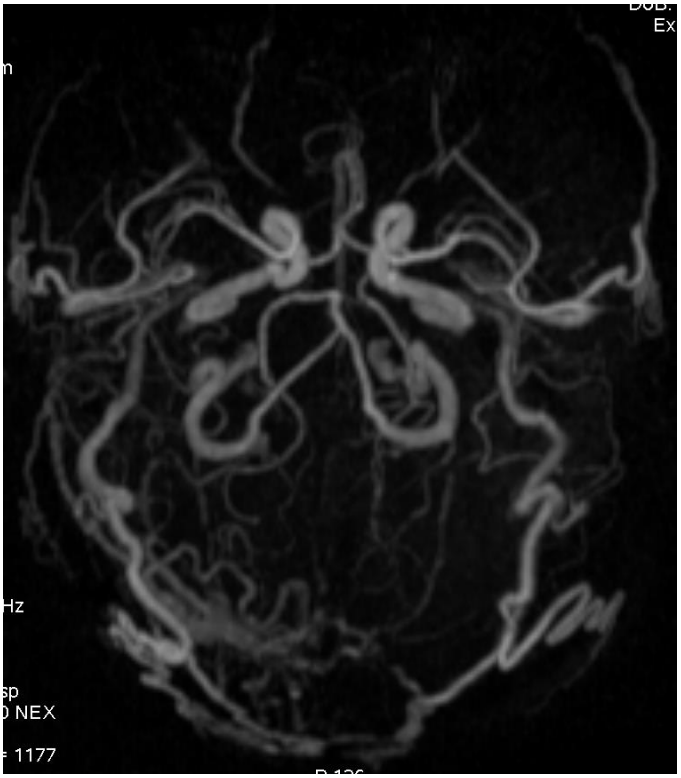


3D TOF

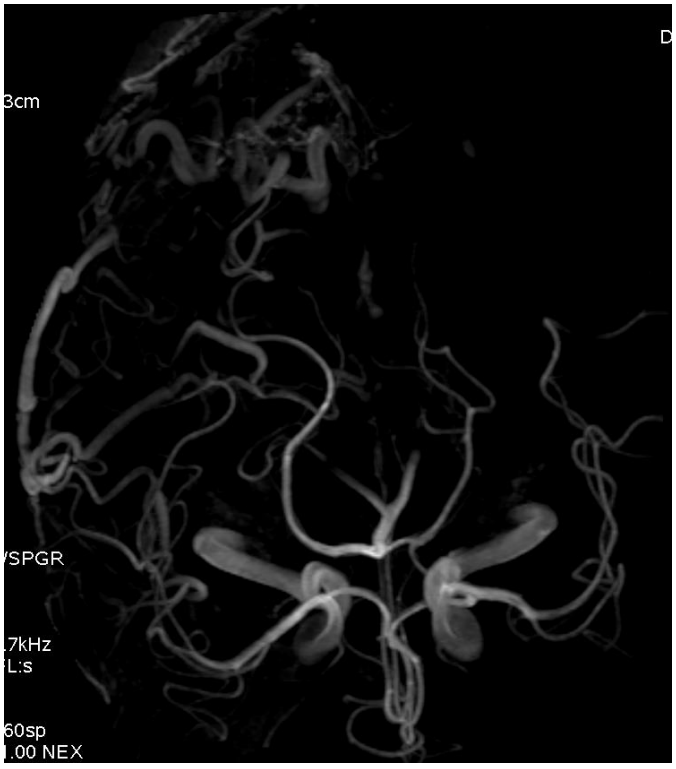


DAVF at right transversal sinus level ,feeding arteries from right MMA,auricular artery,OA

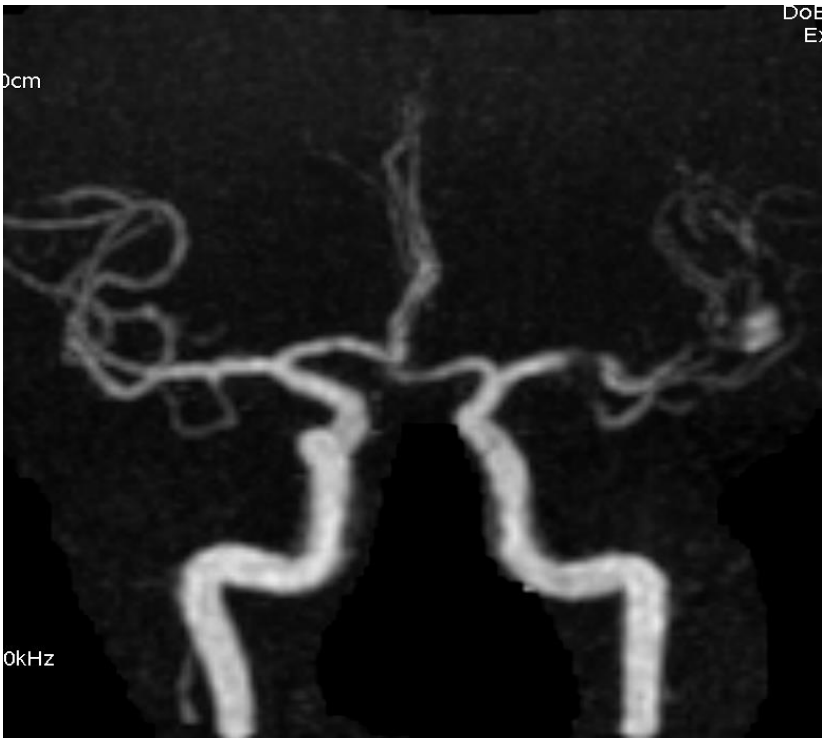
Silent MRA

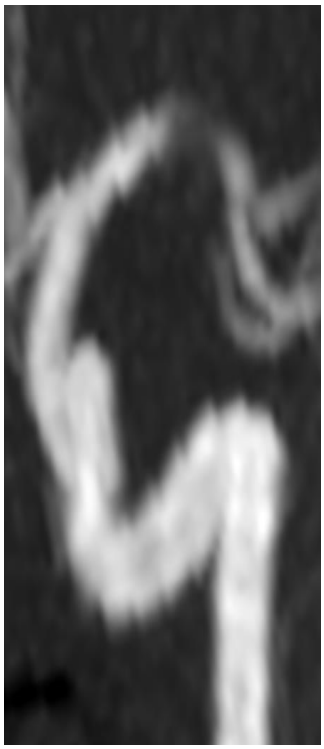


3D TOF MRA



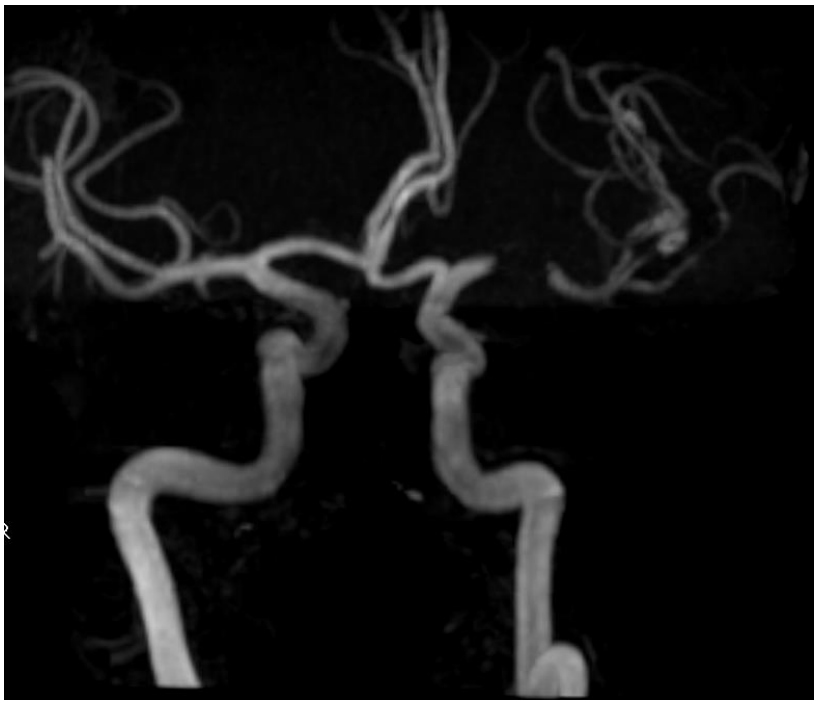
Left MCA aneurysm post stent assisted coil embolization,present MRA shows partial recanalization of aneurysm



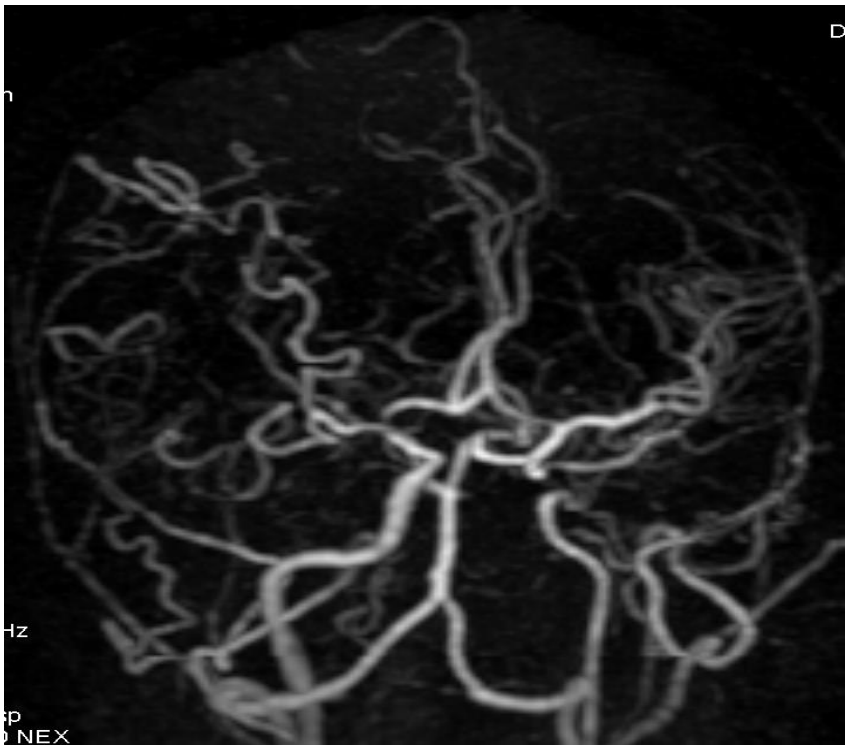


Silent MRA

3D TOF MRA

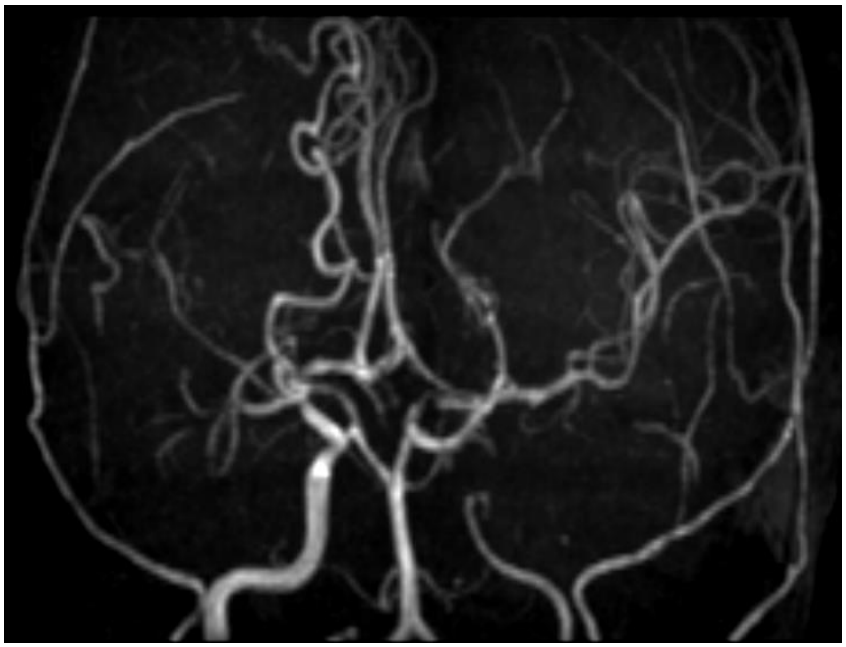


Moya Moya syndrome is a disease in which certain arteries in the brain are constricted. Blood flow is blocked by the constriction, and also by blood clots

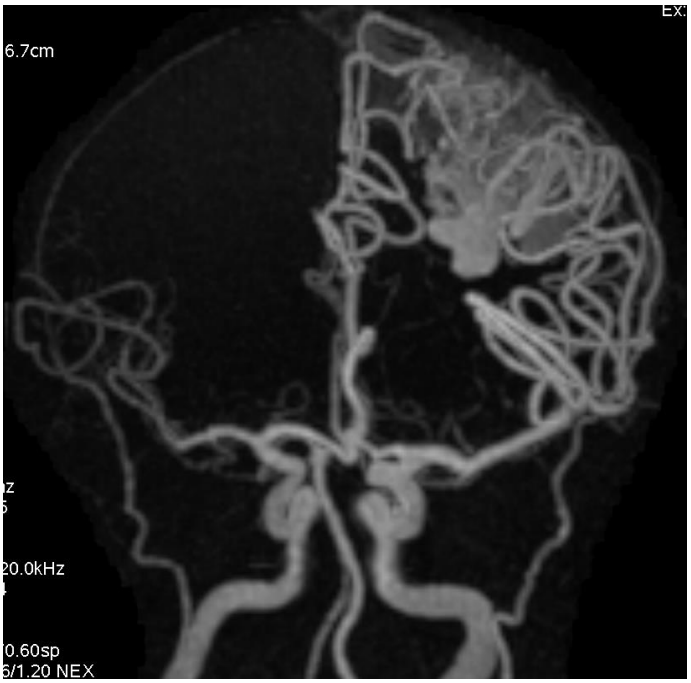


Silent MRA

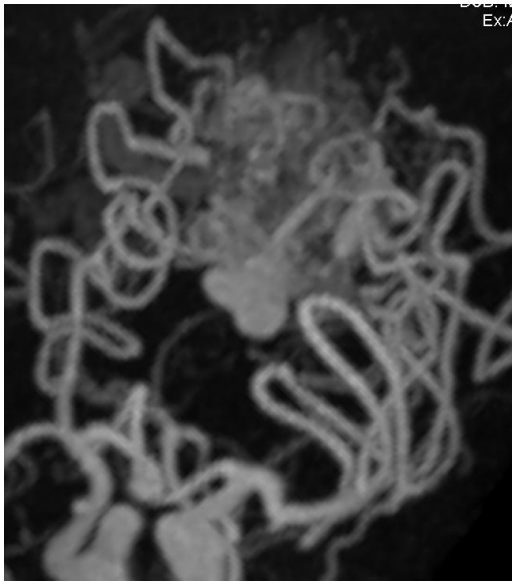
3D TOF



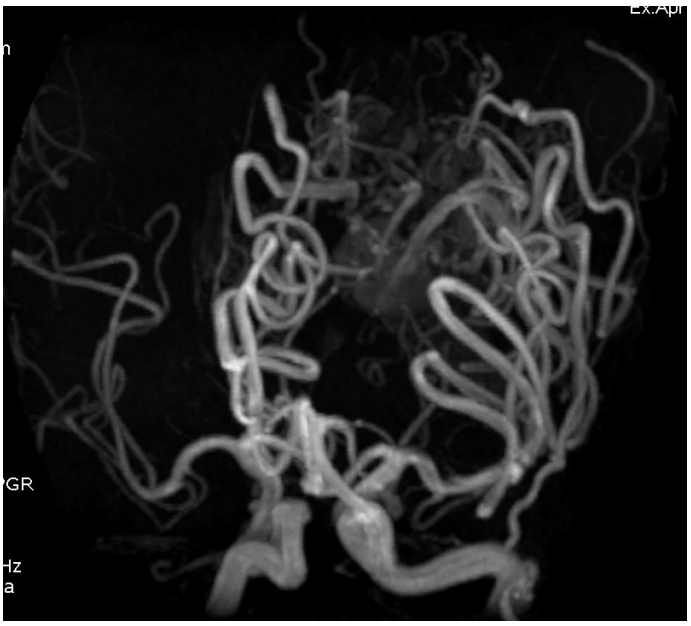
MR angio showing tangle of flow voids to be a AVM nidus with arterial feeders from frontal branches of left ACA and MCA SILENT-MRA could demonstrate each vessel clearly, especially deep part of AVM. It might provide an useful information for preoperative planning for surgery

