차 지 훈
삼성서울병원 영상의학과

Neuroimaging for the General Neurologists - Vascular Imaging

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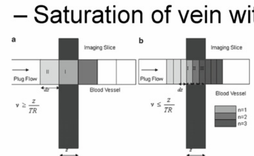
Contents

- MR angiography
  - Physics
  - Pitfalls
- MR venography
  - Cases
- MR vessel wall imaging
  - Concept
  - Protocols
  - Cases

Time-of-flight (TOF) MRA

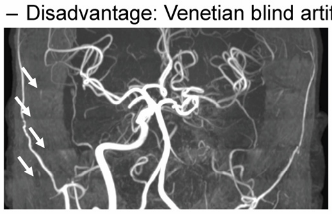
- Flow related enhancement
  - Static spin saturation using short TR
    - TR/TE 25/3.5 ms
  - High signal of unsaturated inflow blood
    - Flow related enhancement
  - Saturation of vein with saturation slap



Time-of-Flight Angiography. Seong-Eun Kim and Dennis L. Parker

Time-of-flight (TOF) MRA

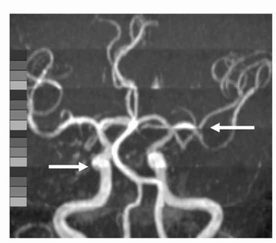
- MOTSA (multiple overlapping thin 3D slab acquisition)
  - Compansation for saturation of blood during moving through the slap
  - Disadvantage: Venetian blind artifact

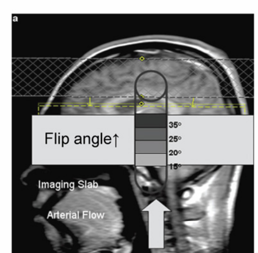


Time-of-Flight Angiography. Seong-Eun Kim and Dennis L. Parker

Time-of-flight (TOF) MRA

- TONE (Tilted Optimized Non-saturating Excitation) pulse

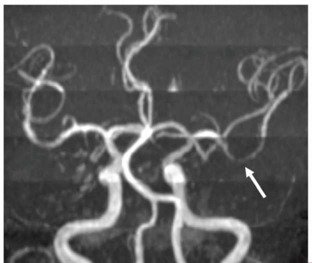




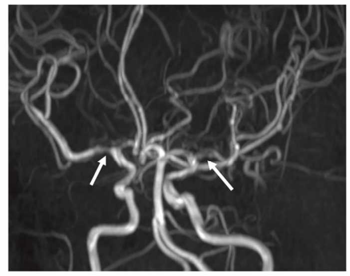
Time-of-Flight Angiography. Seong-Eun Kim and Dennis L. Parker

Pitfalls in TOF MRA

- Inplane saturation
  - Stay long time in single slap → saturation

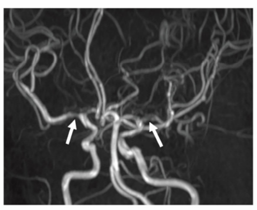


Pitfalls in TOF MRA

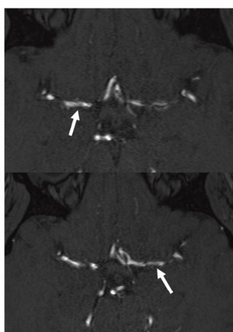


MCA stenosis?

Pitfalls in TOF MRA

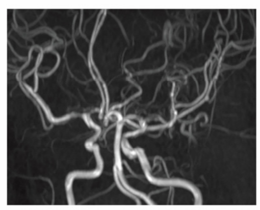


Irregular decreased signal
with diagonal pattern
Increased flow velocity

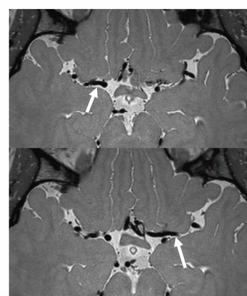


Pitfalls in TOF MRA

- Pseudostenosis d/t related intravoxel dephasing (fast flow)

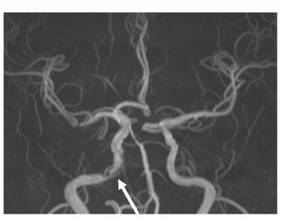


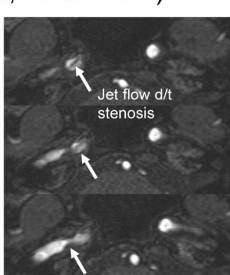
No stenosis or intraluminal
lesion on vessel wall imaging



Pitfalls in TOF MRA

- Pseudostenosis d/t related intravoxel dephasing (turbulence, vortex flow)





