

第31回神奈川MRI技術研究会

今からでも大丈夫!!

MRI入門part5 頭部MRA

**TOF 法**

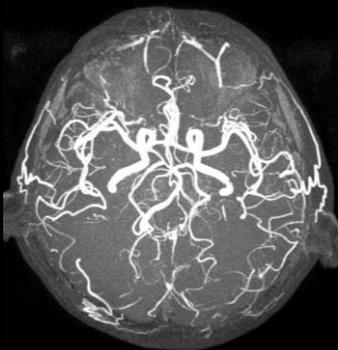


聖マリアンナ医科大学病院

MR検査室 馬野清次

# MRAの分類

TOF



PC bTFFE FBI Labeling B.B. CE  
最も使用頻度が高い

非造影MRA

GRE法による撮像

流入効果を利用

血液が高信号

# 本日の内容

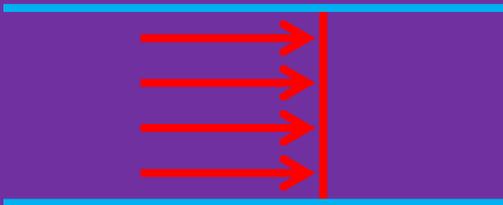
- 流れに関する基礎
- 撮像パラメータと効果

# 血流現象

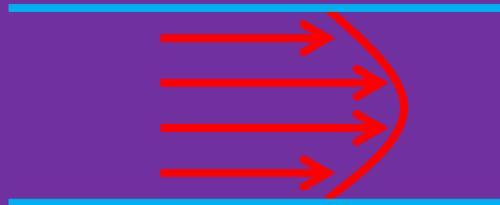
$$V = Q / A$$

V: 血流速度    Q: 血流量    A: 斷面積

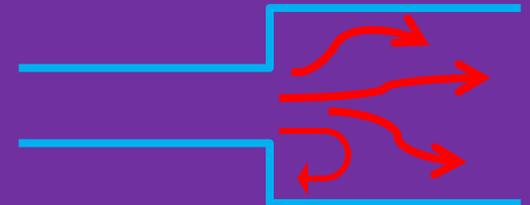
栓流



層流



亂流・渦流



拍動流

# 血流現象

## レイノルズ値

$$Re = \rho v d / \eta$$

$\rho$ : 密度    $v$ : 流速    $d$ : 径    $\eta$ : 粘調度

$Re < 2100$  : 層流

$Re > 2100$  : 乱流

# 血流現象



中・前大脳動脈 : 40 - 70 cm/s

椎骨動脈 : 30 - 50 cm/s

総頸動脈 : 80 - 120 cm/s

上行大動脈 : - 500 cm/s

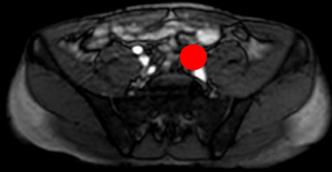
下行大動脈 : 150 - 170 cm/s

総腸骨動脈 : 100 - 150 cm/s

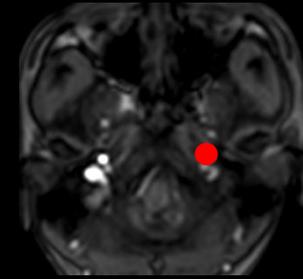
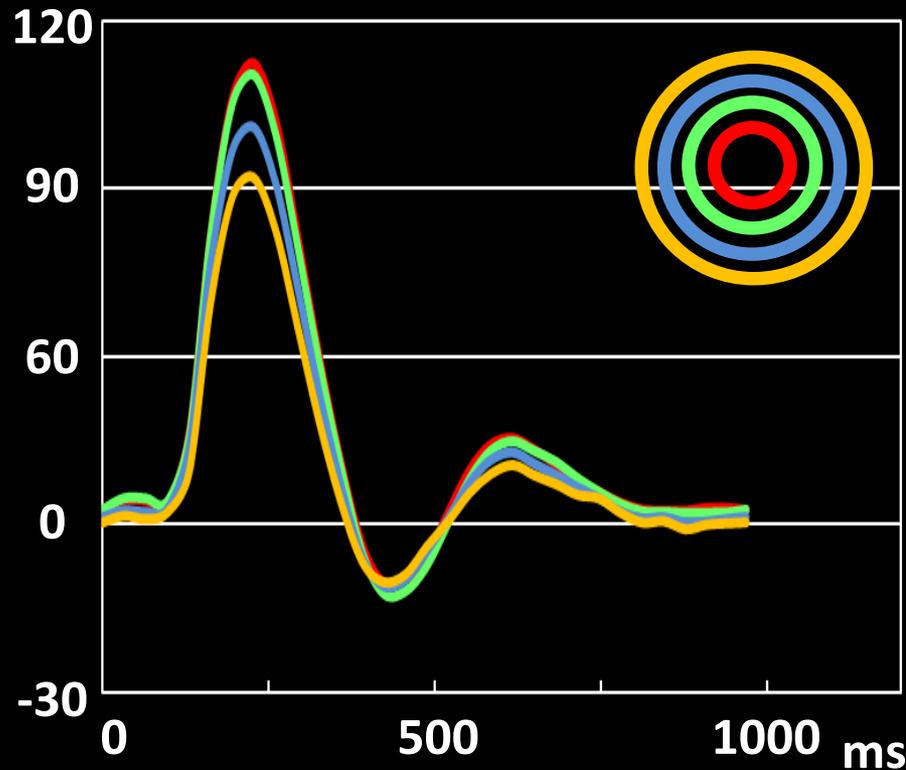
静脈 : < 20 cm/s