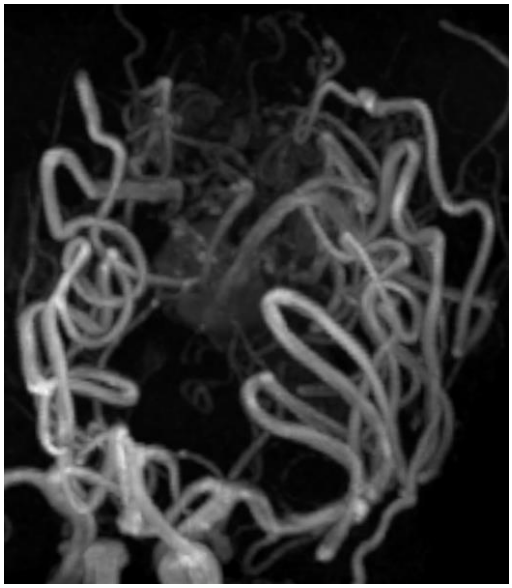


Silent MRA



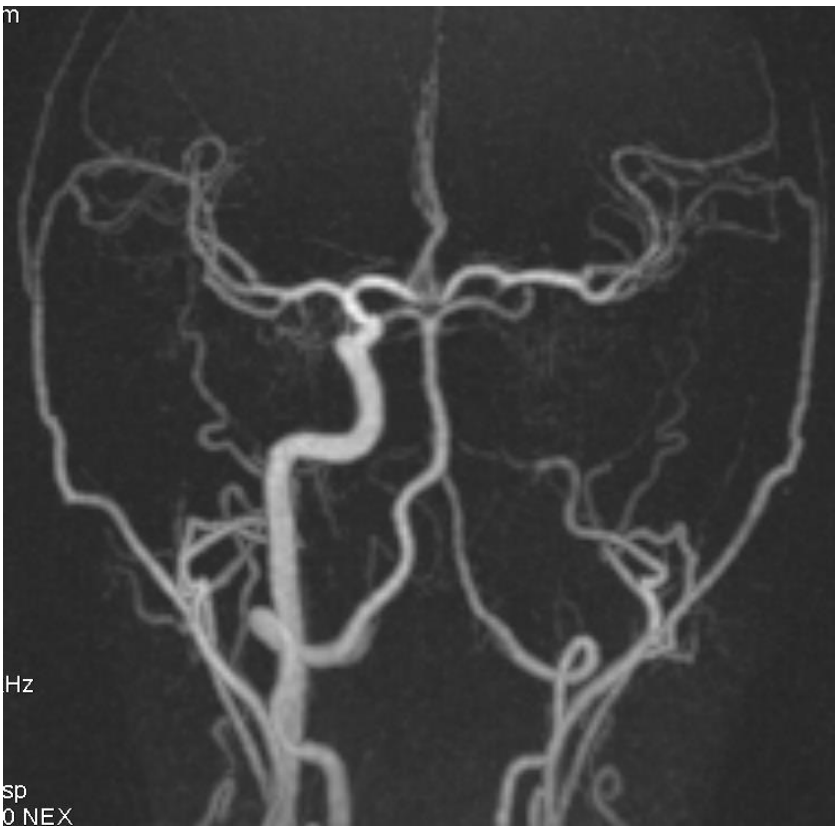
3D TOF



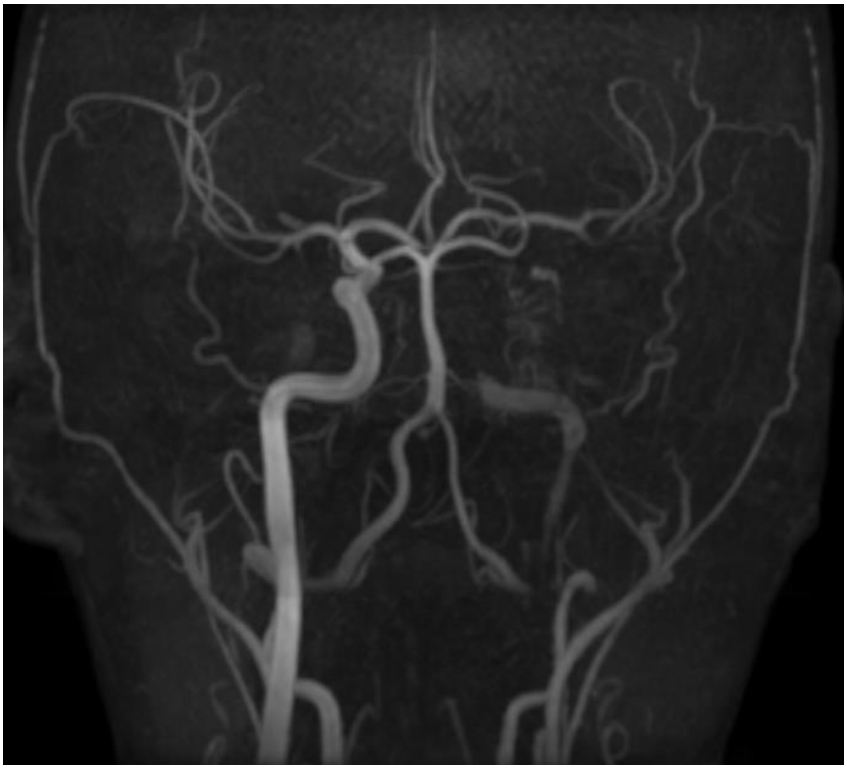


Lt ICA occlusion TOF MRA shows residual Lt ICA due to T1 shortening effect

Silent MRA



3D TOF



DISCUSSION

In this study , we found that Silent MRA was superior to TOF MRA for visualizing flow in stent , AVM , DAVF , cases

The most important characteristic of a Silent scan is the Ultra Short TE (TE =0.016ms) UTE imaging can decrease magnetic susceptibility and visualize short T2 tissues such as the musculoskeletal system , lung parenchyma or carotid plaque . In Silent MRA the UTE can minimize the phase depression of the labelled blood flow signal in the voxel space and decrease magnetic susceptibility accordingly ,the artifact from stent or coils are diminished ,this change enables visualization of flow in stents, effect of the disturbed flow in TOF MRA may also decreased.

In Silent MRA, the angiographic image is obtained by subtraction of images scanned before and after labelling . thus static tissue such as thrombus can't be detected in Silent MRA . in TOF MRA , thrombus in a stent might be detected as a high signal intensity area . Compared with TOF MRA and Silent MRA images are easy to interpret because they consist of only labelled blood flow signal.

- **Uses of Ultra Short TE**

  - **Decrease the susceptibility artifact from a metallic implants**
  - **Reducing T1- shortening effect**
  - **Does not suffer from in-plane, intra-voxel flow dephasing.**
  - **Better visualization of complicated vessel flow (Slow flow, Dural AVF, etc.)**
  - **Subtracted image by ASL technique provides no contamination of T1 weighted -high substance like thrombus.**

CONCLUSSION

Silent MRA could visualize flow in an intracranial stent assisted coil embolization , AVM , DAVF cases more effectively than TOF MRA . Silent MRA may be use full for the follow up imaging after stent assisted coil embolization , AVM and DAVF embolization by using embolic agents such as squid , phil, glue etc. UTE helps to decrease the susceptibility artifact from metallic implants , visualization of small flow signal change with Arterial Spin Labelling method

References

- **Molyneux, A.J., et al., International subarachnoid aneurysm trial (ISAT) of neurosurgical clipping versus endovascular coiling in 2143 patients with ruptured intracranial aneurysms: a randomised comparison of effects on survival, dependency, seizures, rebleeding, subgroups, and aneurysm occlusion. Lancet, 2005. 366(9488): p. 809-17**
- **Takayama, K., et al., Usefulness of contrast-enhanced magnetic resonance angiography for follow-up of coil embolization with the enterprise stent for cerebral aneurysms. J Comput Assist Tomogr, 2011. 35(5): p. 568-72.**
- **Gonner, F., et al., MR angiography with ultrashort echo time in cerebral aneurysms treated with Guglielmi detachable coils. AJNR Am J Neuroradiol, 1998. 19(7): p. 1324-8.**
- **AssessingBloodFlowinanIntracranialStent:AFeasibility StudyofMRAngiographyUsingaSilentScanafterStentAssistedC oilEmbolizationforAnteriorCirculationAneurysms**
- **RobsonMD,GatehousePD,BydderM,etal.Magneticresonance:a n introduction to ultrashort TE (UTE) imaging. J Comput Assist Tomogr 2003;27:825–46**

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

LOG BOOK

SUBMITTED IN FULFILLMENT FOR THE COURSE OF

(DAMIT)

DIPLOMA IN ADVANCED MEDICAL IMAGING TECHNOLOGY

PERIOD: JAN 2015 – DEC 2016

PRAVEEN P.G

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

CERTIFICATE

This is to certify that **PRAVEEN P.G** has participated in Interventional cases and Imaging Cases during the period Jan 2015 to Dec 2016 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).

Dr. T. R. Kapilamoorthy,

Professor &Head,
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 equipments, the routine protocols and the procedures followed in our different labs, number of cases which I have individually done in X-RAY,CT, MRI &3D WORKSTATION, and the cases which I have assisted in Neuro and Cardiac Cath Lab, I also have included the seminars and projects I have done.

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

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

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

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

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

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

ACKNOWLEDGEMENT

First and fore most, I would like to thank my Head of the Department Prof. Dr. Kapilamoorthy , Prof. Dr C Kesavadas, Prof. Dr.Bejoy Thomas Asso 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	7
MRI	8
CT	8
CARDIOLOGY AND BME	15 DAYS

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

PRACTICAL DATA SHEET

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

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

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

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

F) Magnetic Resonance Imaging.
Equipment :
Magnetom Avanto Tim 76 x 18 1.5T / GE Discovery 750w 3T
No of Cases Done :
Brain - 1900
Cervical Thoracic,& Lumbar Spines - 1300
Stereotactic MRI(Pallidotomy & Biopsys) - 23
Musculo Skeletal System
(Pelvis, Hip joint, Knee, Shoulder joint Etc.) - 60

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

H) D S A Lab.

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

No of Cases Assisted:

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

Interventional Procedures :

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

SEMINARS PRESENTED

- CT Hardware & Image Reconstruction
- Image Reconstruction in MRI
- Materials used for Interventional Procedure
- PACS & Tele radiology
- Stereotactic Procedure in Radiology
- Spin Echo Pulse Sequences & Its Clinical Applications
- 1.5 vs 3 T
- Cardiac CT
- fMRI & BOLD
- Cardiac MRI & Recent advances
- MRI Perfusion

INDEX

Magnetic Resonance Imaging

System Specification

1. SIEMENS Magneto Avanto Tim 76x18 1.5T

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

Magnet specifications

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

Gradient specifications

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

RF system

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

Syngo platform

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

2. GE DISCOVERY 750w 3T

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

Magnet specifications

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

Gradient specifications

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

RF system

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

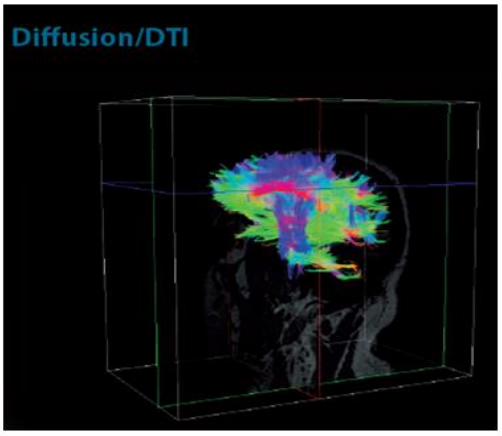
NEW POST PROCESSING SOFTWARE

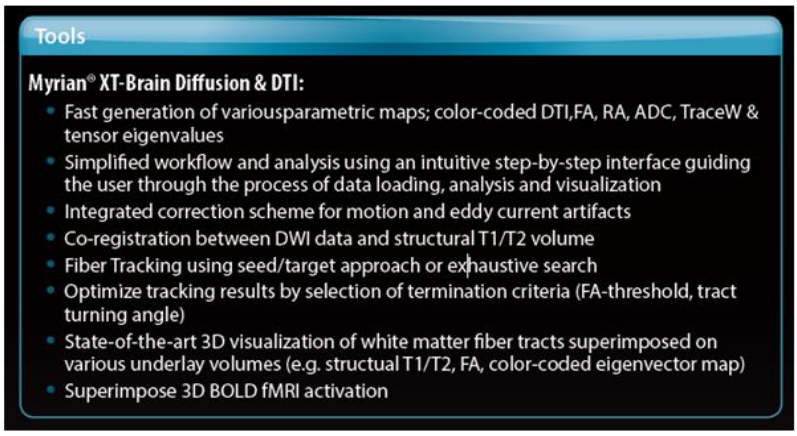
MYRIAN – INTRASENSE

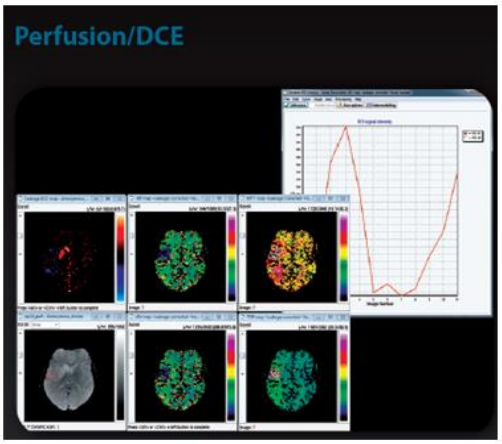
- Module based solution for Diffusion/DTI , Perfusion/DCE imaging
- Windows based software
- Vendor – neutral application , process image from any modality manufacture

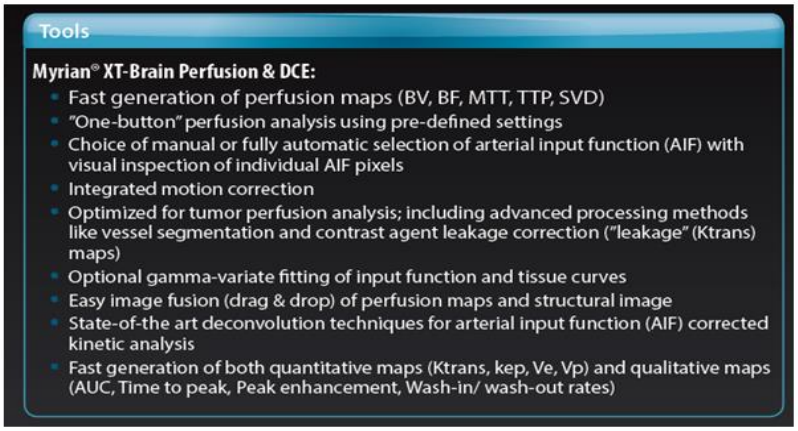
XT- BRAIN nordic ICE

Provide flexibility for research oriented work





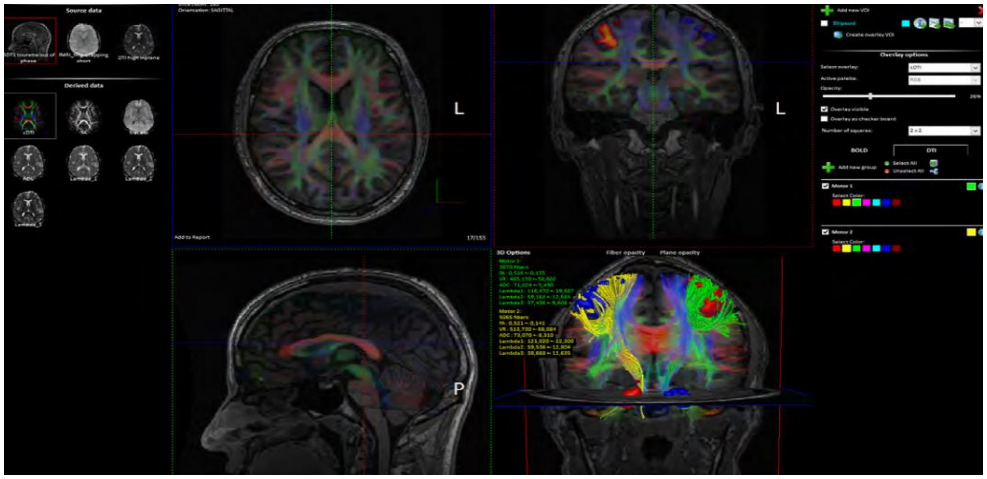




nordic Brain EX :