Pitfalls in TOF MRA

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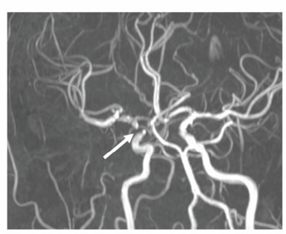
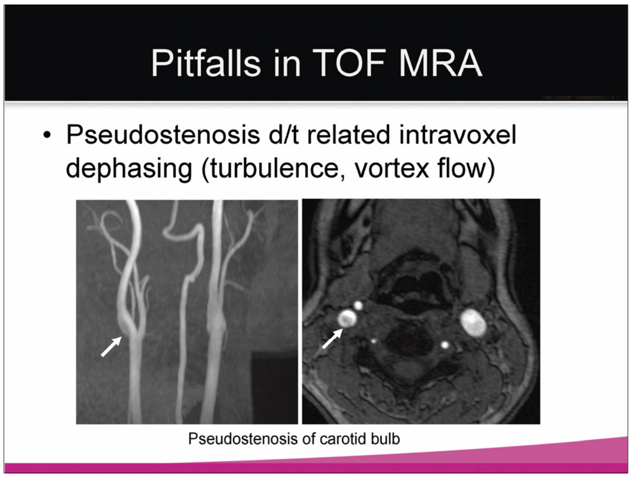
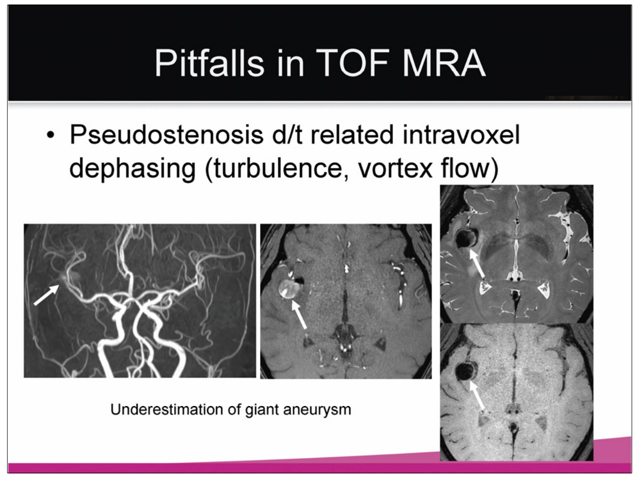
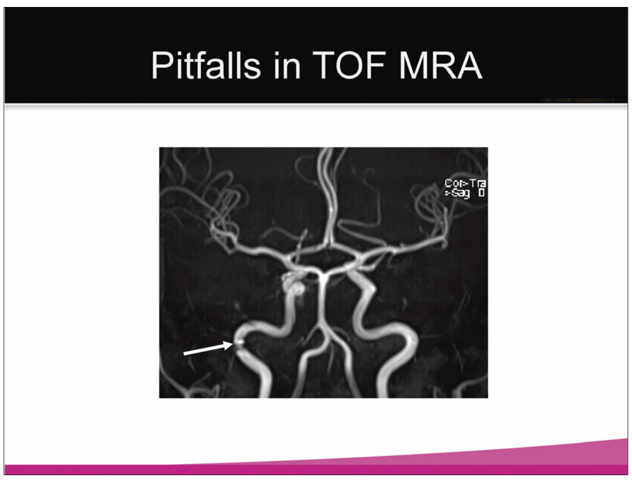
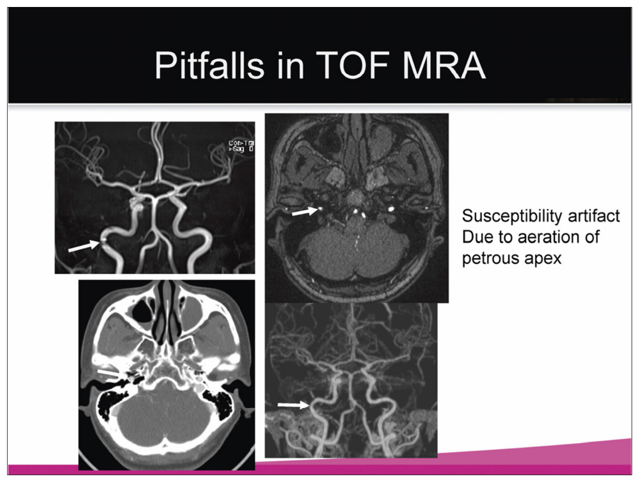


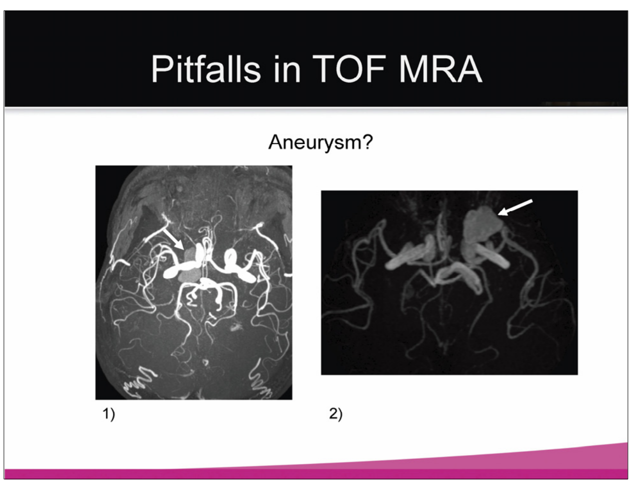
Overestimation of stenosis

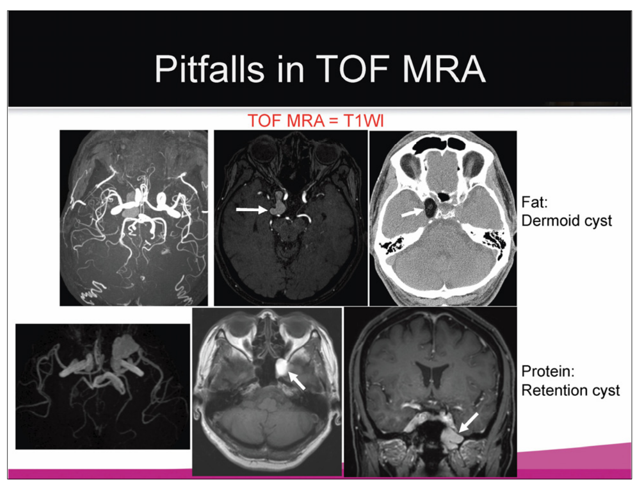

Pitfalls in TOF MRA
• Pseudostenosis d/t related intravoxel dephasing (turbulence, vortex flow)
Pseudostenosis of carotid bulb


Pitfalls in TOF MRA
• Pseudostenosis d/t related intravoxel dephasing (turbulence, vortex flow)
Underestimation of giant aneurysm


Pitfalls in TOF MRA

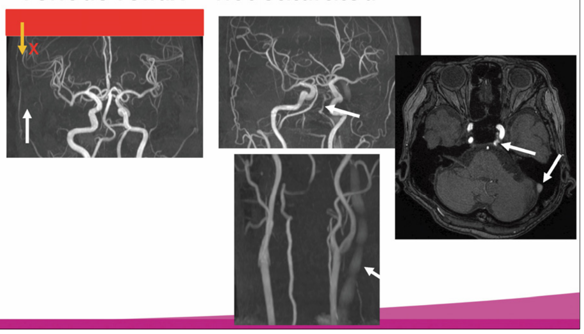

Pitfalls in TOF MRA
Susceptibility artifact
Due to aeration of
petrous apex


Pitfalls in TOF MRA
Aneurysm?
1)
2)