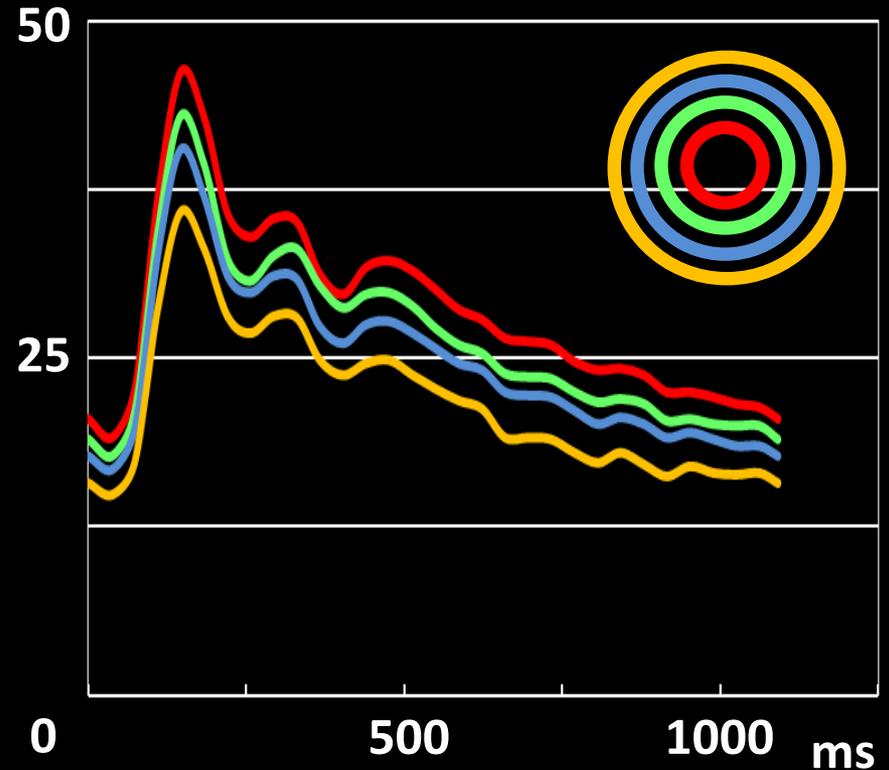
# 流速計測



cm/s

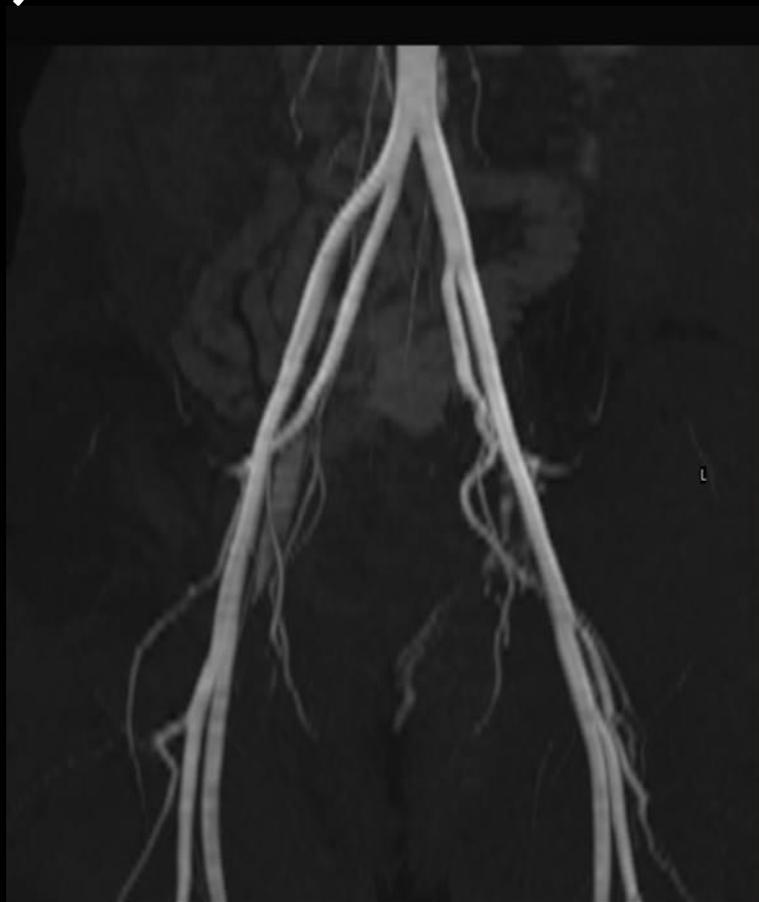


cm/s



# 同期撮像

(+)

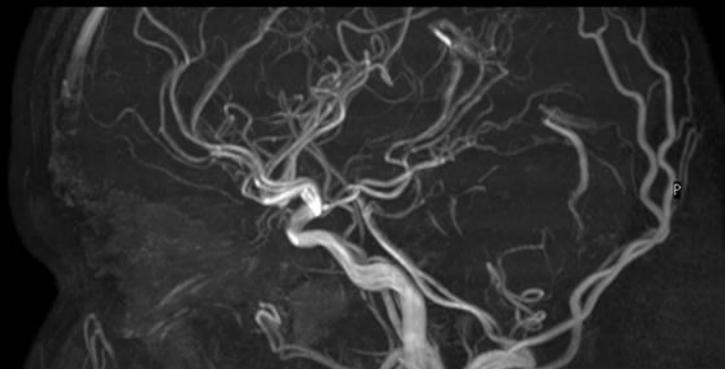


(-)