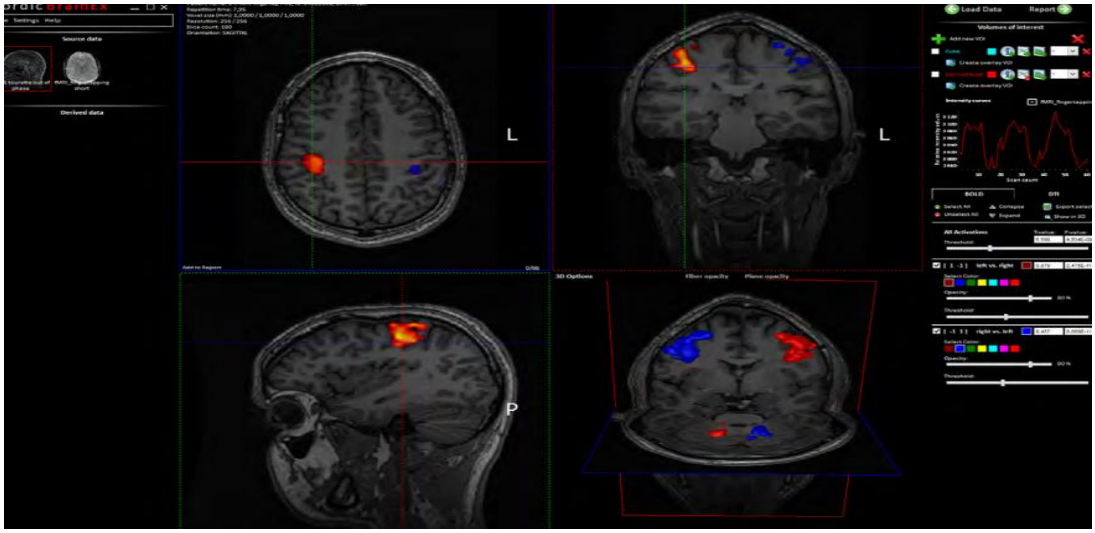
Clinical tool that focus on ease of use and efficiency in clinical setting

- DTI Fiber tracking Module

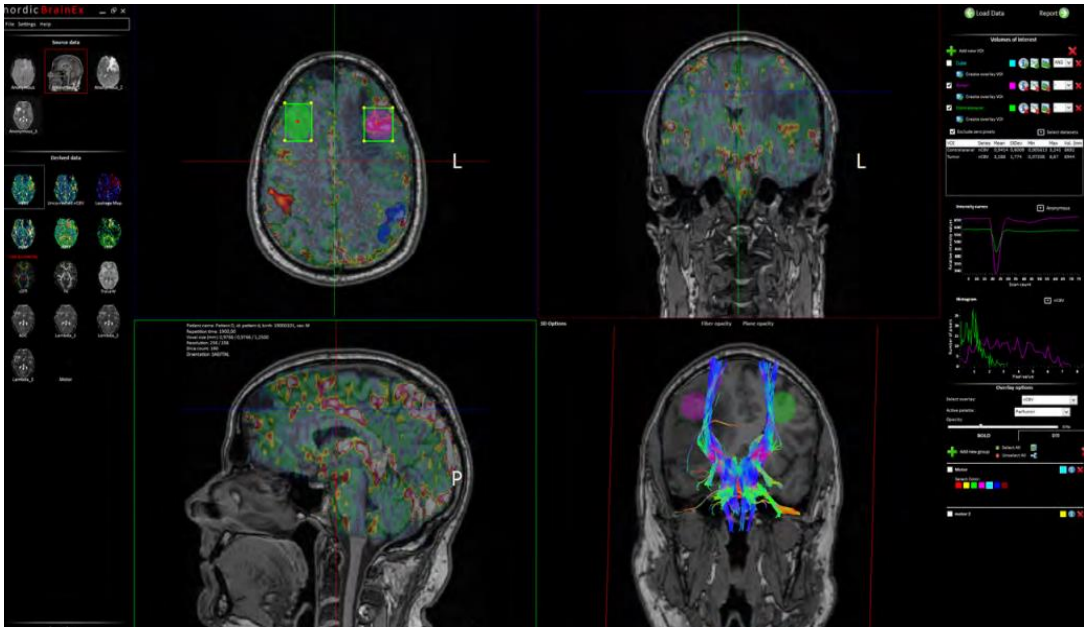


Preprocessing - Motion Correction, Eddy current correction , Smooth , Average ,Adjust noise level
Fibertracking – multiple VOI , AND OR & NOT option

- BOLD fMRI module



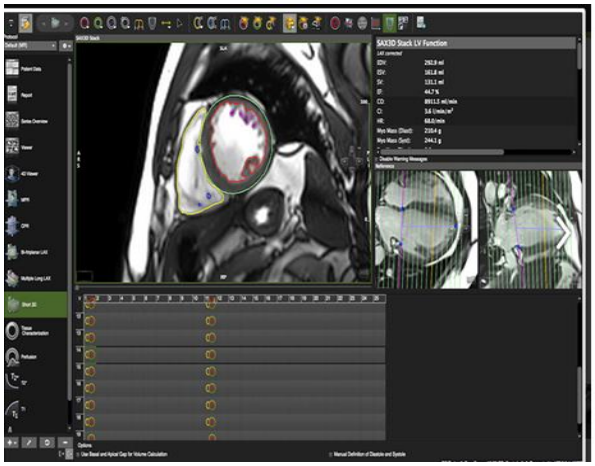
➢ Perfusion/DSC module

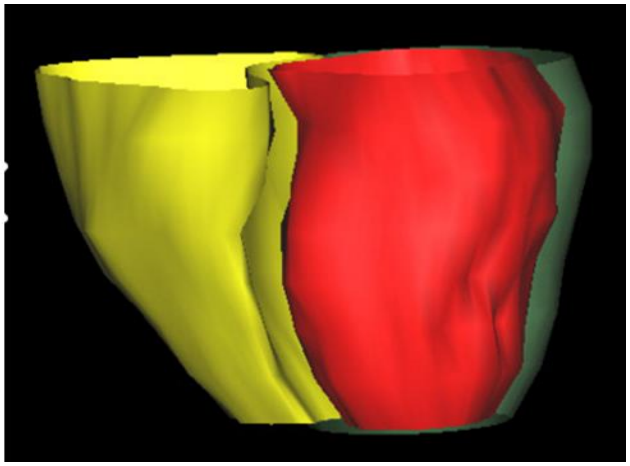


➢ Possible to combine the results from BOLD , DSC PERFUSION and DTI

CIRCLE CARDIO VASCULAR IMAGING

➢ LV/RV FUNCTION





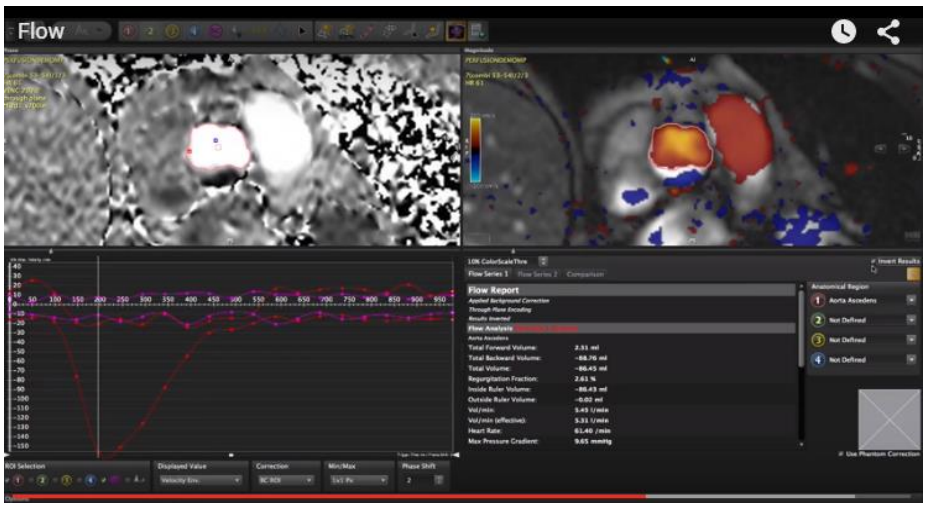
➢ Left and right atrial volumetry [disk area summation & area length method]

➢ Polar maps offering customizable segmentation including AHA segmentation model

➢ Semi-automatic mitral & tricuspid valve correction

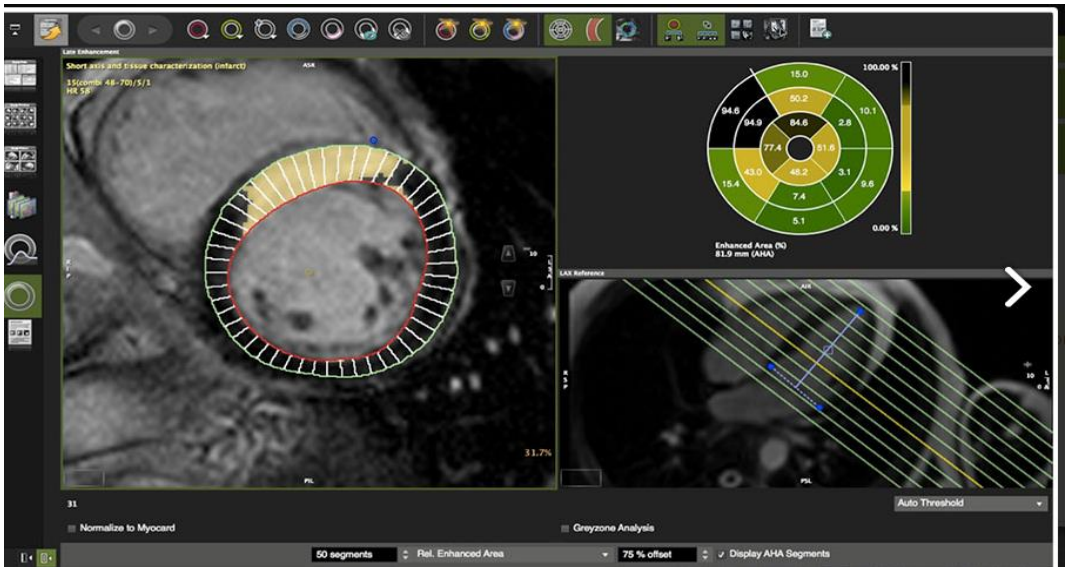
- Optional in- or exclusion of trabeculae and papillary muscles in/from myocardial mass
- Unique threshold based edge detection allows for quick and precise delineation of trabecular structures and/or papillary muscles
- 4D model of left and right ventricle (mesh or solid surface)

FLOW



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

TISSUE CHARACTERIZATION



Late Enhancement and T2 weighted imaging

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

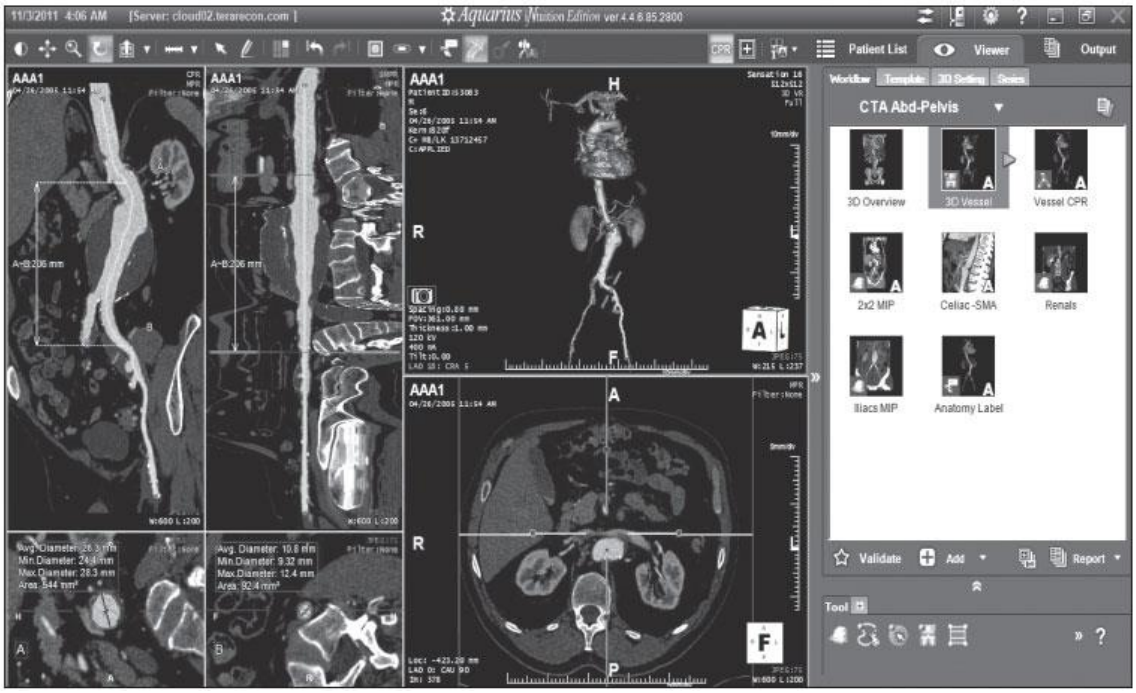
Early Gadolinium Enhancement

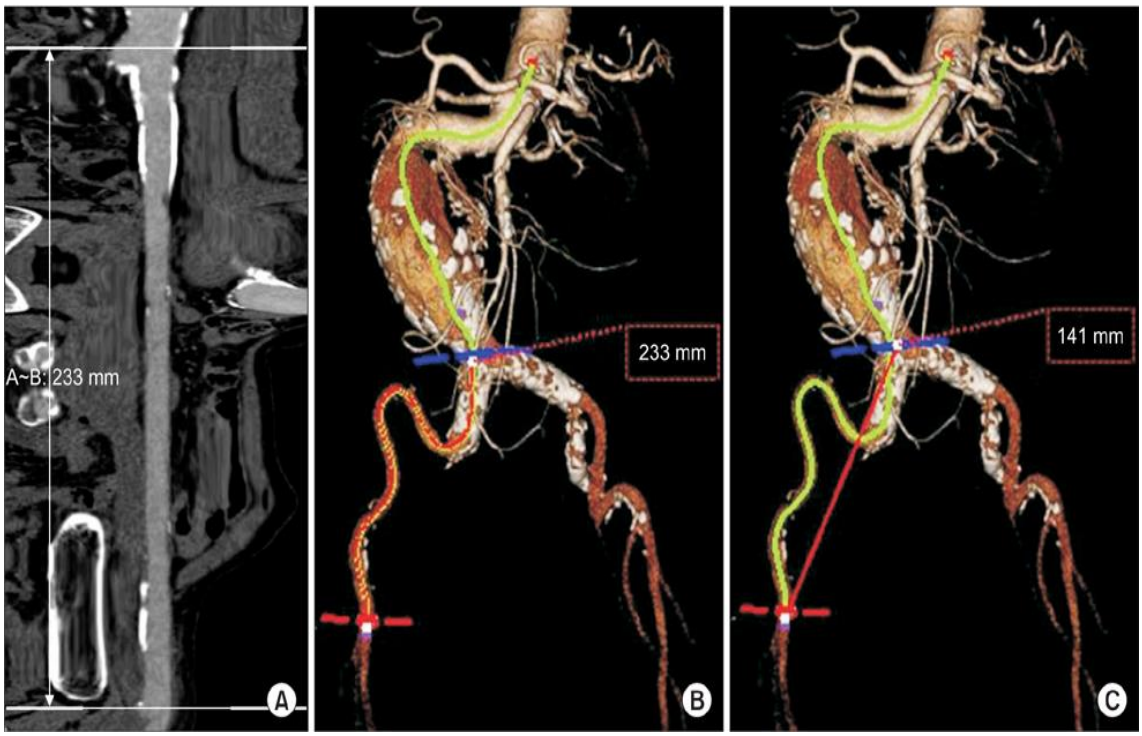
- Assessment of inflammation properties and/or MVO
- Contours are automatically forwarded to the corresponding baseline/post–contrast image
- Calculation and auto–display of myocardial early enhancement and T2 signal intensity ratio (quantitative Lake Louise Criteria for myocarditis)
- Color map of T2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