Pitfalls in TOF MRA
TOF MRA = T1WI
Fat:
Dermoid cyst
Protein:
Retention cyst

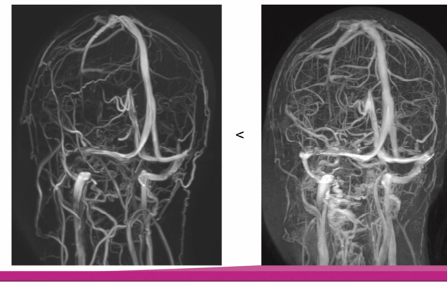
Pitfalls in TOF MRA

- Venous reflux – not saturated

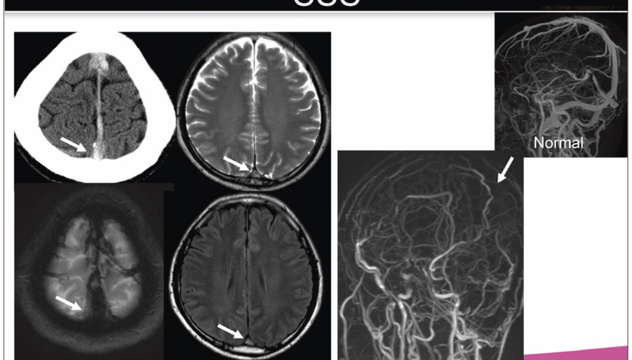


MR venography

- PC (phase contrast) venography
- Contrast enhanced MR venography

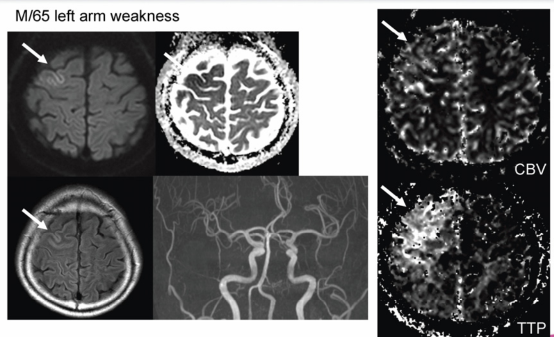


Venous thrombosis - SSS

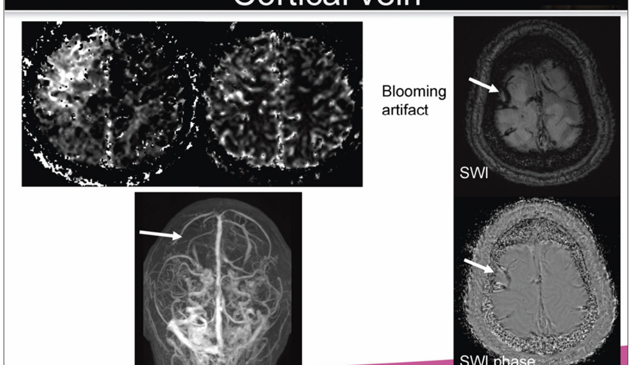


Venous thrombosis - Cortical vein

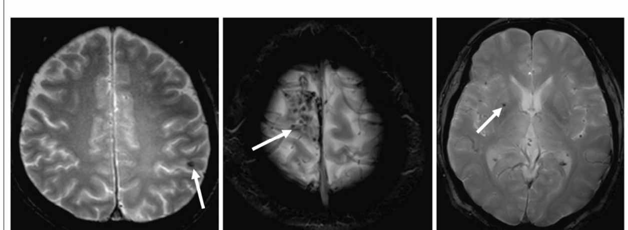
M/65 left arm weakness



Venous thrombosis - Cortical vein

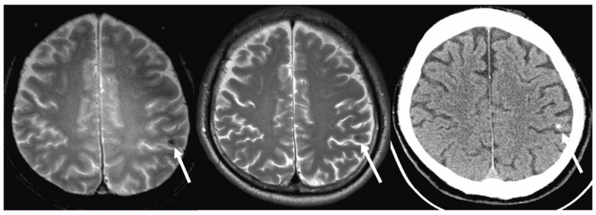


GRE: hemorrhage?

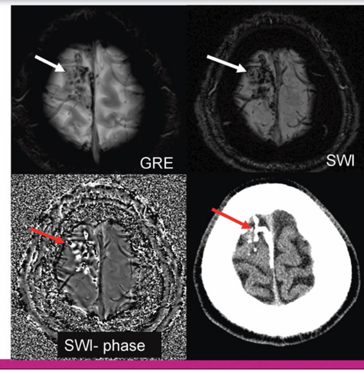


1) 2) 3)

1) Calcified granuloma



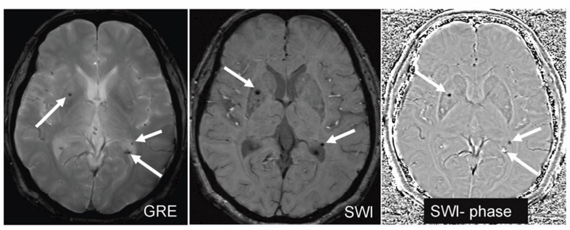
2) Dural calcification



Susceptibility weighted image (SWI)
> gradient echo (GRE)