# 同期撮像

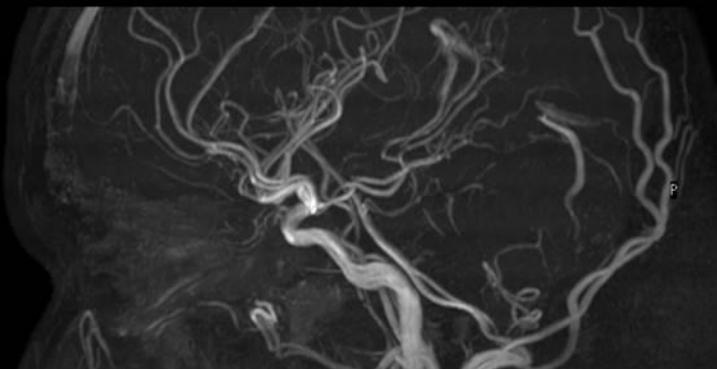
(+)



ic 7  
T1FFE/M  
12

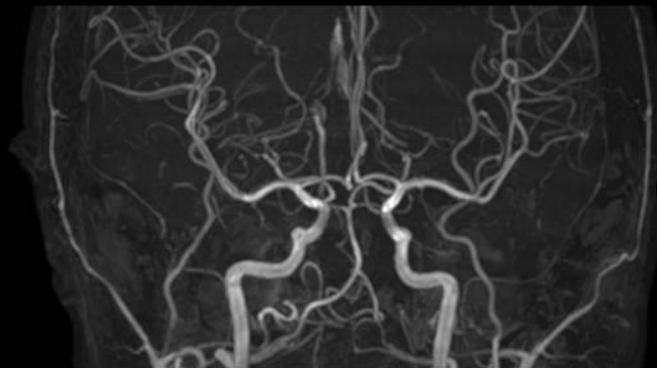
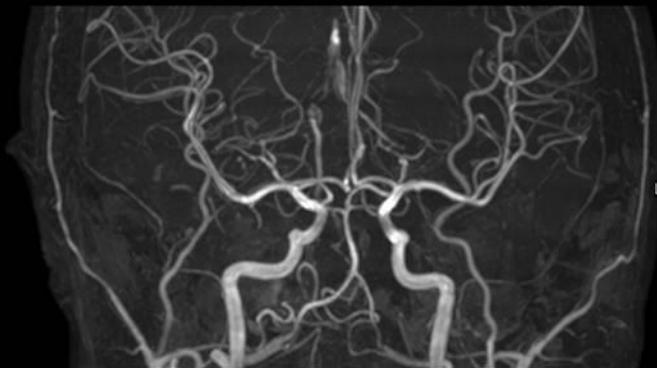
H

(-)



Sc 4  
T1FFE/M  
SI 2

H



# TOF 効果

流れによる信号変化

流入効果 : **TOF 法**

inflow effect

高速度信号流出 : **B.B. 法**

high velocity signal loss

# 流入効果

被検体由来の画像コントラスト要因

プロトン密度

T1 値

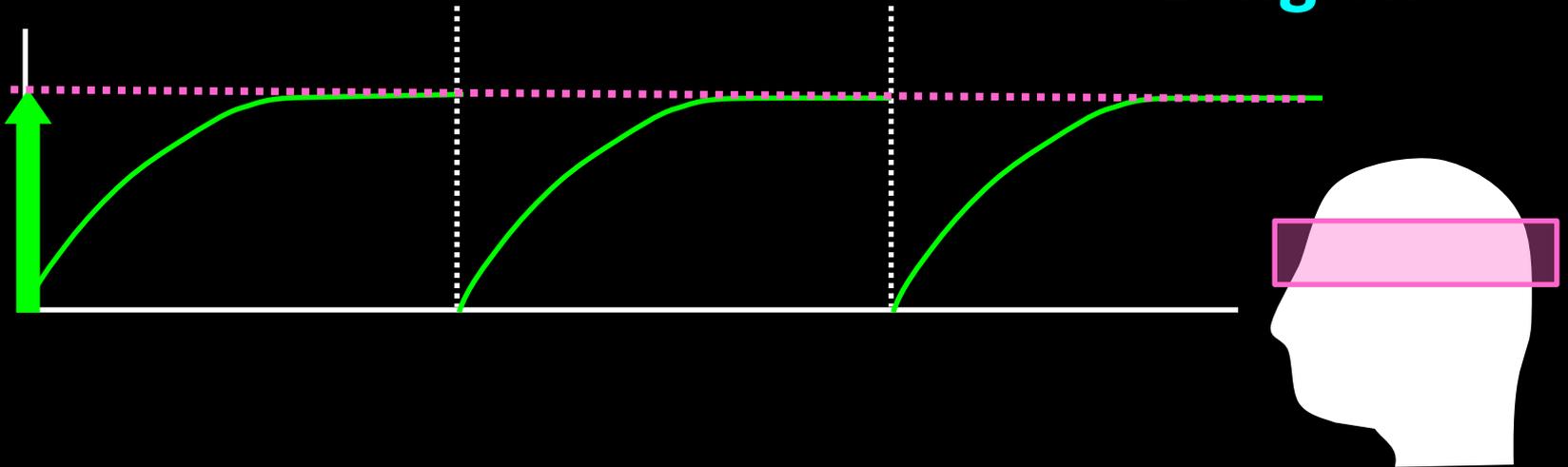
T2 値

移動(流れ)