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

TERARECON – iNtution

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





Advances in MRI

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

ADVANCES IN MRA

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

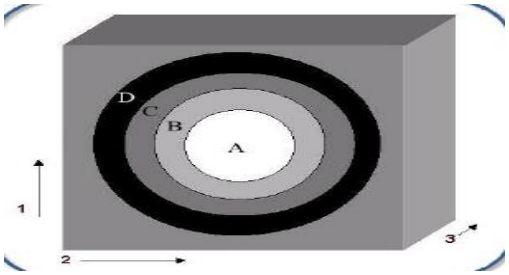
TRICKS / TWIST

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

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

Background:

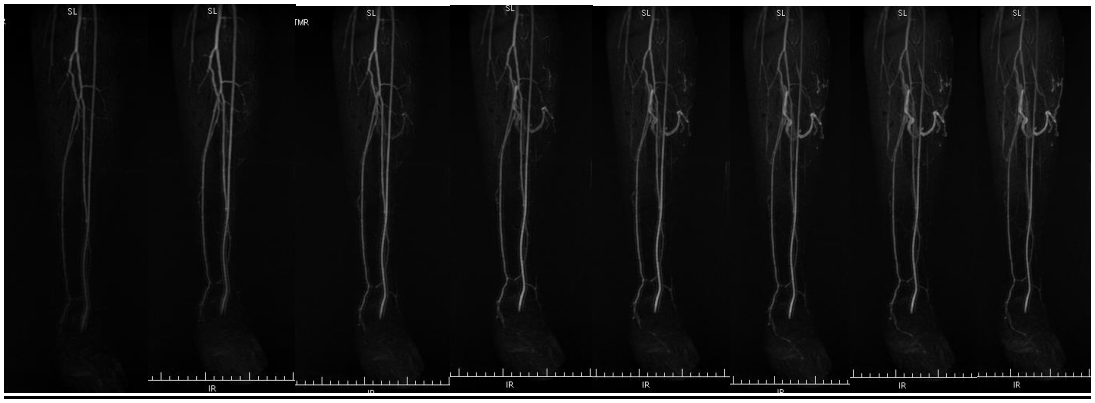
Elliptic Centric-TRICKS is a modified 3D Fast GRE pulse sequence that produces. CE MRA high spatial and temporal resolution images. A mask acquisition used to produce automatically subtracted source images. Collapsed images from each temporal output phase. TRICKS high temporal resolution is achieved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



K – SPACE SCHEME

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

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



TRICKS image of RT Leg

Clinical Applications

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

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

INHANCE / NATIVE - NON CONTRAST ANGIOGRAPHY

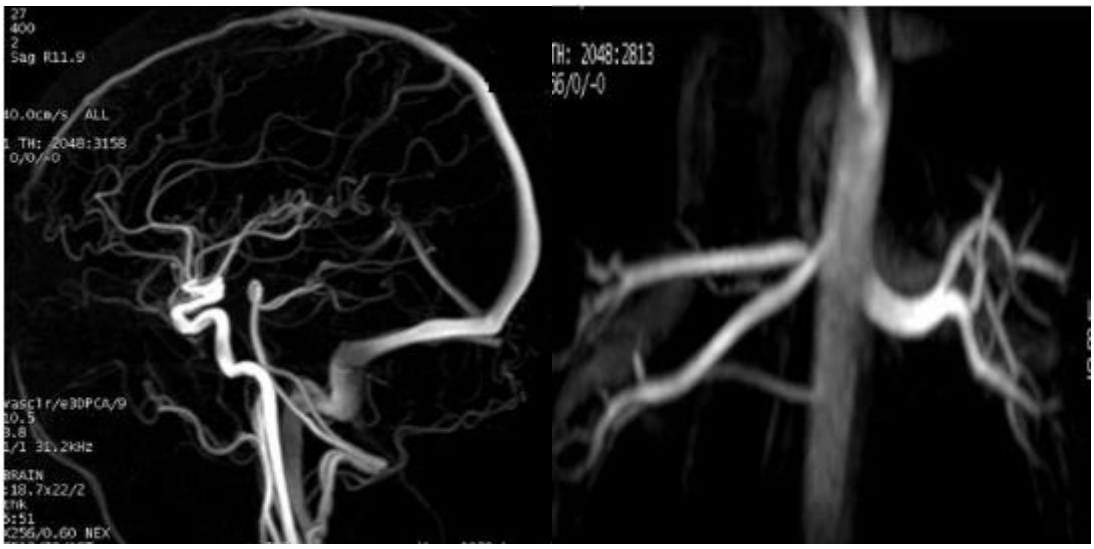
Advances in MRI is help full to provide non contrast MRA in abdominal and peripheral application. The early techniques of NON CONTRAST MRA include 2D &3D TOF IMAGING , GATED 2D TOF , PHASE CONTRAST ANGIOGRAPY

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

INHANCE 3D VELOCITY:

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

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

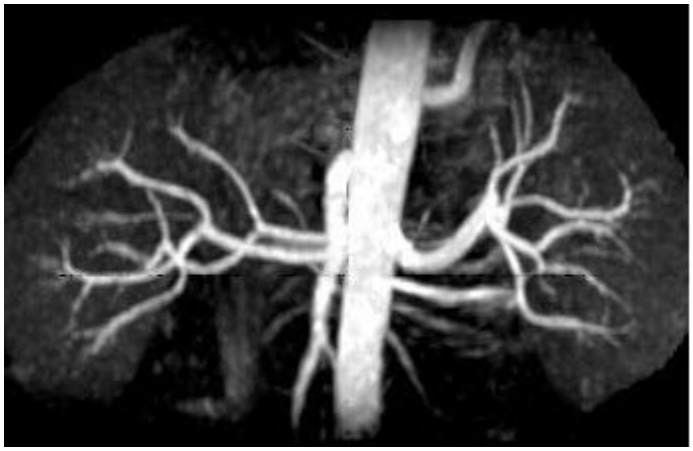


INHANCE INFLOW IR [NATIVE TRUEFISP]

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

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

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



INHANCE 3D DELTA FLOW [NATIVE SPACE]

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

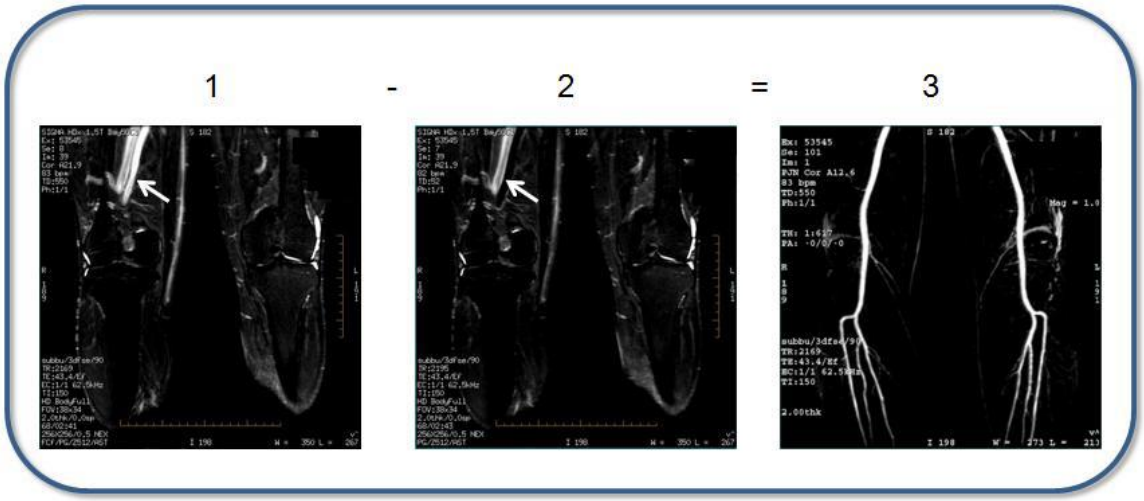
Background:

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

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

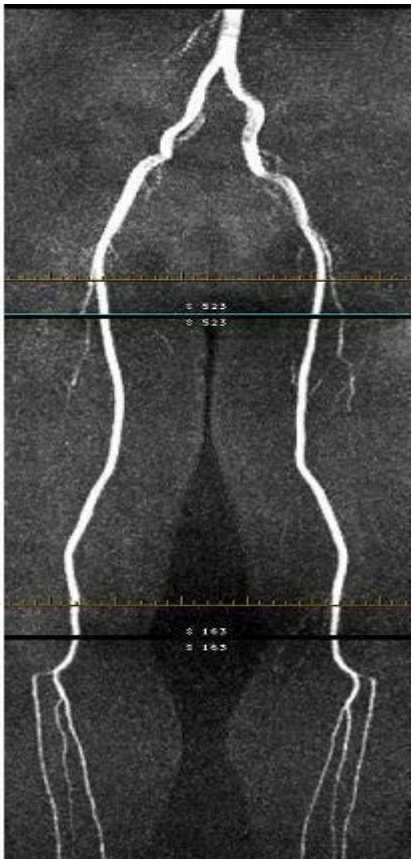
Subtraction of the systolic slab from the diastolic slab results in the visualization of the arteries with good background suppression. A STIR pulse can be applied to both the systolic and diastolic acquisition for additional fat suppression.

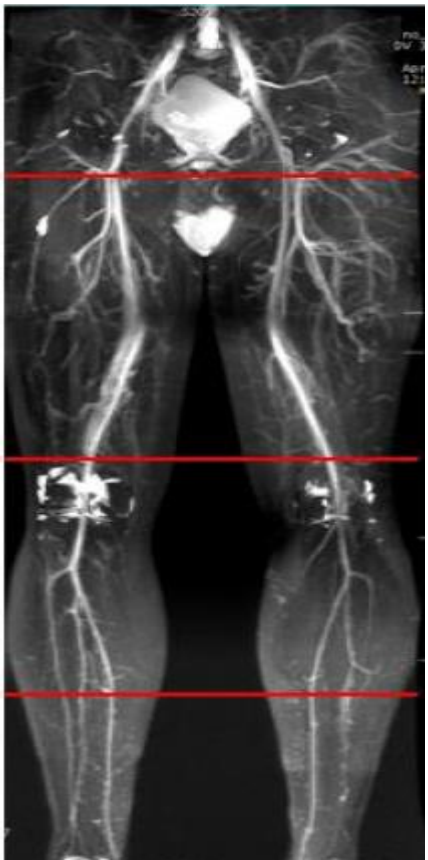
Inhance Deltaflow image results when the diastolic slab is subtracted from the systolic slab



Multi-phase SSFSE

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





MR-Echo

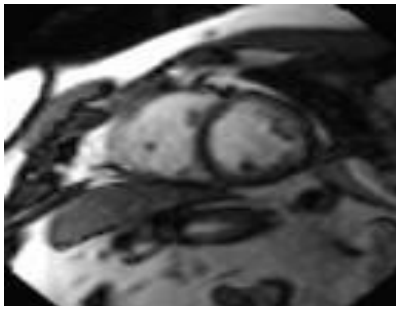
The ***MR-Echo*** application is for cardiac real-time prescription and acquisition. Real time acquisition is particularly useful in patients with irregular heart beats and with patients who cannot perform a breathhold
acquisition. Using real-time images as localizers, the following batch scans can be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

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

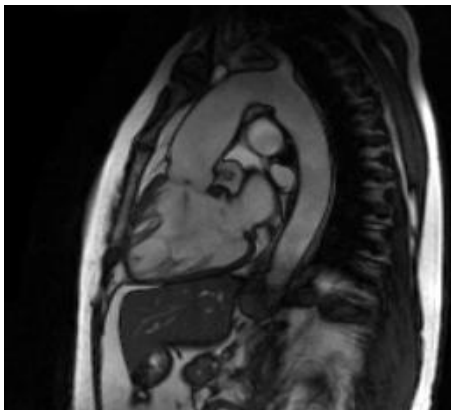
Background

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

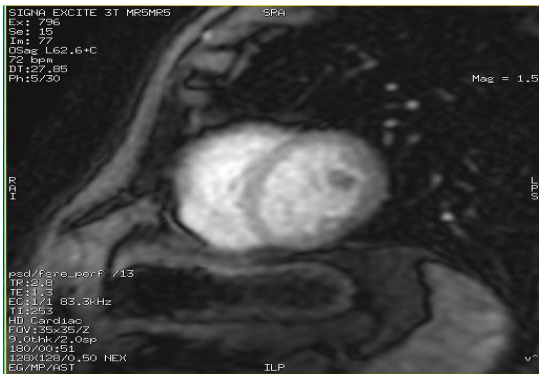
Realtime uses a non-gated 2DFIESTA PSD for acquiring real-time images of the heart using a FIESTA (bright blood) pulse sequence. The PSD acquires images at a high-frame rate for localization and qualitative ventricular function assessment.



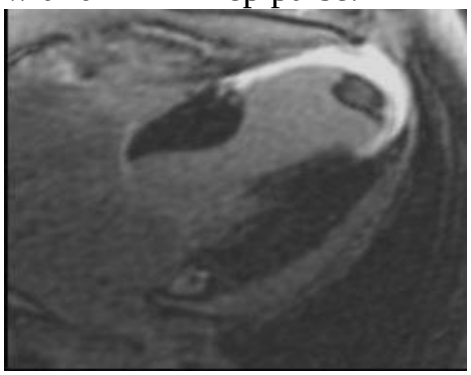
Function uses a gated 2D FIESTA PSD. It provides a multi-phase CINE high-frame rate acquisition mode for high-image quality breath-hold cardiac images that are added to the image database. This mode functions with both ECG2 or peripheral gating.