Hemorrhage – dark
Calcification – bright

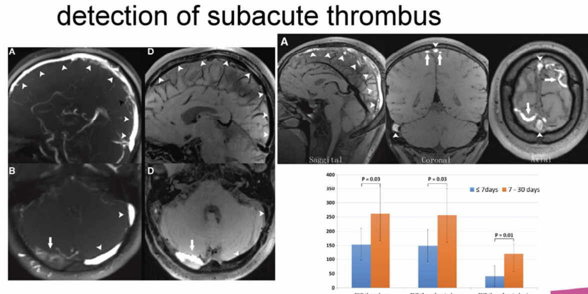
3) Microbleed



Hemorrhage – dark
Calcification – bright

Black blood imaging for thrombus detection

- Black blood 3D variable flip angle TSE for detection of subacute thrombus



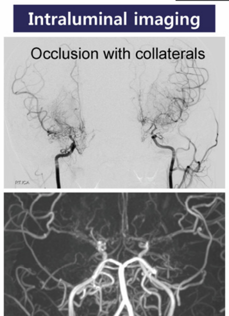
Qi Yang *et el. stroke 2016*

MR vessel wall imaging

Moyamoya disease

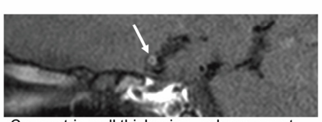
Intraluminal imaging

Occlusion with collaterals



Vessel wall imaging

Outer contour of vessel
- Negative wall remodeling



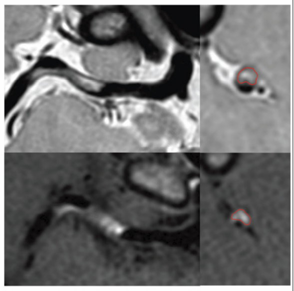
Concentric wall thickening, enhancement

Characteristics of intracranial vessel wall imaging

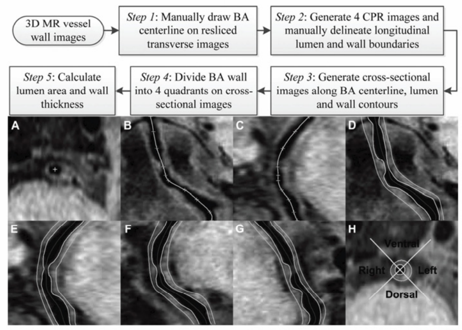
- High resolution, black blood MR imaging
  - Intraluminal (stenosis) → vessel wall pathology
    - Wall thickening, wall signal, enhancement, remodeling
  - High resolution imaging, 3D imaging perferred
    - MCA diameter: 2~3mm, normal vessel wall<0.4mm
    - In-plane resolution ≤0.4~0.7mm
    - Isotropic voxel 3D imaging ≤0.4~0.7^{3}mm
  - Black blood imaging
    - White blood (angiography) vs black blood (wall imaging)

Vessel wall imaging protocol

- Vessel wall imaging
  - 2D – T1/T2/PD/CE
  - → 3D
    - Spin echo (VISTA, SPACE, Cube), gradient echo (MPRAGE)
    - Flow suppression
      - iMSDE, DANTE
    - Curved planar reconstruction (CPR)

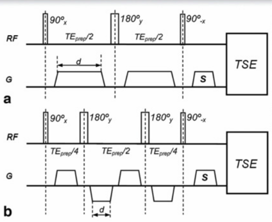


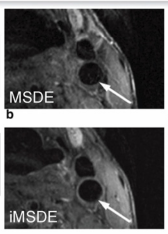
Semiautomated BA plaque analysis

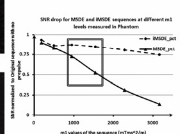


Zhensen Chen *et al. JMRI 2016*

MSDE vs improved MSDE







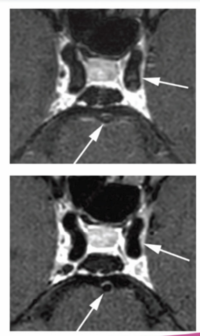
20-60% higher SNR

- Sets of diffusion gradient to suppress moving spins
- iMSDE: extra refocusing pulse and gradients
  - Compensate eddy currents and local B_1 inhomogeneity.
  - Improved soft-tissue SNR and CNR without sacrificing flow suppression capability and time efficiency

Wang et al. JMRI 2010

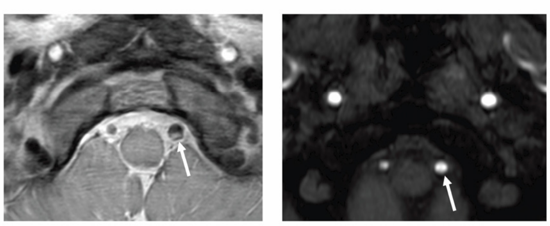
VISTA with/without iMSDE

- Without iMSDE
  - High SNR
  - Poor suppression of
    - Slow flow large artery
    - Small artery
    - Vein
- With iMSDE
  - Low SNR (20~30% loss)
  - Better suppression of blood
    - Especially after contrast enhancement



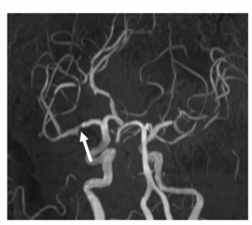
VISTA with/without iMSDE

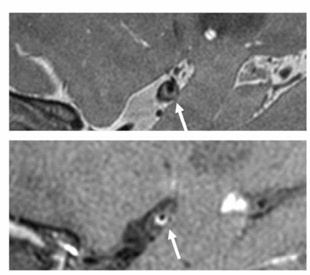
- Pseudolesion due to unsuppressed blood



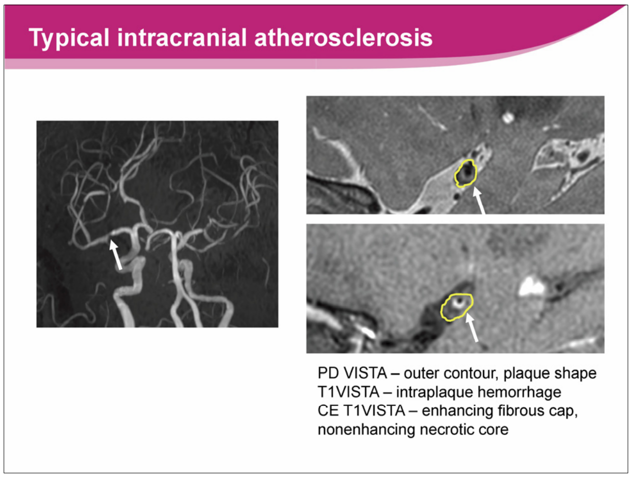
Artifact > dissection

Typical intracranial atherosclerosis





PD VISTA – outer contour, plaque shape
T1VISTA – intraplaque hemorrhage
CE T1VISTA – enhancing fibrous cap, nonenhancing necrotic core