# 流入効果

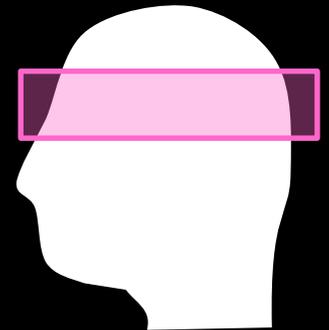
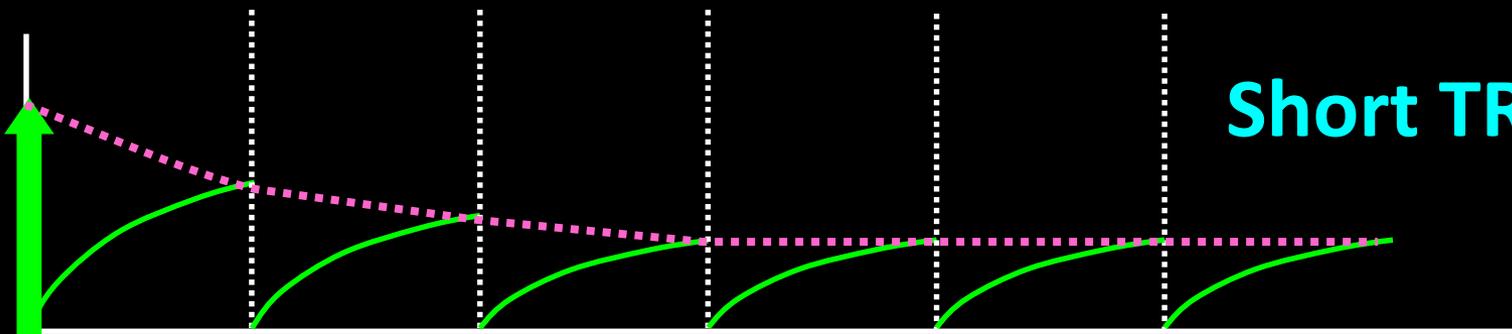
z