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



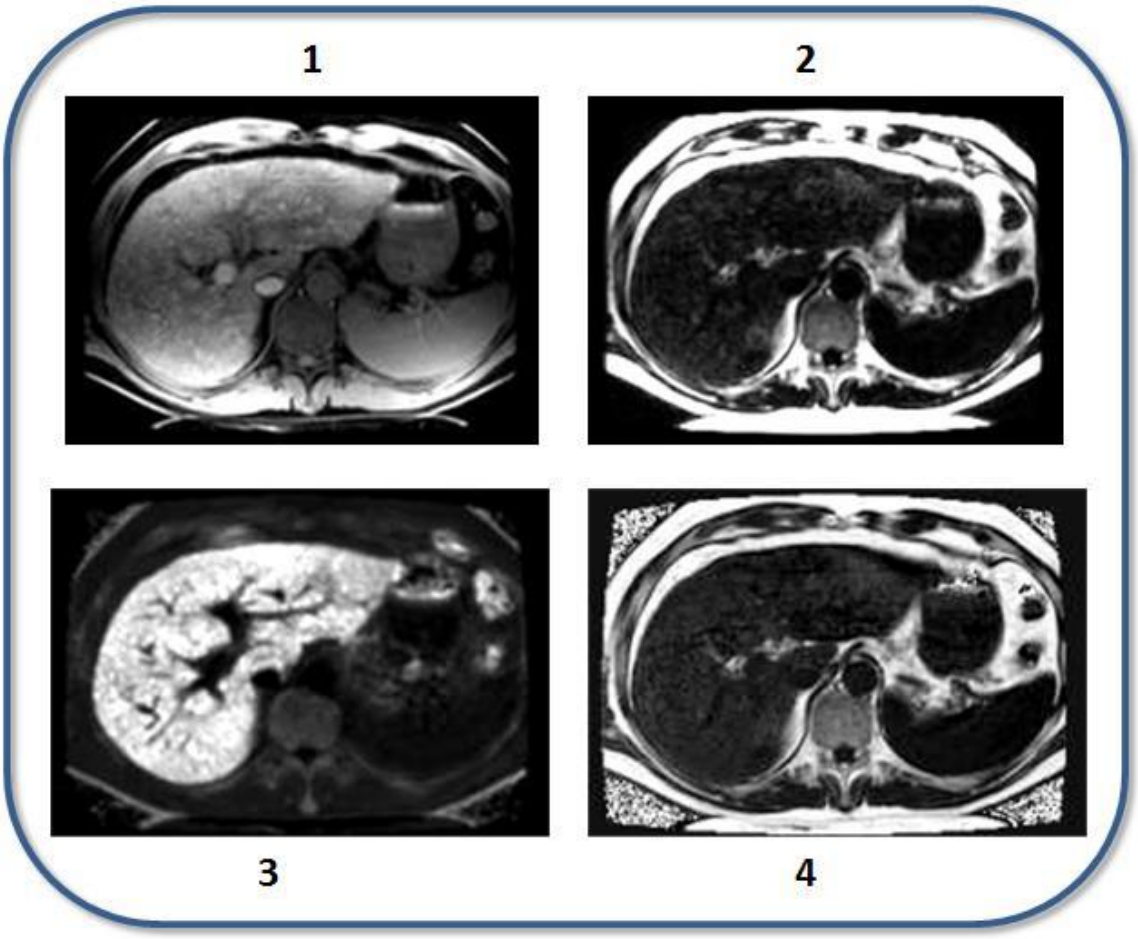
Myocardial Evaluation uses a single-phase, cardi ac-triggered Fast GRE with an IR1-Prep pulse.



IDEAL IQ

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

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

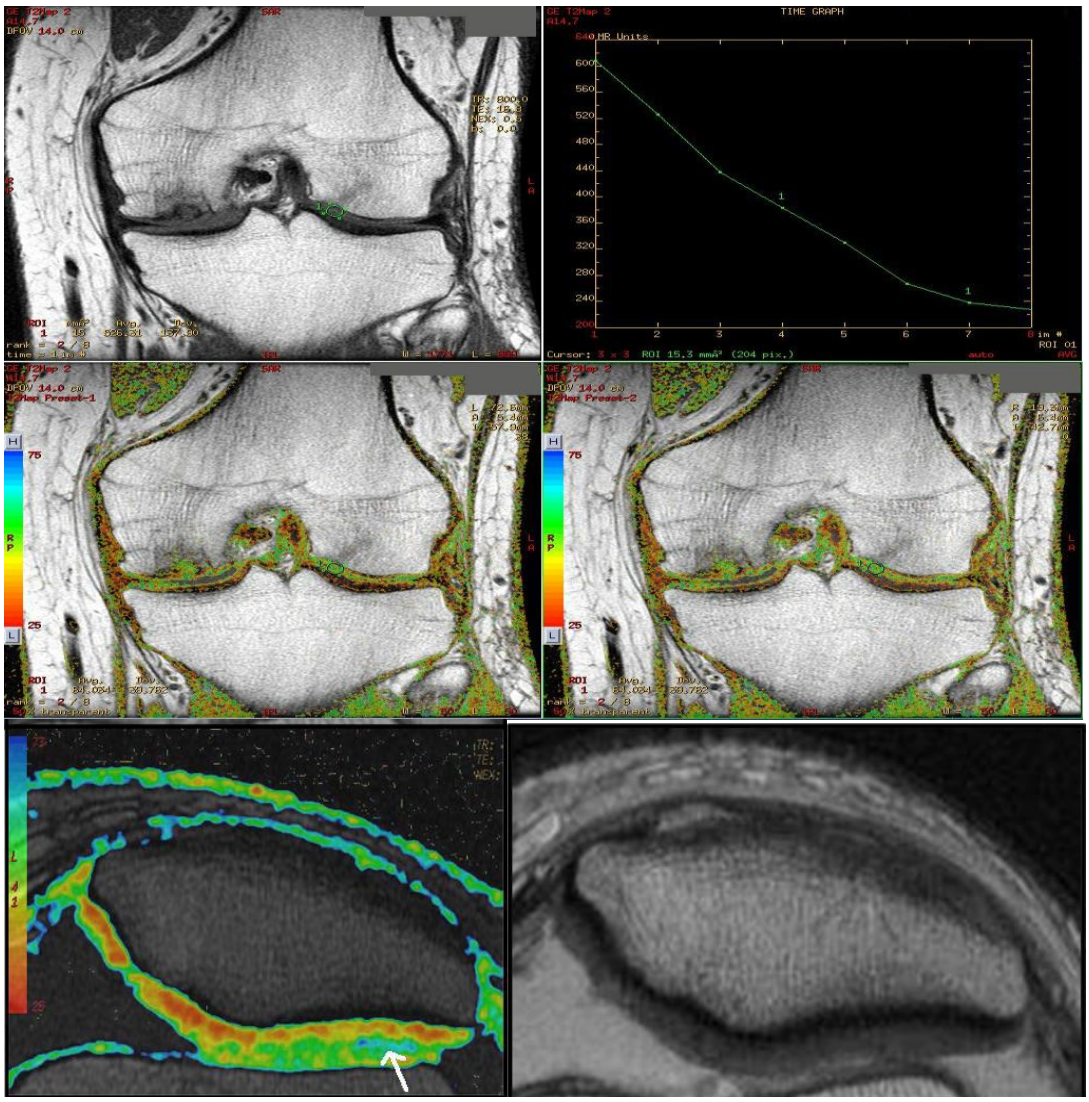


1= T2* corrected waterIDEAL IQ image ,2 T2* corrected triglyceride fat IDEAL IQ image ,3 R2* map IDEAL IQ image , 4 Triglyceride fat-fraction IDEAL IQ image

T2 Map (Cartigram)

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

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



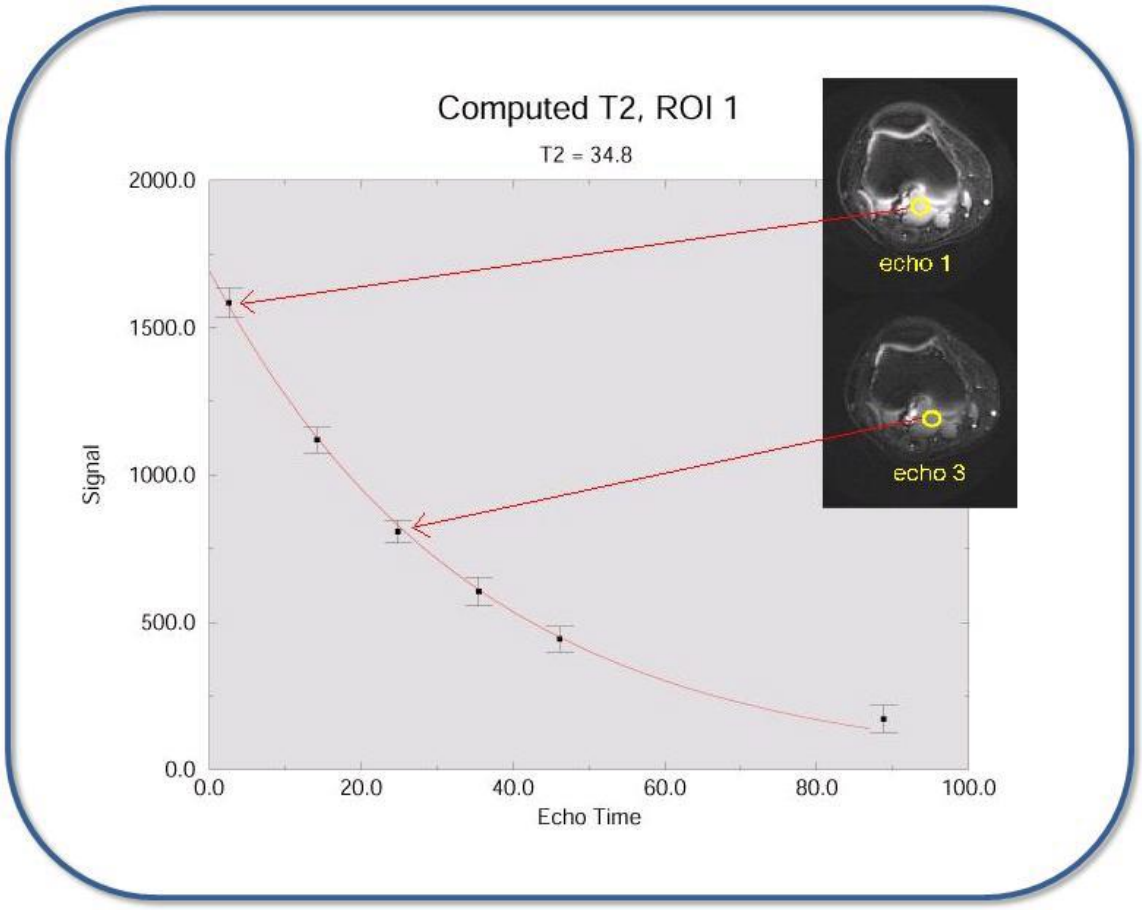
T2 Map

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

Background:

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

T2-weighted images because all lines of k-space are filled with one
(each individual) TE. This differs substantially from the traditional Fast Spin Echo sequence.



Perfusion weighted imaging

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

Two type of techniques

- Exogenous contrast
- Endogenous method

Exogenous method

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

Endogenous contrast

- ASL

Dynamic susceptibility imaging

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

Steps follow the workflow for the acquisition

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

The contrast agent

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

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

The acquisition of DSC-MRI data.

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

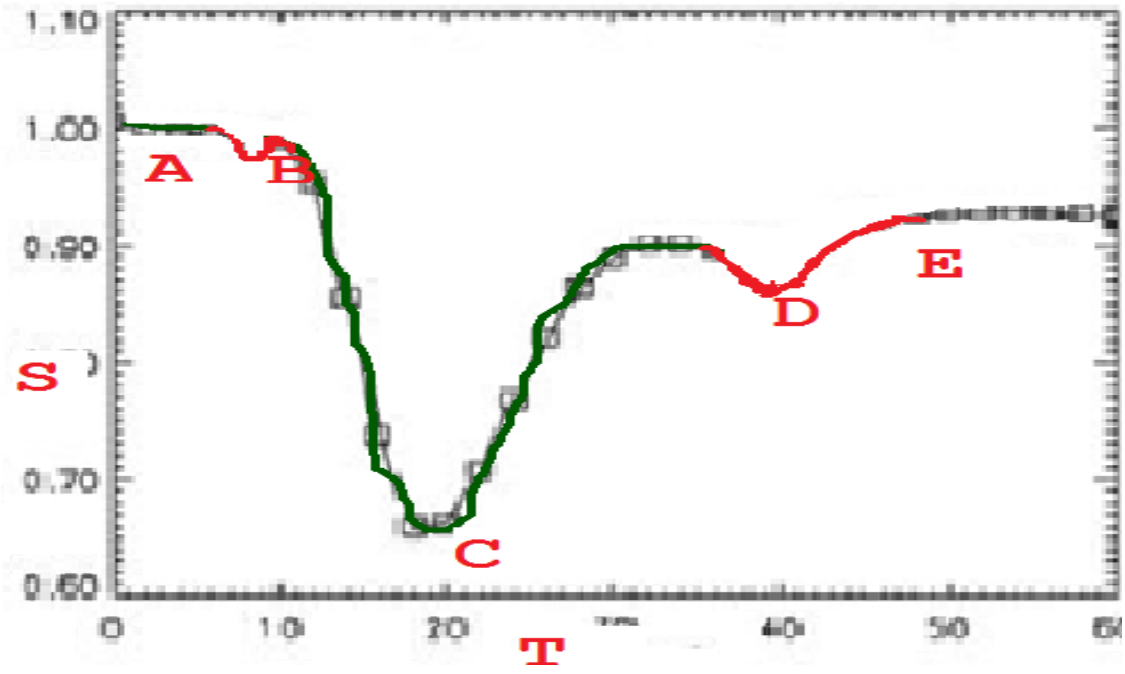
Alternative (less commonly available) acquisition methods have been implemented with a view to reduce EPI artifacts, whilst improving susceptibility contrast, spatial and temporal resolution. Segmented EPI has the advantage of less distortion, but is more sensitive to T1 effects because of shorter TRs.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

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

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

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

The Concentration–Time Course



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

Common Perfusion Parameters

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

Cerebral blood volume (CBV);

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

  CBF X MTT=CBV

Cerebral blood Flow (CBF);

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

Mean Transit Time (MTT)

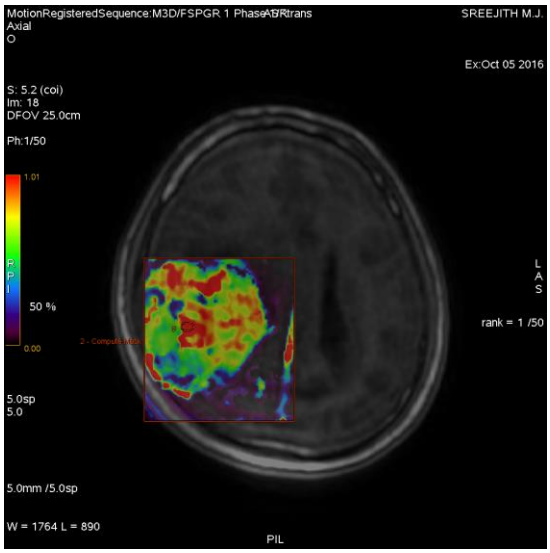
- Mean Transit Time (MTT)
- Average time to flow through capillaries (artery → vein)
- MTT=CBV/CBF
- Units: seconds
- 5 S

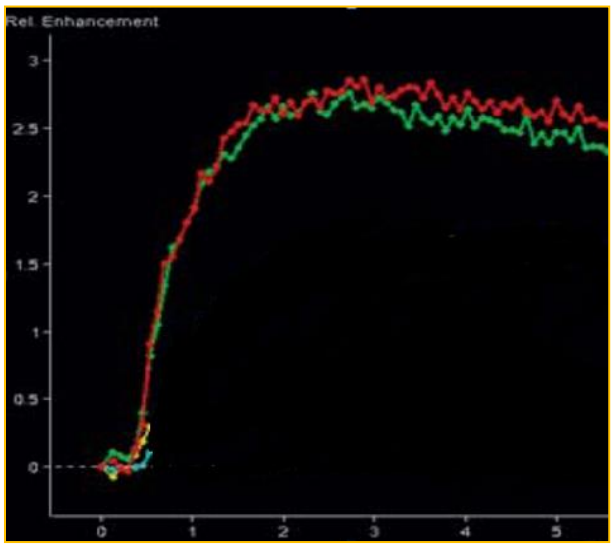
Time to maximum (Tmax)