Typical intracranial atherosclerosis
PD VISTA – outer contour, plaque shape
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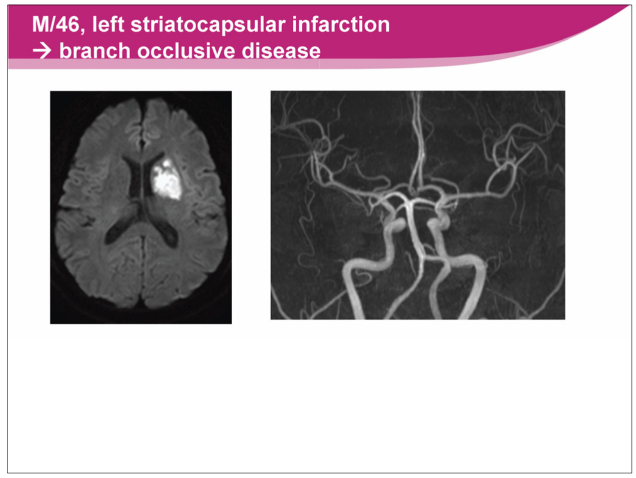
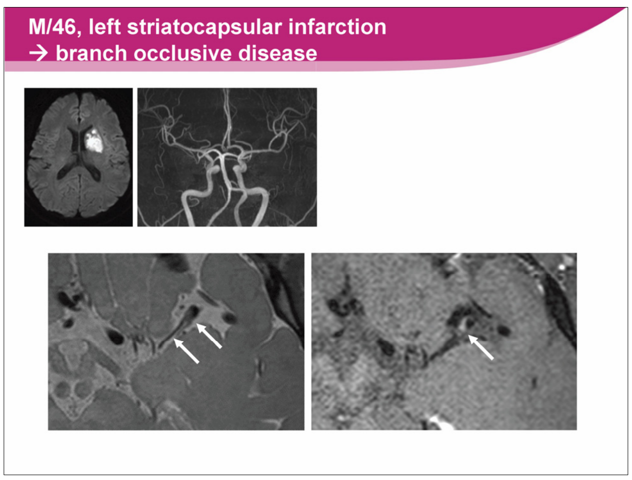

M/46, left striatocapsular infarction
→ branch occlusive disease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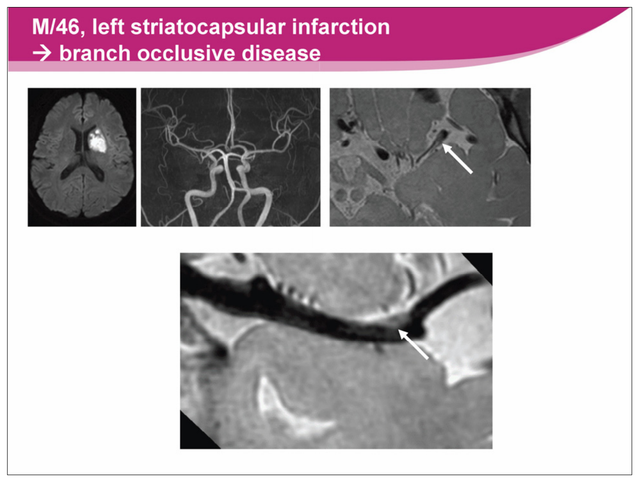
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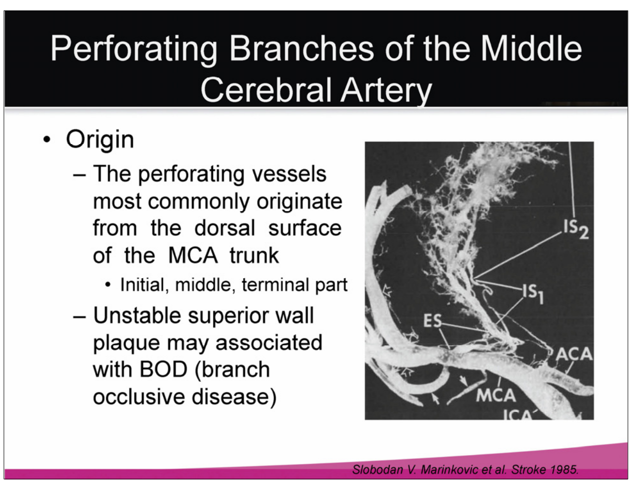
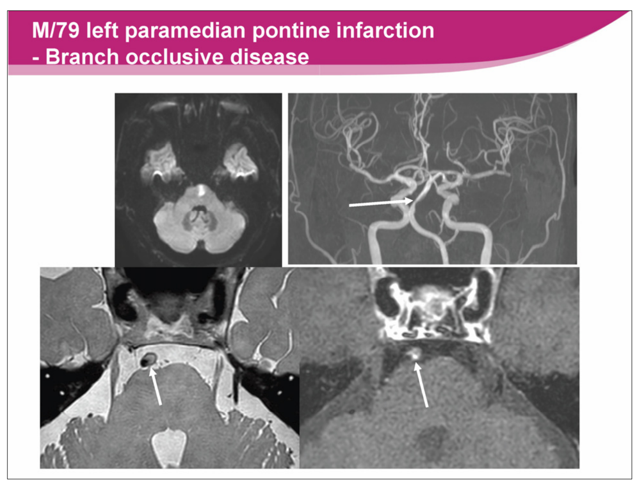
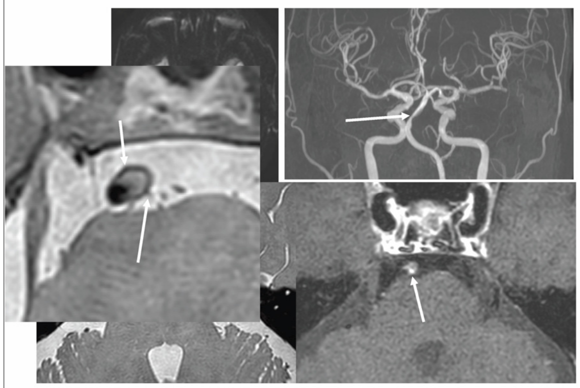
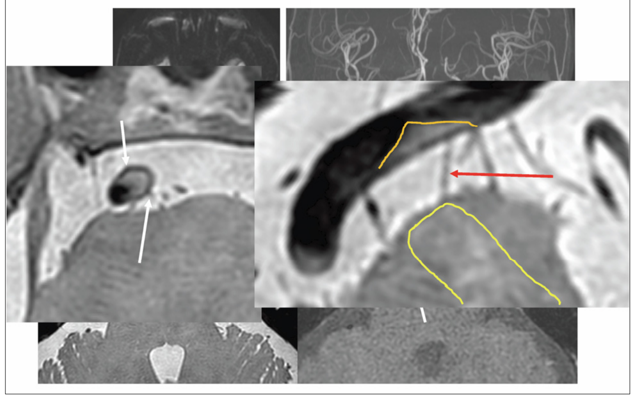