Long TR



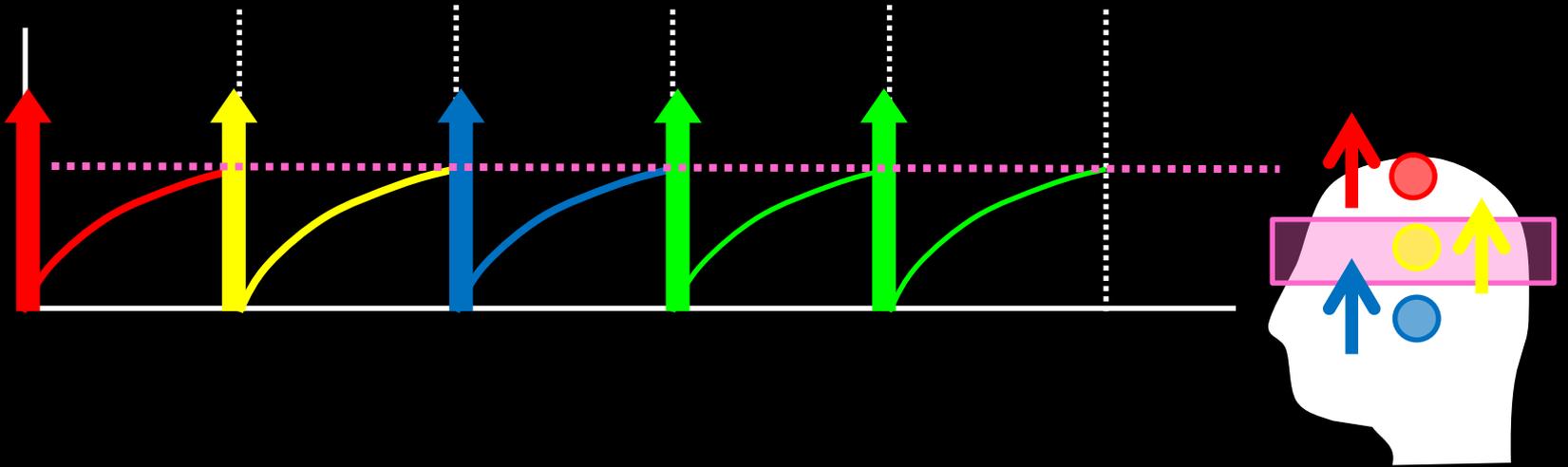
z

Short TR

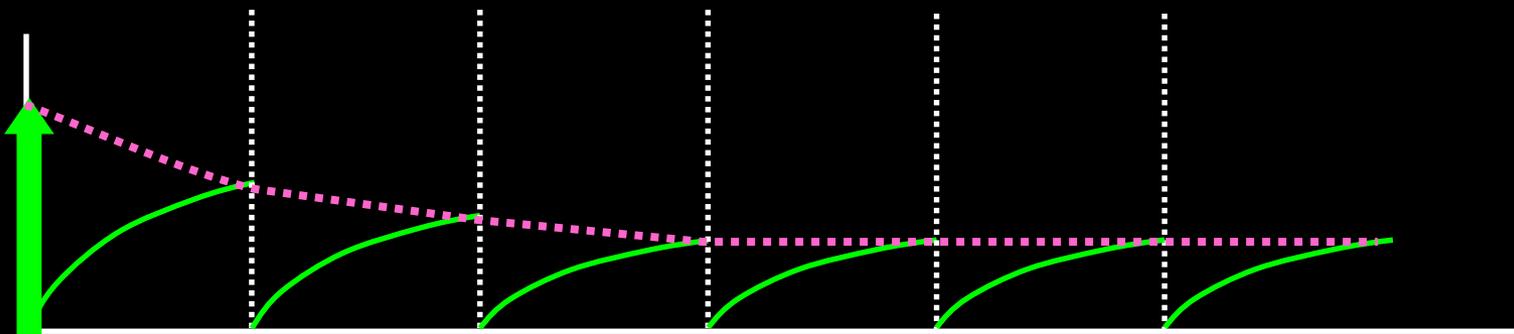


# 流入効果

Z

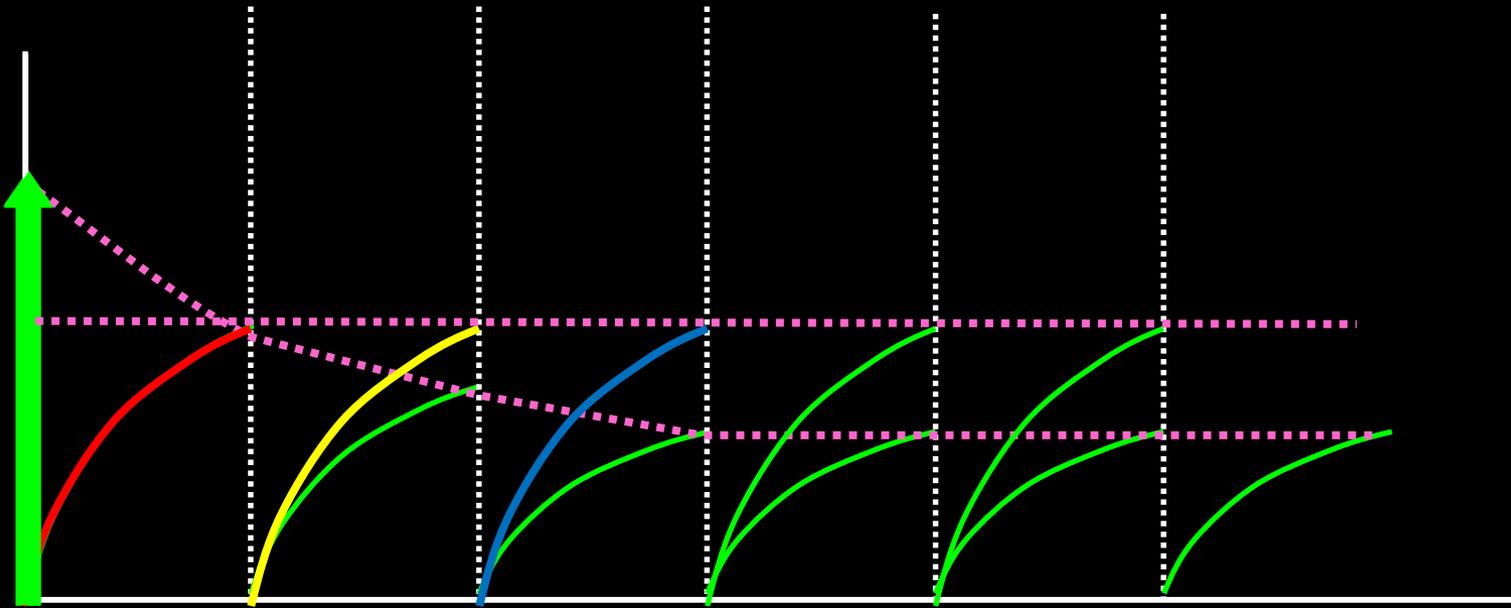


Z

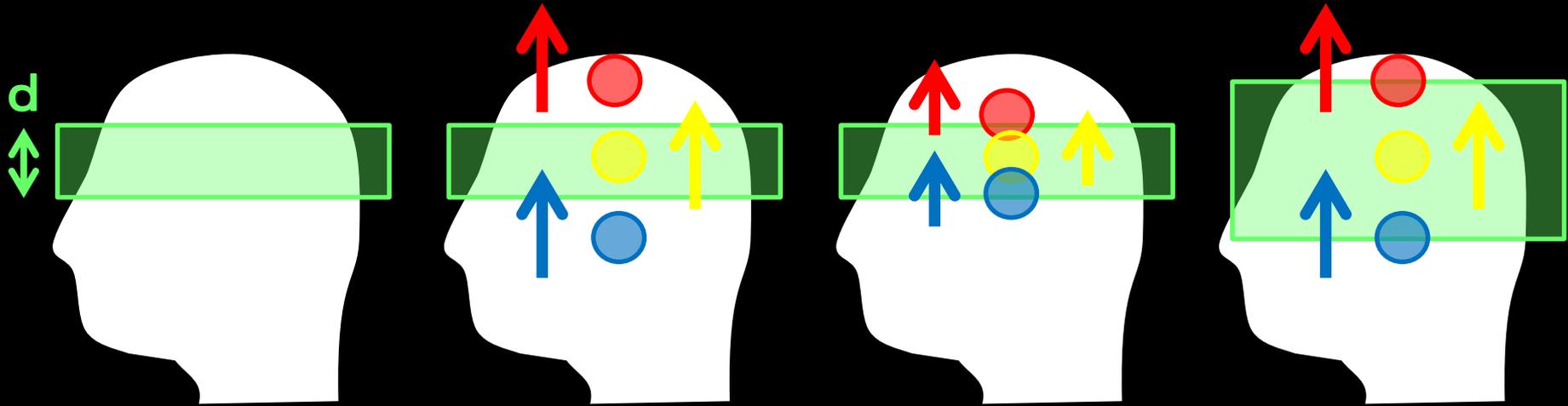


# 流入効果

z



# 流入効果



$$V = 0$$

$$V = d / TR$$

$$V < d / TR$$

# 流入効果

## 関連撮像パラメータ

TR

FA  
(可変FA)

スラブ厚  
(2D/3D マルチスラブ)