- Tmax is the arrival delay between AIF and the tissue

DCE Perfusion (T1 perfusion)

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





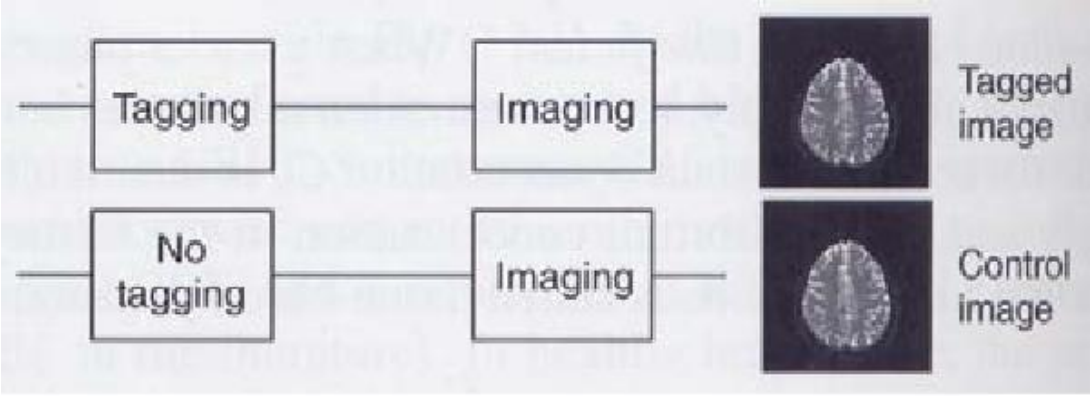
The upslope curve

Clinical application

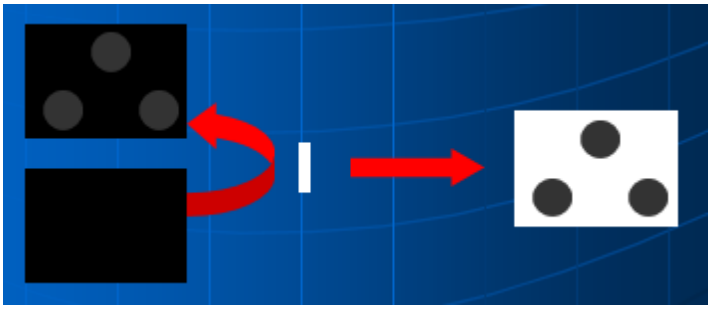
- Evaluation of ischemic penumbra in stroke.
- Classification of brain tumor.
- Grading of brain tumor.
- Cerebral infarction risk assessment
- Selection of patients for extracranial to intracranial bypass surgery
- Moyamoya evaluation
- Assessing risk of hyperperfusion syndrome
- Balloon test occlusion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

ASL

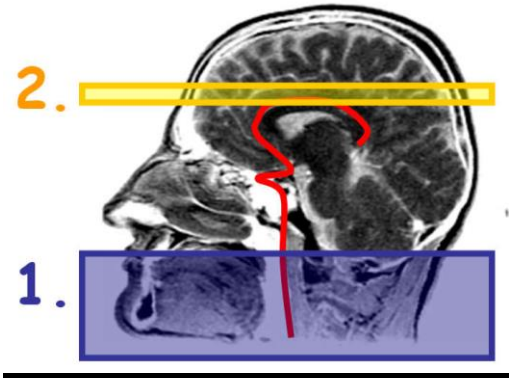
- ASL technique was conceived more than 15yrs ago.
- No exogenous contrast bolus required.
- ASL is based on labeling protons in the blood in supplying vessels outside the imaging plane and waiting for a period called post delay period for reaching the parenchyma.



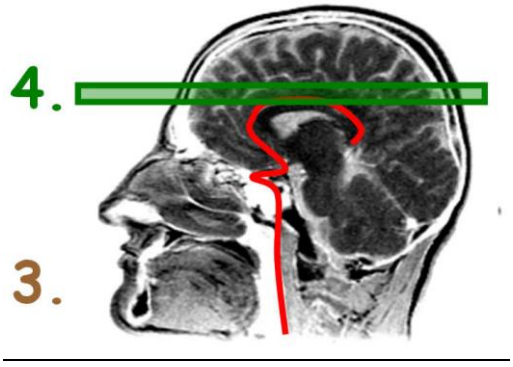
- Images are obtained from the parenchyma in labeled and controlled state.
- Subtracting these two type of images eliminates the static tissue signal will give CBF images.



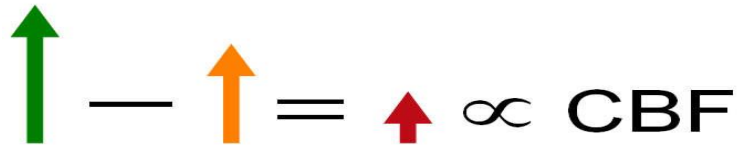
Principle of ASL

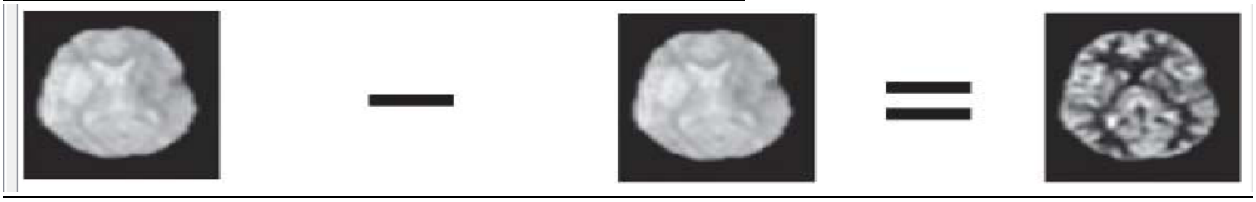


1Tag inflowing arterial blood by magnetic inversion
2. Acquire the **tag image**



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

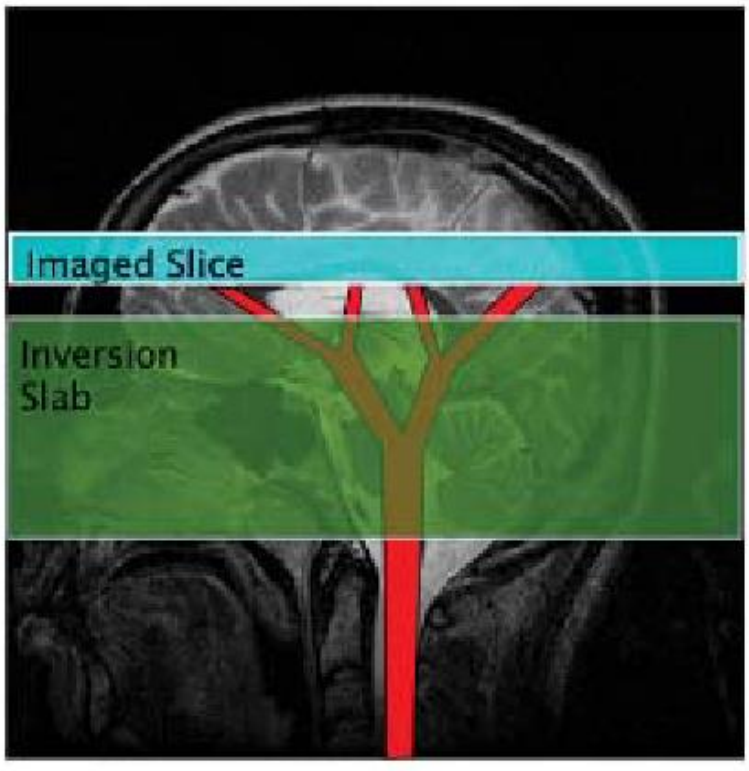




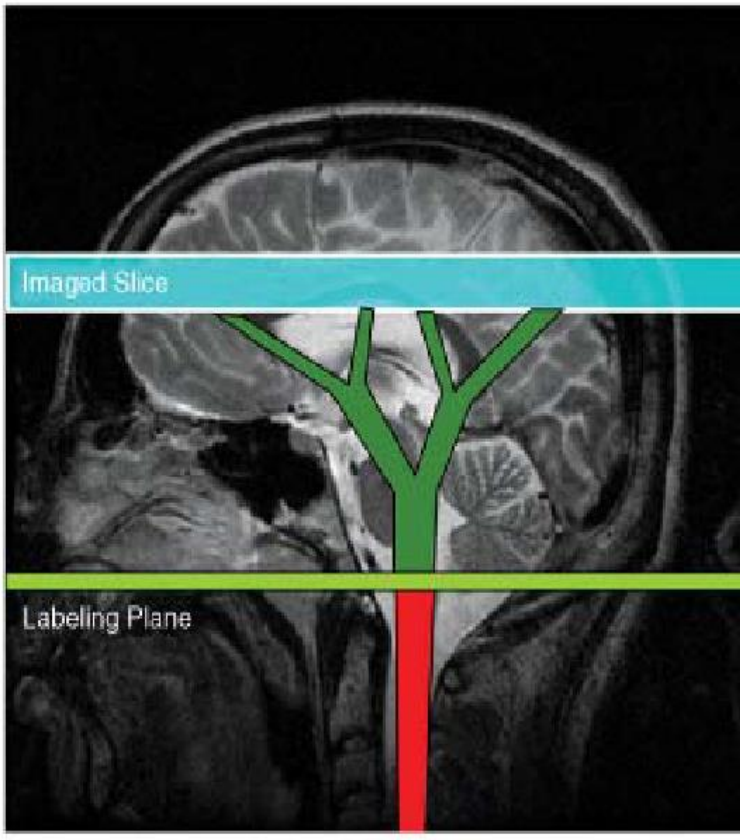
TYPES OF ASL

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

PASL



CASL



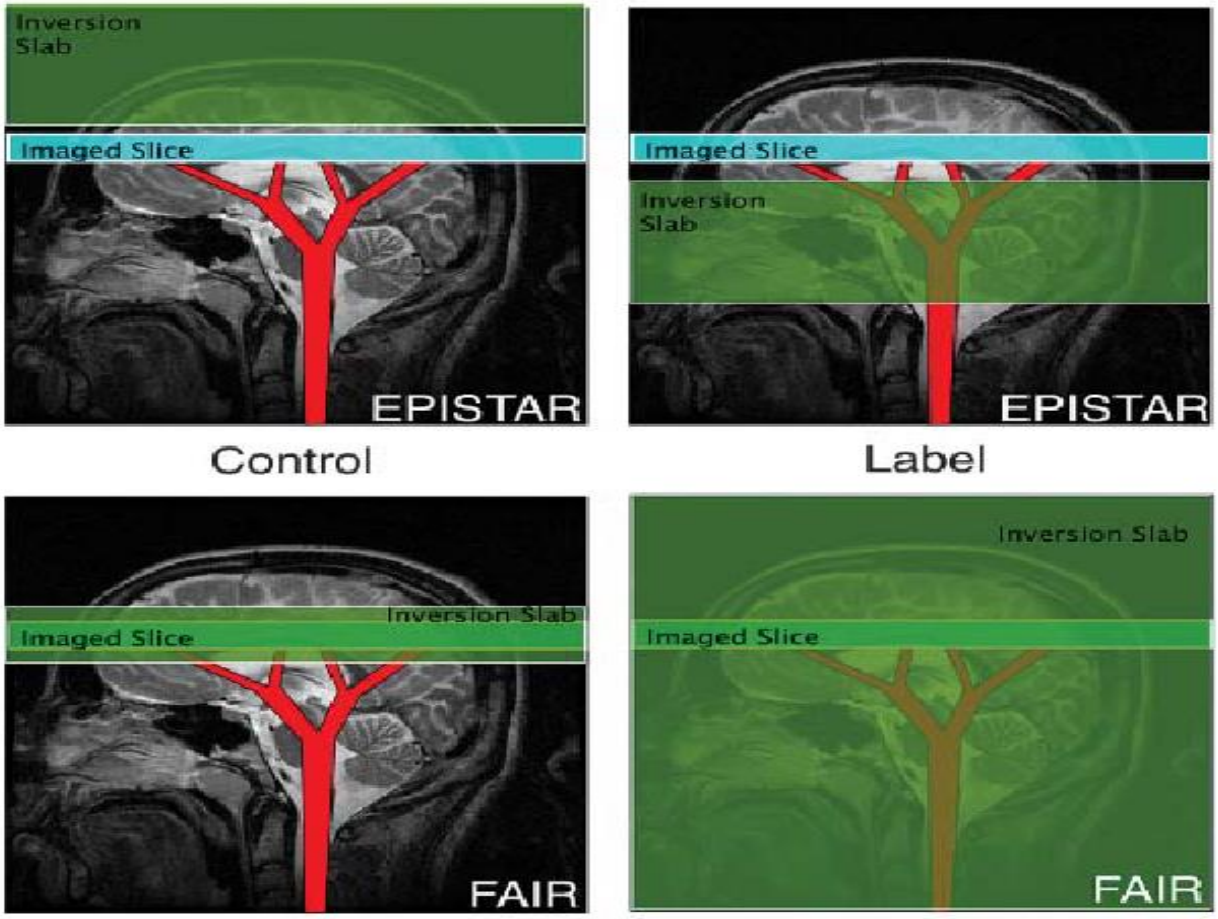
DAMIT

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

Sequence for ASL

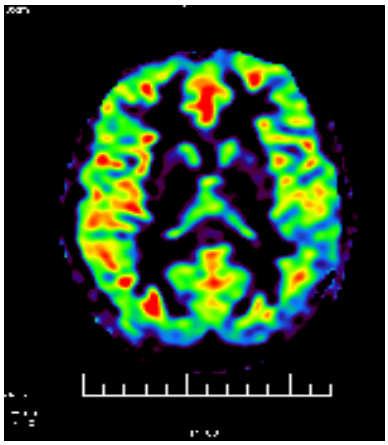
- EPISTAR-Echo planar imaging and signal targeting with all radiofrequency.
- PICORE-proximal imaging with a control for off resonance effect.
- TILT-transfer insensitive labeling technique.
- FAIR-flow sensitive alternating inversion recovery.
- FAIRER-FAIR with extra radiofrequency pulse.

BASE-basis image with selective inversion



Clinical application

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



Diffusion Tensor imaging

Diffusion

Random transnational molecular motions driven by internal kinetic energy.

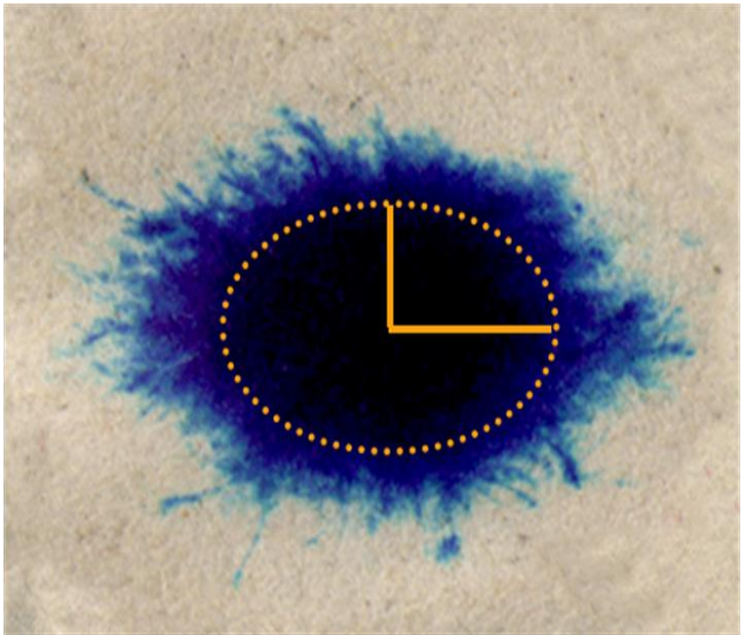
Observed in 1827, by Robert brown.