Perforating Branches of the Middle Cerebral Artery
• Origin
– The perforating vessels most commonly originate from the dorsal surface of the MCA trunk
• Initial, middle, terminal part
– Unstable superior wall plaque may associated with BOD (branch occlusive disease)
IS2
IS1
ES
ACA
MCA
ICA
Slobodan V. Marinkovic et al. Stroke 1985.


M/79 left paramedian pontine infarction
- Branch occlusive disease

M/79 left paramedian pontine infarction - Branch occlusive disease



M/79 left paramedian pontine infarction - Branch occlusive disease



Atherosclerosis f/u - monitoring statin response

- Significant reductions in vessel wall thickness and vessel wall area, without changes in lumen area, were observed in both aortic and carotid arteries, 12 months after statin treatment

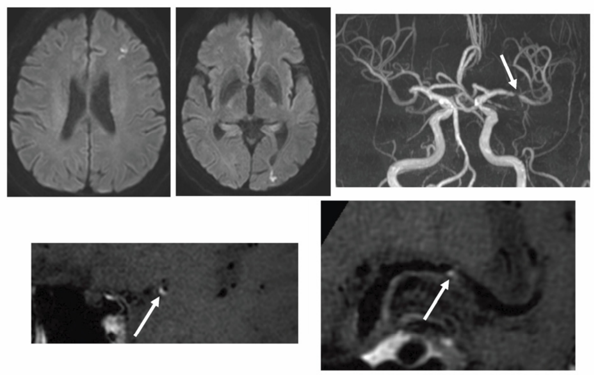
Table 3 Effects of aggressive versus conventional lipid-lowering therapy using statins on atherosclerosis, as evaluated by magnetic resonance imaging

Clinical trials	n/months	Changes in LDL-C	MRI measurements					
			Thoracic aorta			Carotid artery		
			VWA	VWT	LA	VWA	VWT	LA
Corti *et al.*[82]	51/12							
Conventional (simvastatin 20 mg/day)		−36%	−10%	−9%	+5%	−14%	−10%	+4%
Aggressive (simvastatin 80 mg/day)		−46%						
			Thoracic aorta			Abdominal aorta		
			VWA	VWT	LA	VWA	VWT	LA
Yonemura *et al.*[85]	40/12							
Conventional (atorvastatin 5 mg/day)		−34%	+4%	+1%	0%	+12%	+5%	−3%
Aggressive (atorvastatin 20 mg/day)		−47%	−18%	−12%	+5%	+3%	−1%	0%

LDL-C, low density-lipoprotein cholesterol; MRI, magnetic resonance imaging; VWA, vessel wall area; VWT, vessel wall thickness; LA, lumen area.

Corti et al. Circulation 2001.
H. Yanai et al. Q J Med 2007

M/64 MCA atherosclerosis



M/64 MCA atherosclerosis

Vertebral artery dissection

- Suspected
  - Aneurysmal dilatation
  - Pearl-and-string luminal irregularity
  - Tapered steno-occlusion
- Definite
  - Intramural hematoma
  - Double lumen
  - Intimal flap

Dissection - intramural hematoma

- T1 weighted sequence
  - Age >4~14 days → T1 high (subacute)

Table 3 VWH age classified after criteria proposed by Gomori et al

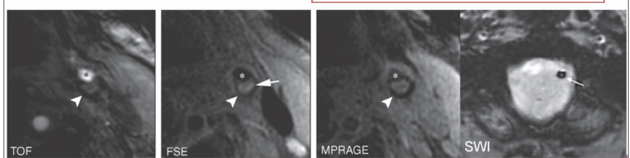
	<1 Day	1-3 Days	4-7 Days	8-14 Days	>14 Days
Observations (n = 35)	**0**	**n = 2**	**n = 6**	**n = 10**	**n = 17**
Hyperacute (n = 0)	0	0	0	0	0
Acute (n = 1)	0	1	0	0	0
Early subacute (n = 6)	0	1	4	1	0
Late subacute (n = 21)	0	0	2	9	10
Chronic (n = 7)	0	0	0	0	7