スライス断面

# 位相分散

## 位相スピン効果

傾斜磁場による位相変化

位相分散  $\neq$  位相スピン効果

速度及び傾斜磁場強度に比例

傾斜磁場の印加時間の2乗に比例

# 位相分散

## 関連撮像パラメータ

TE

位相補正

位相に関する詳細はこの後のPCで・・・

# 本日の内容

- 流れに関する基礎
- 撮像パラメータと効果

# 基準撮像

## 3D-TOF Scan parameters

FOV : 200 × 200mm

Matrix size : 0.63 × 0.98

Slice thickness : 1.0mm

Number of slice : 150

Number of slab : 3

TR : 25msec

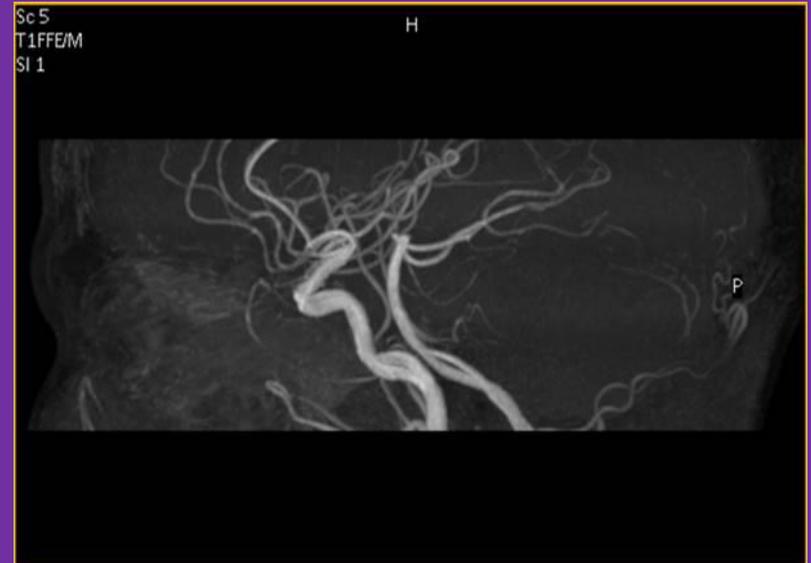
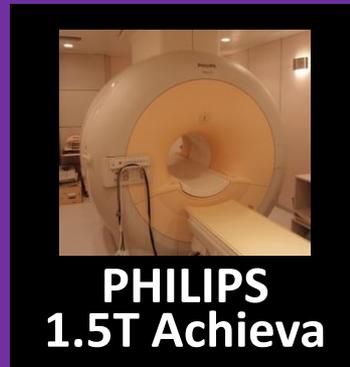
TE : 6.9msec