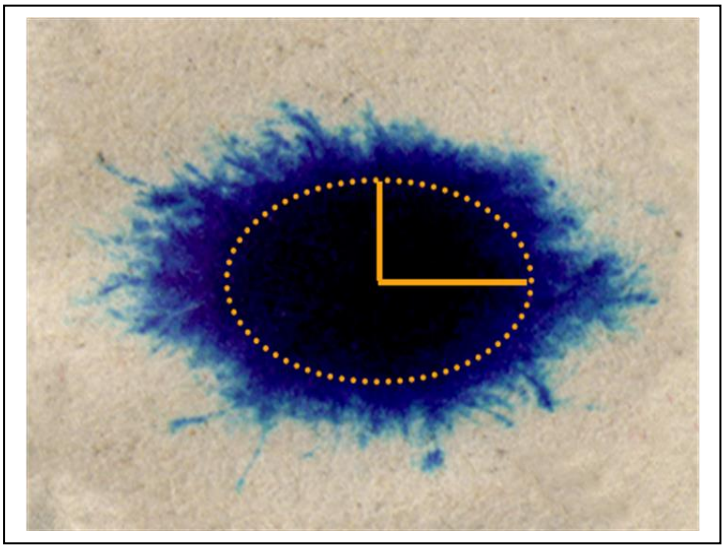
Diffusion refers to the transport of gas or liquid molecules through thermal agitation randomly, that is, it is a function of temperature above 0 K. In pure water, collisions between molecules cause a random movement without a preferred direction, called Brownian motion. This movement can be modeled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

Isotropy and anisotropy

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

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





Diffusion-Weighted Imaging

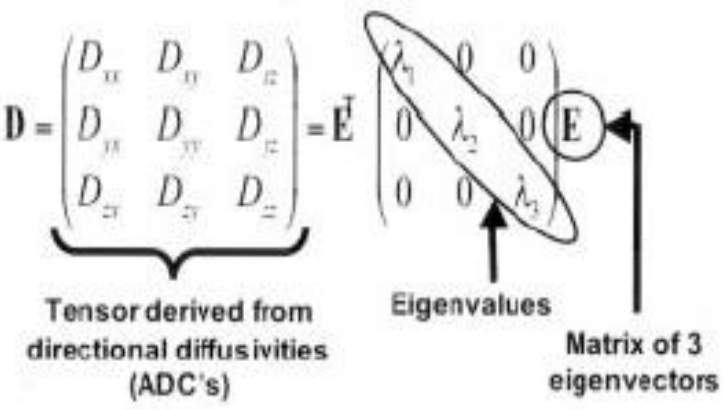
MR image contrast is based on intrinsic tissue properties and the use of specific pulse sequences and parameter adjustments. The image contrast is based on a combination of tissue properties and is denominated "weighted," as the contribution of different tissue properties are present, but one of them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

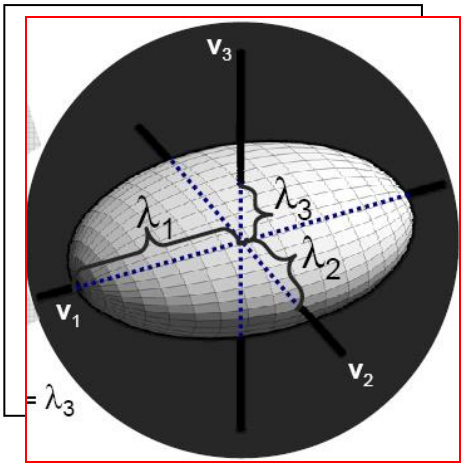
Routine acquisitions have some degree of diffusion influence that is actually quite small. Some strategies have been developed to make diffusion the major contrast contributor, and dedicated diffusion-weighted imaging (DWI) sequences are available nowadays on commercial

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

Diffusion tensor

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





Diffusion-weighting factors

Trace

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

b-Value

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

ADC maps

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

FA

- Degree of anisotropy

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

Clinical application

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

SWI / SWAN

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

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

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

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

Imaging acquisition and image processing

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

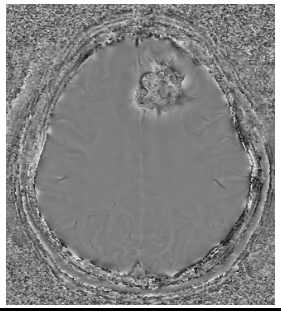
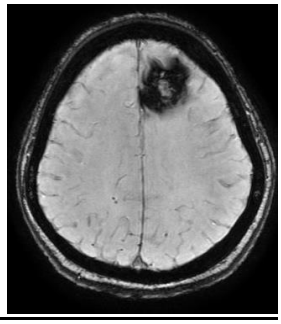
Usefulness of SWI phase imaging

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

Blood oxygen level-dependent MR Venography / small vessel imaging

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

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

Phase image	mIP image
	

Clinical applications

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

Functional MRI

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

fMR imaging uses blood-oxygen-level-dependent (BOLD) effects to localize regional cerebral blood flow changes temporally and spatially coupled with changes in neuronal activity. When groups of neurons are active, the blood flow to the active neurons increases in excess of what is needed to provide the additional oxygen consumed metabolically. The net result of increased
neuronal activity is a decrease in paramagnetic deoxygenated hemoglobin in the veins and capillaries within the vicinity of the active neurons. The amount of change depends on many factors including the nature of the task and the region of brain affected. The decrease in deoxy hemoglobin produces a small change in signal intensity, which is typically less than 5% in T2*-weighted images acquired at 1.5 Tesla. These slight changes in

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

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

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

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

Hemodynamic response

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

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

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

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

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

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

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

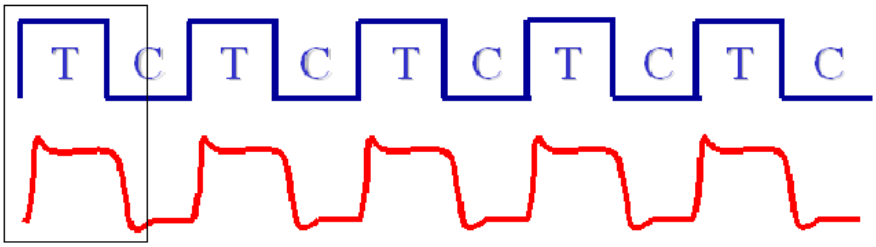
Hence there has been a push for larger field scanners to both improve localization and increase the signal

Types of f MRI

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

Block designs

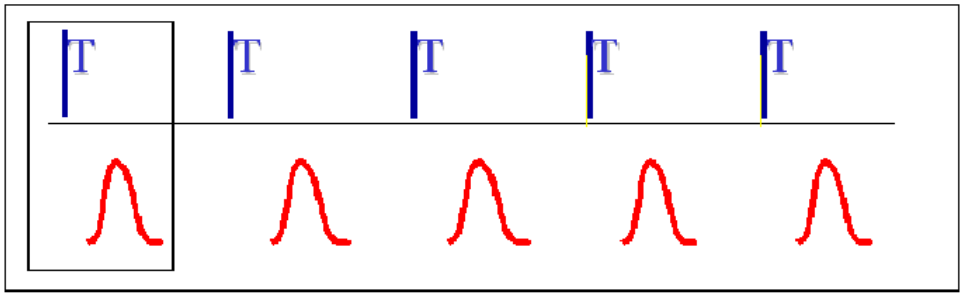
- First used in f MRI and still and the most useful in prevalent neurosurgery.
- It involves subject performs a task, alternated for a similar time with one or multiple control tasks.



Event related f MRI

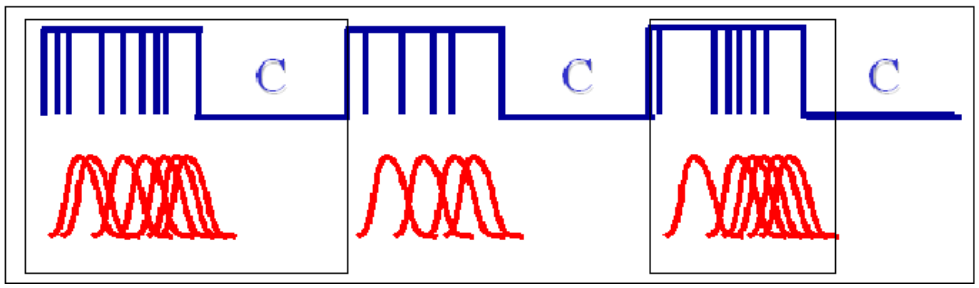
- The individual trials are randomized.

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



Mixed designs

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



Echo planar imaging

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

Clinical paradigms

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

Different types

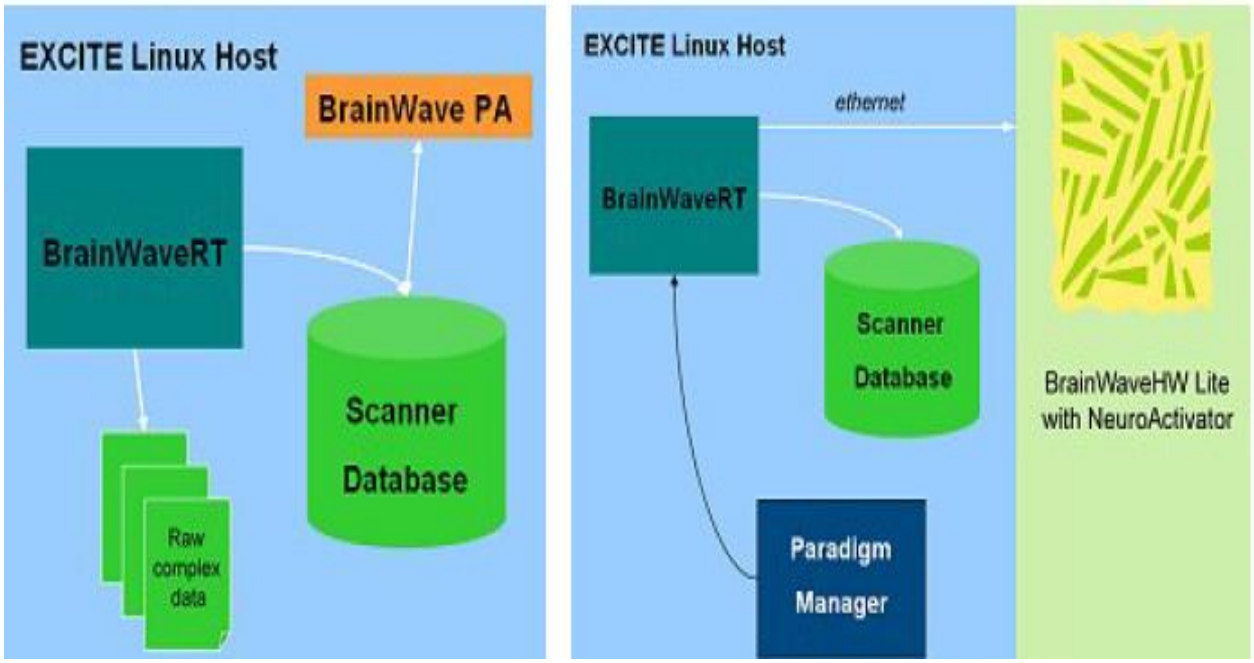
1. Motor paradigms
2. Bilateral finger tapping Vs Rest
3. Lip Pouting vs rest
4. Bilateral leg motor vs Rest
5. Language paradigms
6. Verb generation
7. Word pair
8. Syntax
9. Sematics

Clinical application

- Epilepsy
- Surgical planning

BrainWave- Application for fMRI processing in 3T

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

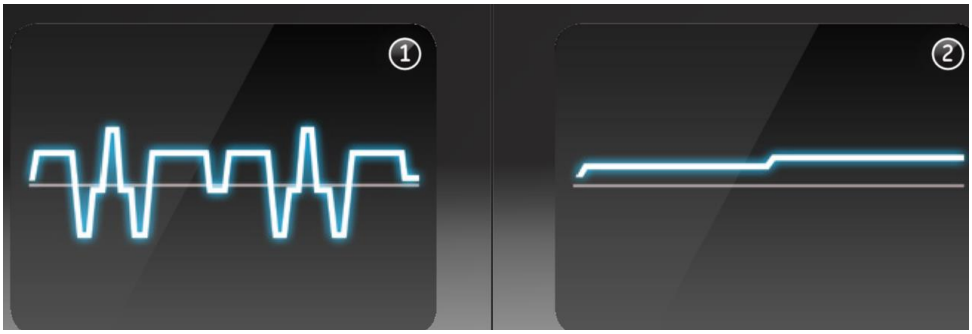


BrainWaveHW Lite comprises equipment used to create custom audio, visual, language and motor paradigms and play them out into the patient environment when used with BrainWaveRT. This equipment consists of a stimulus computer mounted in a rack in the MR equipment room. Paradigm Studio software on
the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

SILENT MRI

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

1 Conventional MR gradient sequence
2 Silent gradient sequence



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

COMPUTED TOMOGRAPHY

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

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

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

System specification

Brilliance iCT

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

X-ray tube

X-ray Tube

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

Detectors

Detector

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

Collimators

Collimator

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

Image Quality

Image Quality

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

Advances in CT

- Cardiac CT
- CT perfusion

Cardiac CT

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

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

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

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

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

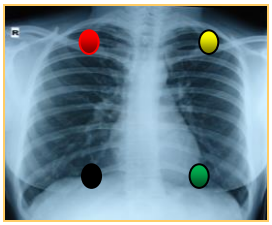
To acquire data over several heart cycles, scanning has to be done in relation to the heart beat. Retrospective ECG gating is therefore useful.

PHILIPS BRILLIANCE iCT 256-SLICE CT SCANNER

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

ECG CONNECTING TO PATIENT

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



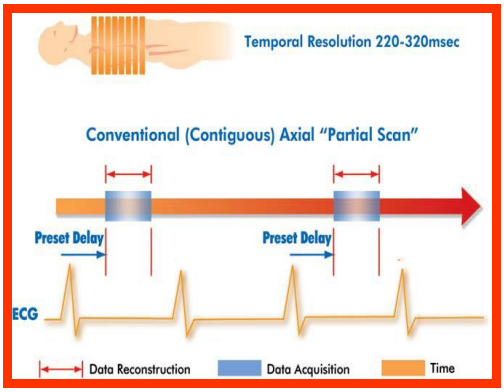
- Red electrode: on the right mid-clavicular line, directly below the clavicle
- Yellow electrode: on the left mid-clavicular line, directly below the clavicle
- Black electrode: right mid-clavicular line, 6 or 7 intercostal space
- Green electrode : on the left mid-clavicular line, 6 or 7 intercostal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

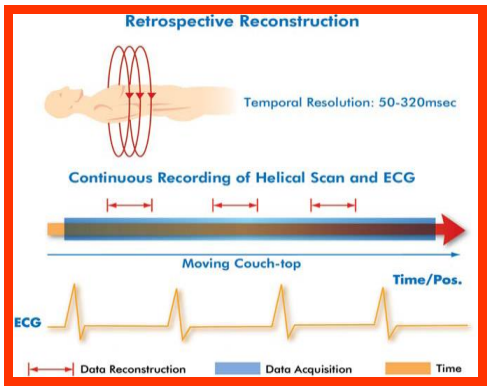
TWO MODES OF ACQUISITION

i. PROSPECTIVE
ii. RETROSPECTIVE

PROSPECTIVE SCANNING (AXIAL)

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





RETROSPECTIVE SCANNING (SPIRAL)

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

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

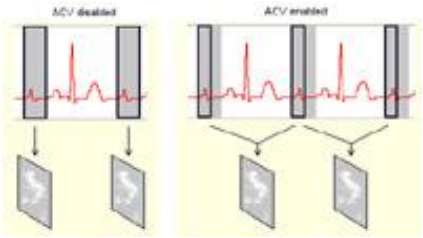
IMAGE RECONSTRUCTION

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

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

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

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

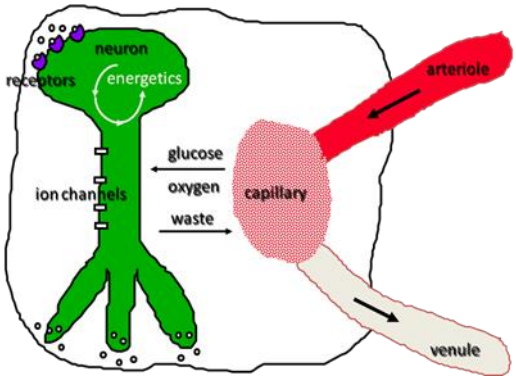


With the collimated slice width used (0.625 mm), images of nominal slice width of 0.625, 1, 2 and 3 mm can be reconstructed. We recommend to use slice widths of 1 mm to increase image quality by reducing artifacts.