Habs et al. Journal of Cardiovascular Magnetic Resonance 2011, 13:76

Dissection - intramural hematoma

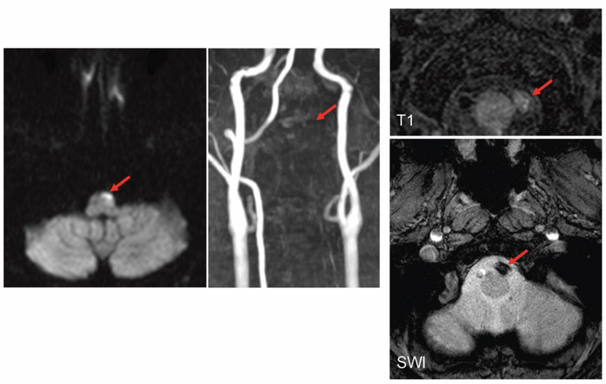
- T1 weighted sequence → subacute
  - TOF, 2D FS FSE T1WI, 3D MPRAGE
- GRE, SWI → acute

	Sensitivity	Specificity
TOF	70%	92%
2D FS FSE	56%	96%
MPRAGE	80%	97%
SWI	90%	96.6%

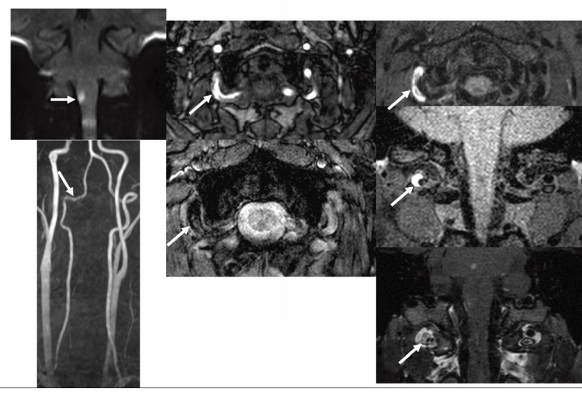


Hideki Ota et al. radiology 2010.
Tae-Won Kim et al. cerebrovasc dis 2013

M/45 Vertebral artery dissection, V4 segment - acute



M/33 Vertebral artery dissection, V3 segment - subacute



Dissection – intimal flap

Eur Radiol (2014) 24:3017–3024
DOI 10.1007/s00330-014-3296-5

MAGNETIC RESONANCE

Feasibility of high-resolution MR imaging for the diagnosis of intracranial vertebrobasilar artery dissection

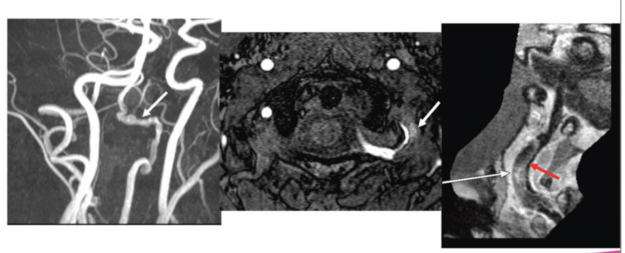
Miran Han · Nae-Jung Rim · Jin Soo Lee · Sun Yong Kim · Jin Wook Choi

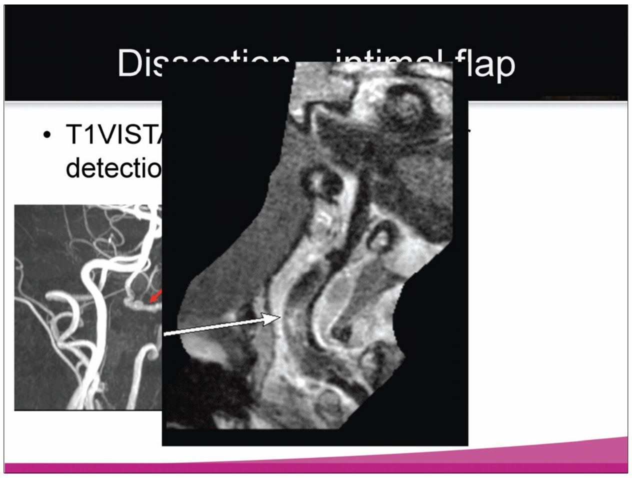
Table 3 Dissection signs on HR-MR images with inter- and intraobserver agreement values

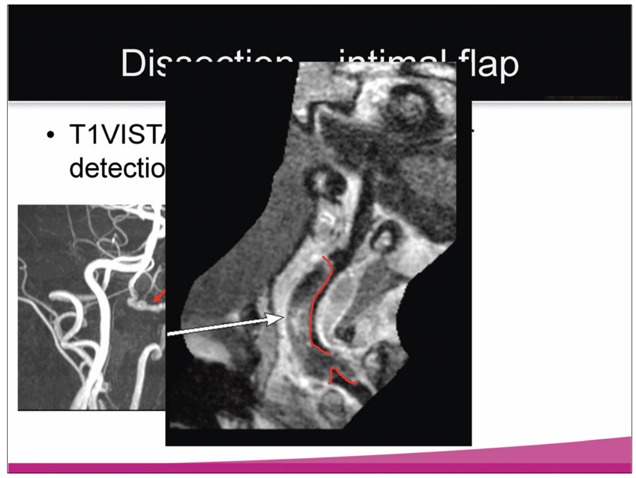
Dissection signs on each sequence (N=35)	PDWI	T2WI	T1WI	CE-T1WI
Mural haematoma	15 (42.9 %)	9 (25.7 %)	19 (54.3 %)	19 (54.3 %)
• Interobserver agreement *Kappa**	*0.82*	*0.66*	*0.88*	*0.88*
• Intraobserver agreement *Kappa**	*0.88*	*0.77*	*1.00*	*1.00*
Dissection flaps	13 (37.1 %)	24 (68.6 %)	17(48.6 %)	32 (91.4 %)
• Interobserver agreement *Kappa**	*0.82*	*0.63*	*0.60*	*0.72*
• Intraobserver agreement *Kappa**	*0.88*	*0.87*	*0.89*	*0.84*
Enlargement of outer wall	-	22 (62.9 %)	-	-
• Interobserver agreement *Kappa**		*0.88*		
• Intraobserver agreement *Kappa**		*0.81*		