FA : 20°

TONE : +

PE : +

Scan time : 04:13



# TR

流入効果

飽和効果

撮像時間

$$V = d / TR$$

TR

18

25

40

Sc 6  
T1FFE/M  
SI 69



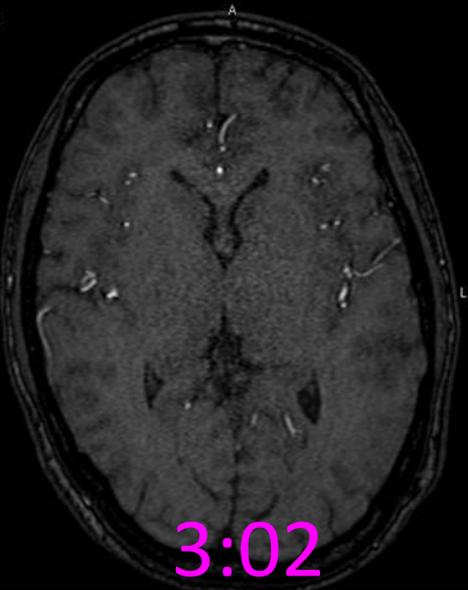
Sc 5  
T1FFE/M  
SI 69



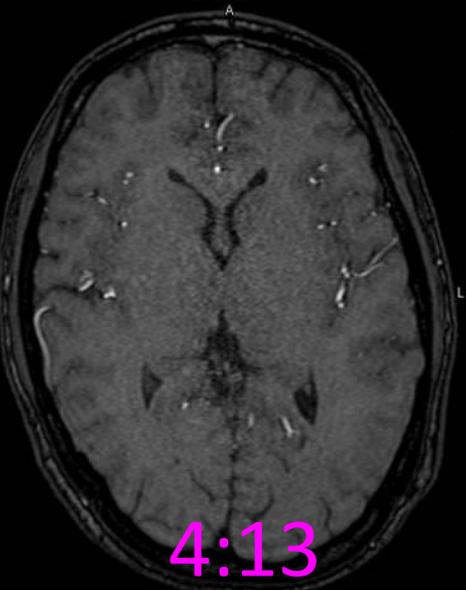
Sc 7  
T1FFE/M  
SI 69



Sc 6  
T1FFE/M  
SI 127



Sc 5  
T1FFE/M  
SI 127



Sc 7  
T1FFE/M  
SI 127



3:02

4:13

6:44

TR

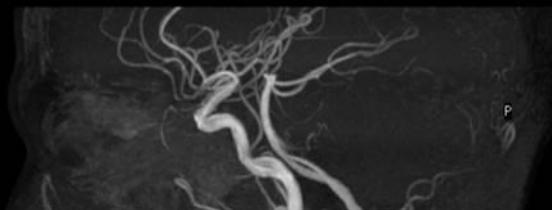
18

25

40

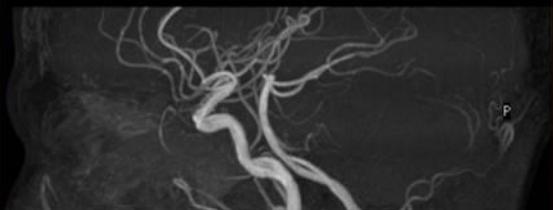
Sc 5  
T1FFE/M  
SI 1

H



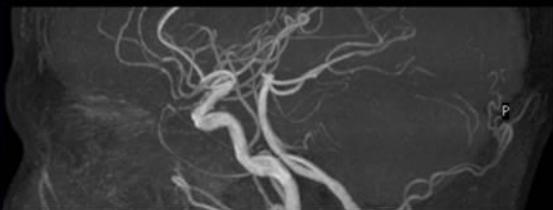
Sc 5  
T1FFE/M  
SI 1

H



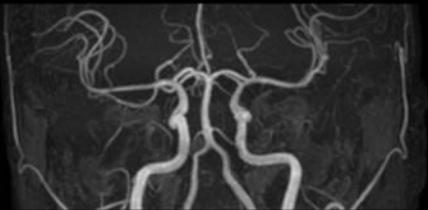
Sc 7  
T1FFE/M  
SI 1

H



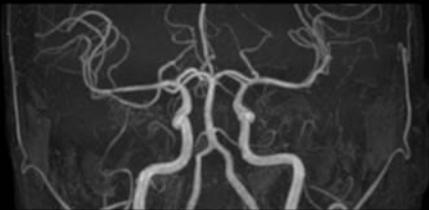
Sc 6  
T1FFE/M  
SI 2

H



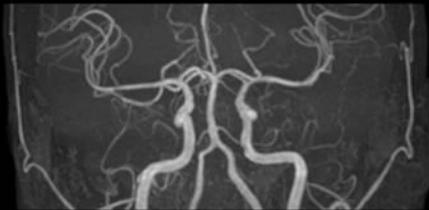
Sc 5  
T1FFE/M  
SI 2

H



Sc 7  
T1FFE/M  
SI 2

H



Sc 6  
T1FFE/M  
SI 3

A



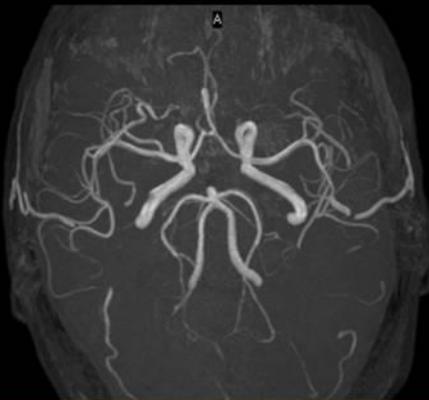
Sc 5  
T1FFE/M  
SI 3

A



Sc 7  
T1FFE/M  
SI 3

A



TR



背景信号の飽和効果が高い (+)

流入効果が低い (-)



背景信号の飽和効果が低い (-)

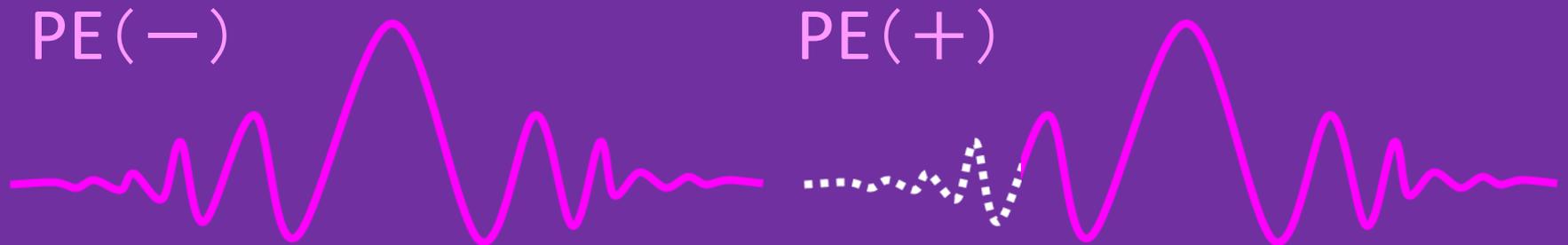
流入効果が高い (+)