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

PERFUSION CT

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



CERBRAL HEMODYNAMICS

CBV

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

CBF

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

MTT

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

Historical aspects of perfusion imaging

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

Applications of CTP

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

II. Tumours

Protocol of CTP

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

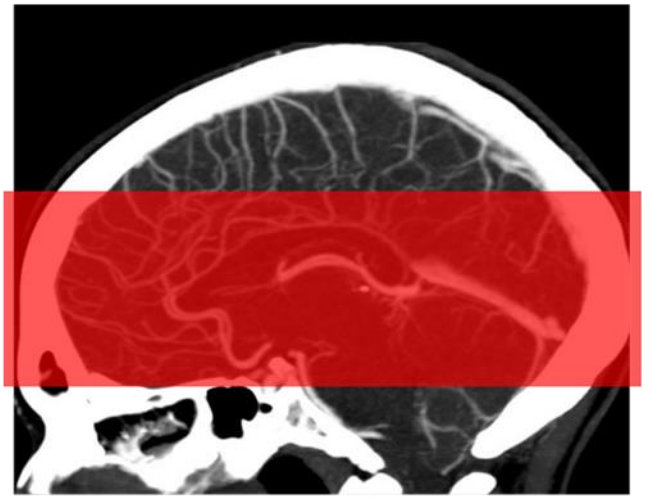
Steps of CT Perfusion Scan

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

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

1. Jog mode
2. Non-jog mode

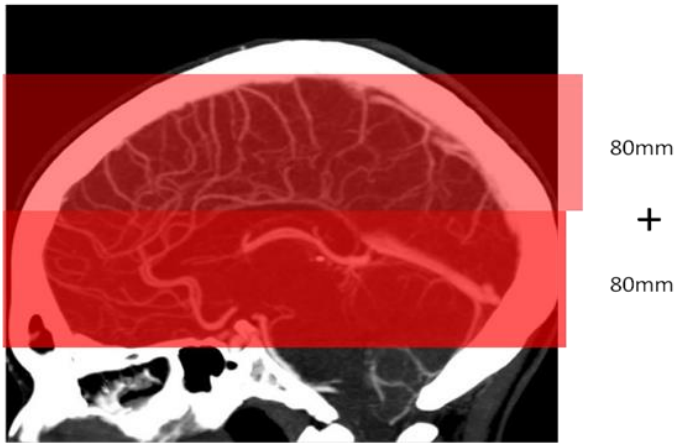
➢ NON-JOG MODE



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

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

➢ JOG SCAN



Total Scan Area: 160 mm (16cm)

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

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

Digital Subtraction angiography

System specification

Innova 3131

Company	GE Healthcare
Model	Innova 3131
Type	Biplane digital flat panel fluoroscopic system
Acquisition zoom	Yes
Other imaging software options	Fluoro, DSA, instant mapping, cine, Innova Breeze runoff, Innova Chase, Innova Sub 3-D and CT, stenosis & vent analysis
Minimum room size to accommodate system	19.8 x 24 feet, 6 in. procedure
PATIENT TABLE	
Motion	8-way horizontal float
Length x width, cm (inches)	Omega V table: 333 (131) x 46 (18)
Vertical range, cm (inches)	Omega V table: 30 (12)
Lateral range, cm (inches)	Omega V table: 14 (5.5)
Longitudinal, cm (inches)	All tables up to 170 (66.9)
Tilt	NA
Maximum patient weight, lb.	All tables 450
X-ray density	Omega V table < 1 mm AI
Swivel	NA

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

Materials used for Neuro and Peripheral Interventions

MICRO CATHETER

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

FasTRACKER-10

MICROCATHETERS

OVER THE WIRE MICRO CATHETER

FLOW GUIDED CATHETER

OVER THE WIRE MICROCATHETERS

Used for the infusion of thrombolytic agent.

Echelon™ Micro Catheter

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

pre-shaped microcatheters offer the best tip shape out of the package and after simulated use.

Rebar™ Micro Catheter

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

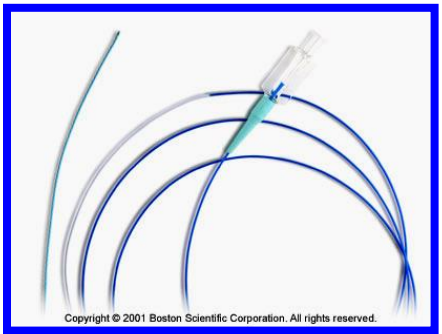
Prowler microcatheter(braided)

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

FLOW GUIDED MICROCATHETERS

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

SPINNAKER ELITE



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

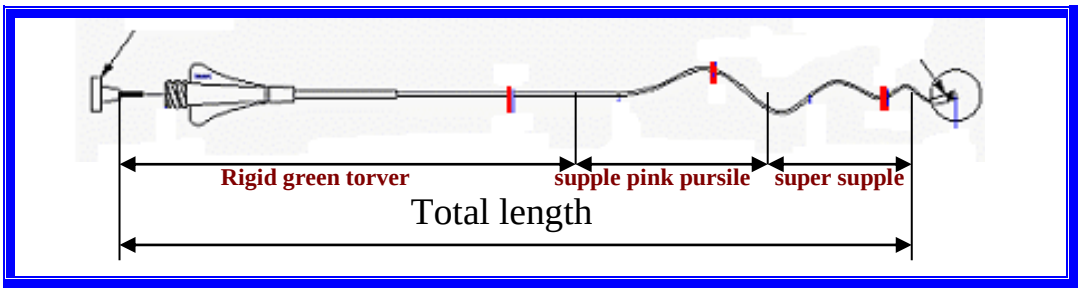
Marathon™ Flow Directed Micro Catheter

Developed as an Onyx Delivery Catheter, the Marathon offers the user the lowest available tip profile while providing unmatched burst and tensile strength, making it the ideal catheter for the treatment of Brain AVMs.It has proximal pushability due to the stainless steel coil reinforcement in proximal shaft.Soft flow-directable distal segment Distal tip of 1.3F, marker band profile of 1.4F and robust reinforcement Nitinol braid reinforcement in distal "floppy" segment and has lubricious (PTFE) ID liner - from hub to tip for excellent guidewire interaction

BALT MAGIC

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

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

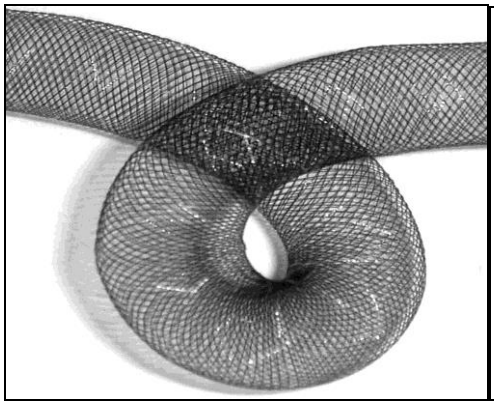


OBLITERATION PROCEDURE

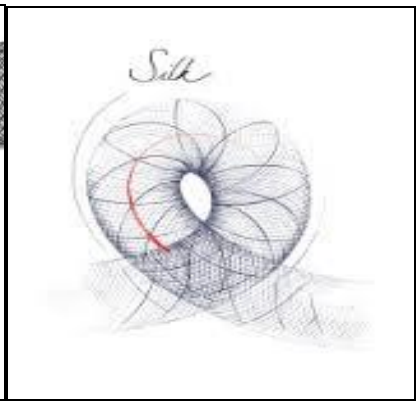
Otherwise referred to as 'Therapeutic Embolisation', using particulate materials delivered through micro catheters can be used in settings of acute bleeding from tumor vessels, vascular malformations, Aneurysms, Vascular tumors. Embolic materials in use include alcohol, metallic coils, gel foam,vascular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

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

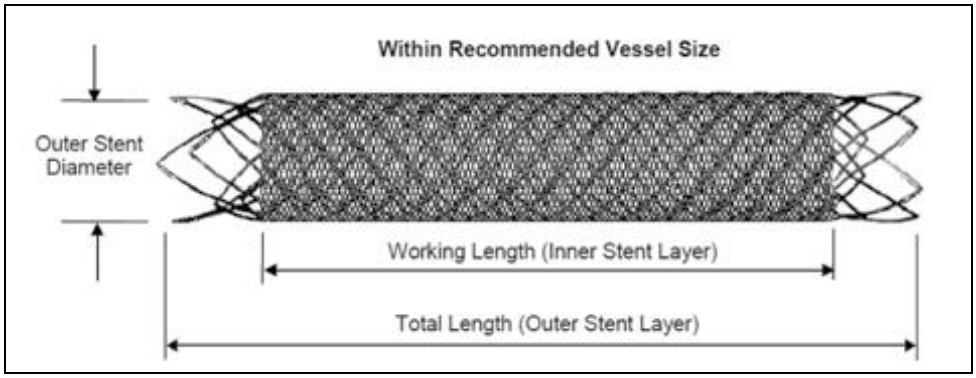
- **Pipeline embolization device** (PED ev3/ Covidien, Irvine, California)
- **Silk flow diverter (**SILK; Balt Extrusion, Montmorency, France)
- **Fred flow diverter(**FRED, Microvention, Terumo,P64)
- **Surpass flow diverter(**SURPASS; Stryker Neurovascular, Fremont)
- **phenox64 (p64)**



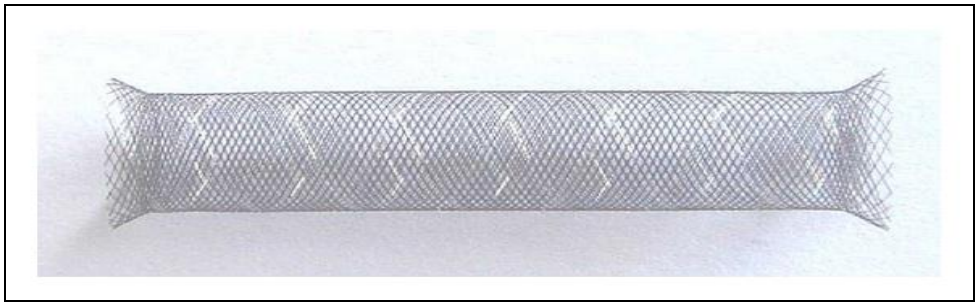
Pipeline flow diverter



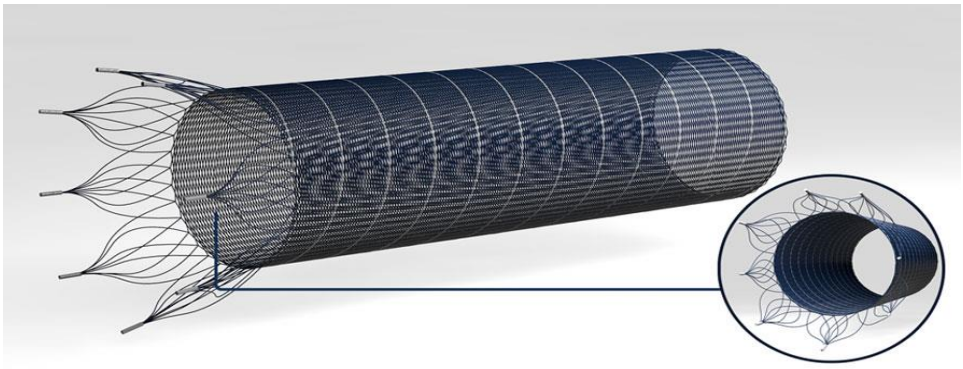
Silk flow diverter



Fred system



Surpass flow diverter



P64 by phenox

Aortic and Carotid Stents

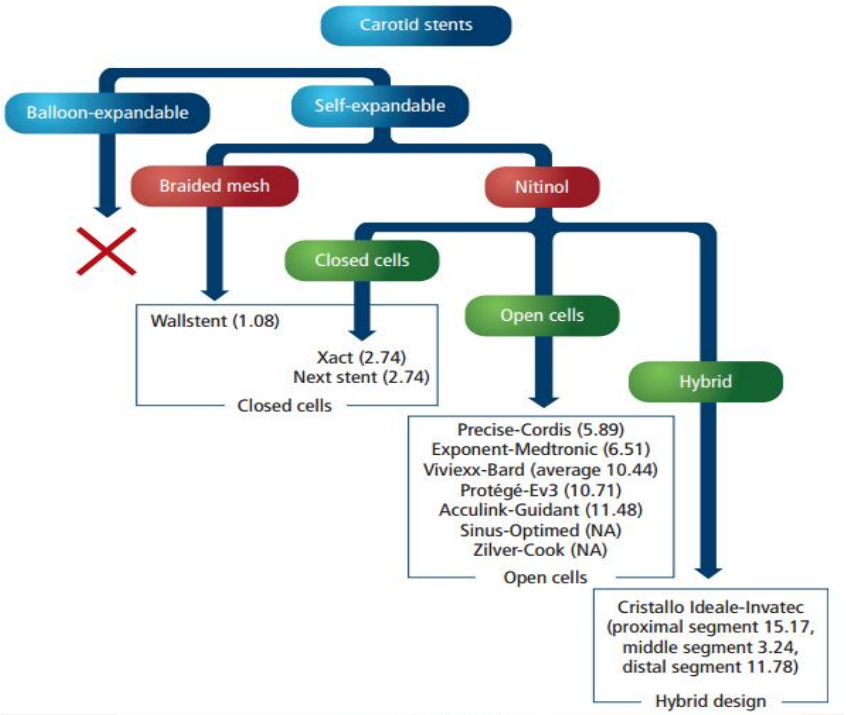
- Widest range of diameters currently available
  - Proximal five-peak bare spring allows for crossing the LCC or LSA without occluding blood flow4
  - Tapered distal main
  - Distal bare spring option to avoid covering the celiac artery

Thoracic covered stent graft

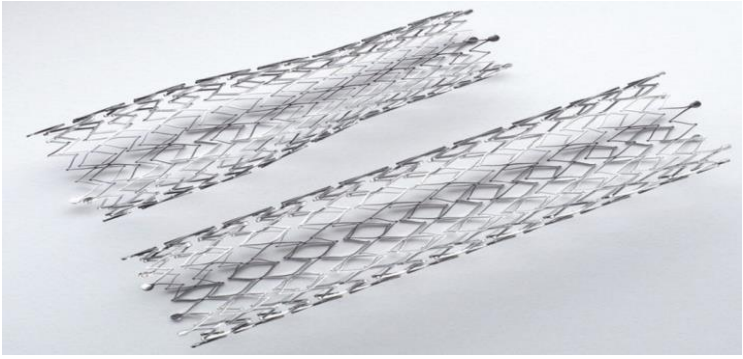
Carotid stent

Stent Technical Features

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



Cristallo ideale…. …..Protage Rx



LIQUID EMBOLIC AGENTS

Liquid agents for interventional procedures consist of ,

CYANOACRYLATES (GLUE)

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

HISTOACRYL CONCENTRATION CHART

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

DEHYDRATED ALCOHOL

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

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

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

ONYX/SQUID

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

PHIL- Precipitating Hydrophobic Injectable Liquid

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

PENUMBRA –ACE

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

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