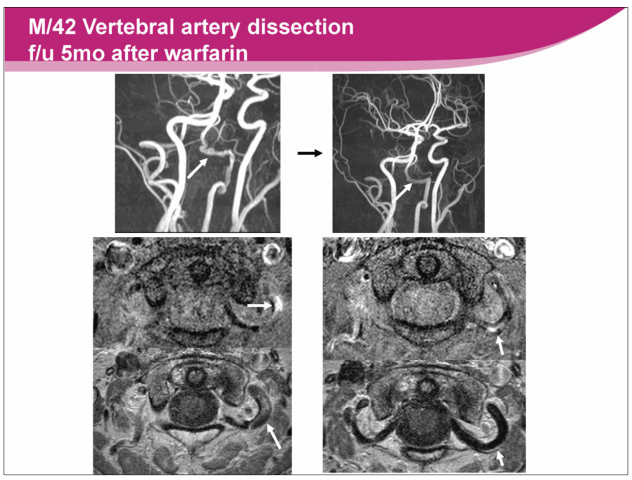
Dissection – intimal flap

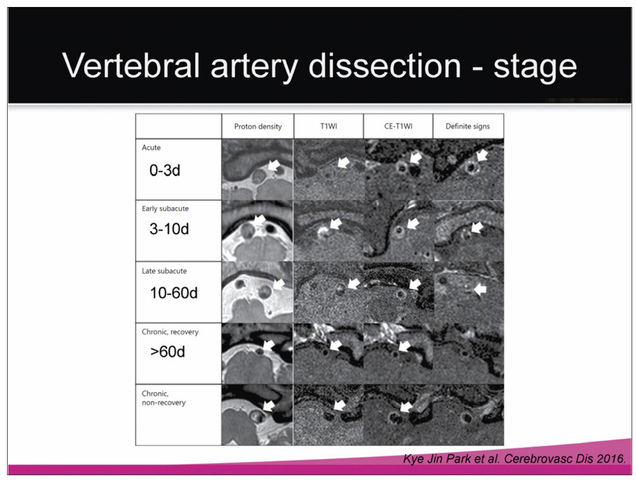
- 3D T1VISTA (pre or postcontrast) for detection of intimal flap

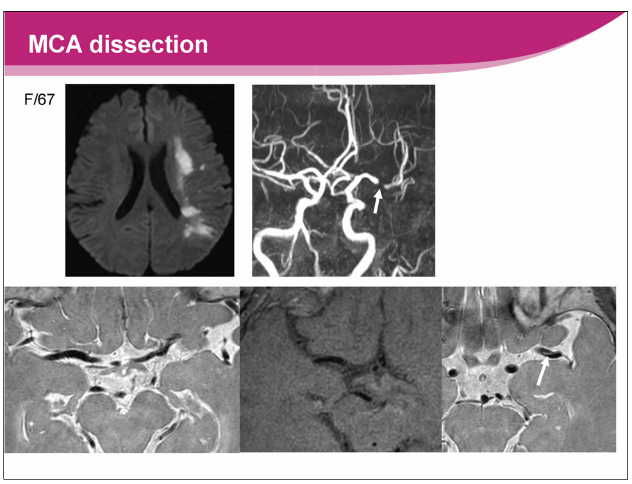


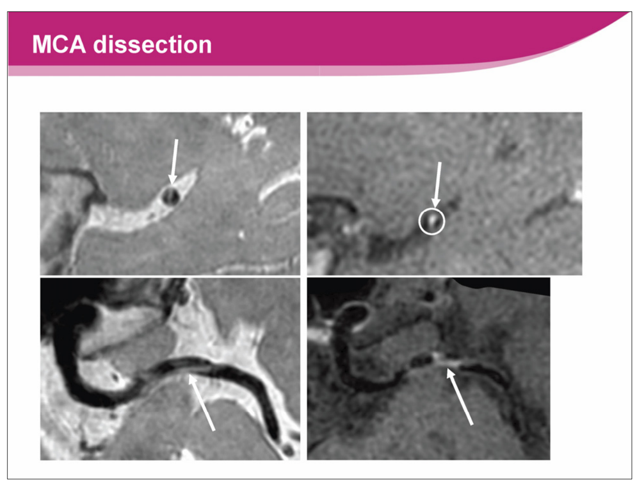

Dissection – intimal flap
• T1VISTA
detection


Dissection – intimal flap
• T1VISTA
detection

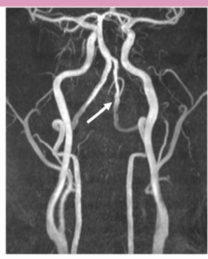

M/42 Vertebral artery dissection
f/u 5mo after warfarin


Vertebral artery dissection - stage
Proton density
T1WI
CE-T1WI
Definite signs
Acute
0-3d
Early subacute
3-10d
Late subacute
10-60d
Chronic, recovery
>60d
Chronic, non-recovery
Kye Jin Park et al. Cerebrovasc Dis 2016.

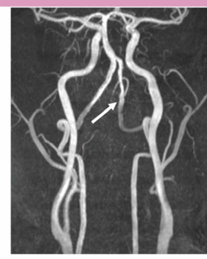

MCA dissection
F/67

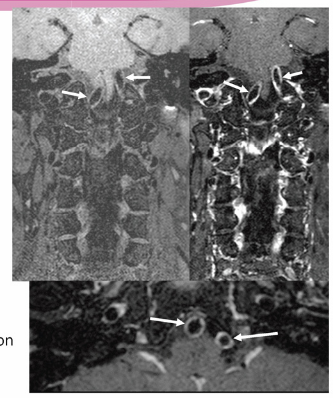

MCA dissection

M/54 Vertebral artery luminal irregularity R/O dissection



M/54 Vertebral artery luminal irregularity R/O dissection





Atherosclerosis > dissection

Take home message

- MR vascular imaging
  - Understanding of physics is necessary to avoid misdiagnosis
- Complemenatary use of advanced technique (i.e. SWI, vessel wall imaging) is problem-solving