# TE

位相分散  
位相スピン効果

水・脂肪の位相差

部分エコー



# TE

## 位相補正



TE

2.8

6.9

11.5

Sc 8  
T1FFEM  
SI 170



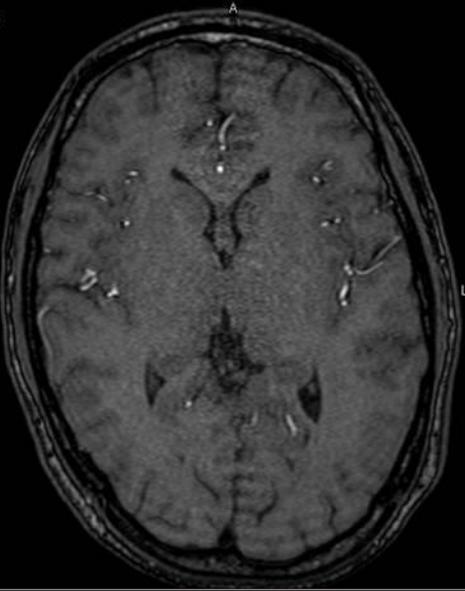
Sc 5  
T1FFEM  
SI 169



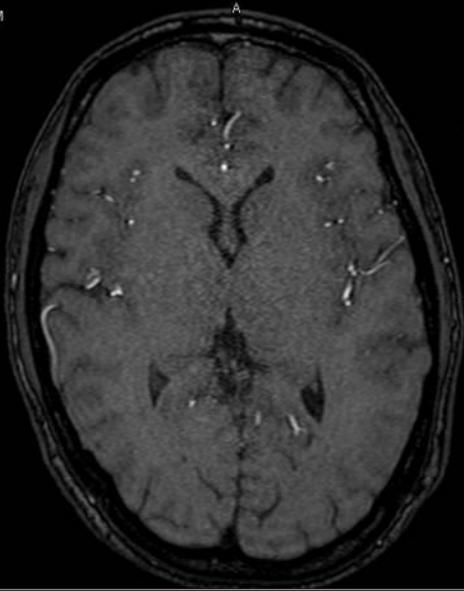
Sc 9  
T1FFEM  
SI 170



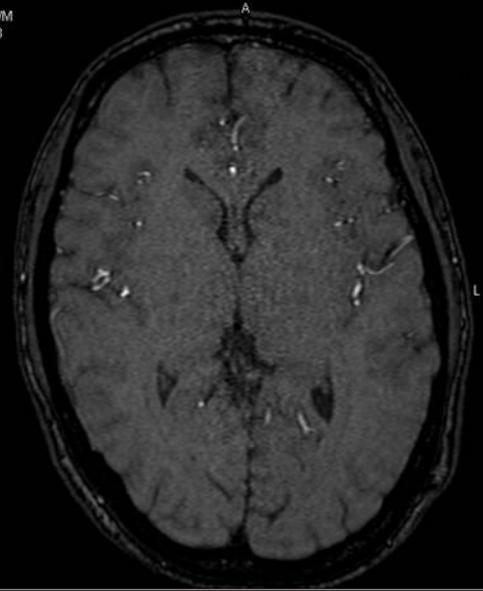
Sc 8  
T1FFEM  
SI 128



Sc 5  
T1FFEM  
SI 127



Sc 9  
T1FFEM  
SI 128



# TE

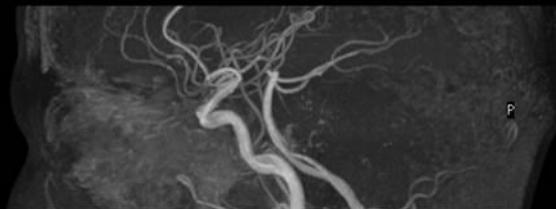
## 2.8

## 6.9

## 11.5

Sc 8  
T1FFE/M  
SI 1

H



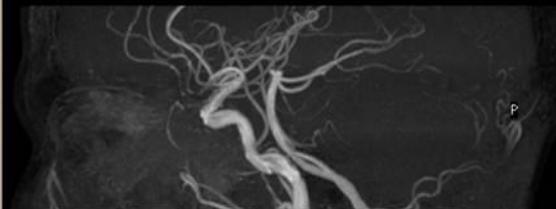
Sc 5  
T1FFE/M  
SI 1

H



Sc 9  
T1FFE/M  
SI 1

H



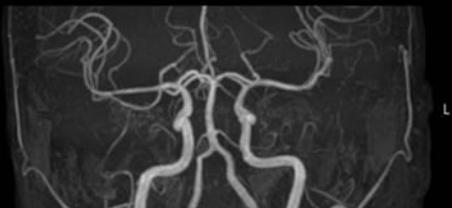
Sc 8  
T1FFE/M  
SI 2

H



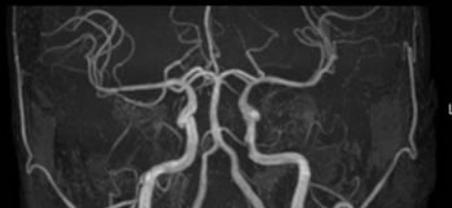
Sc 5  
T1FFE/M  
SI 2

H



Sc 9  
T1FFE/M  
SI 2

H



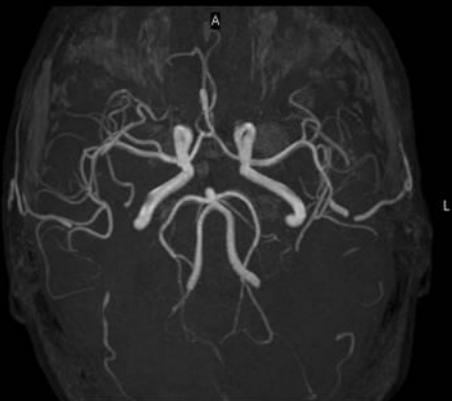
Sc 8  
T1FFE/M  
SI 3

A



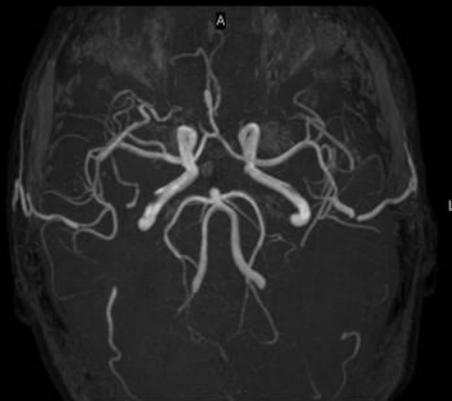
Sc 5  
T1FFE/M  
SI 3

A



Sc 9  
T1FFE/M  
SI 3

A



TE

6.9

6.9 (PE-)

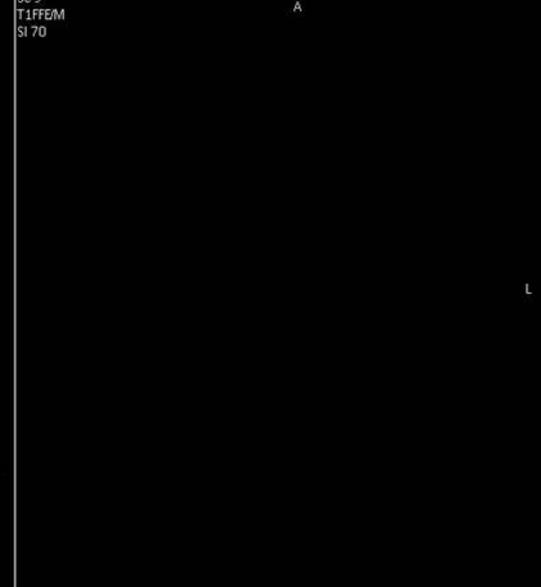
Sc 5  
T1FFEM  
SI 69



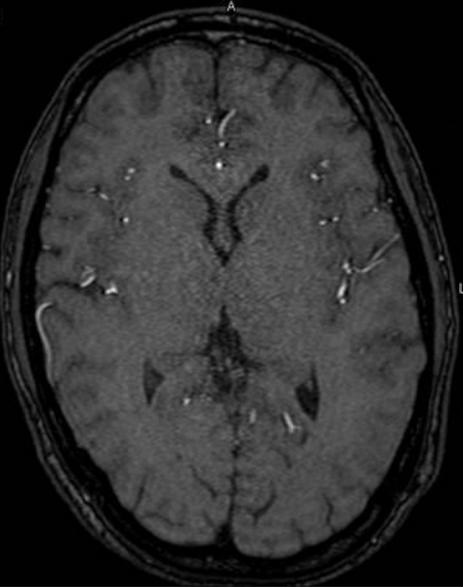
Sc 11  
T1FFEM  
SI 71



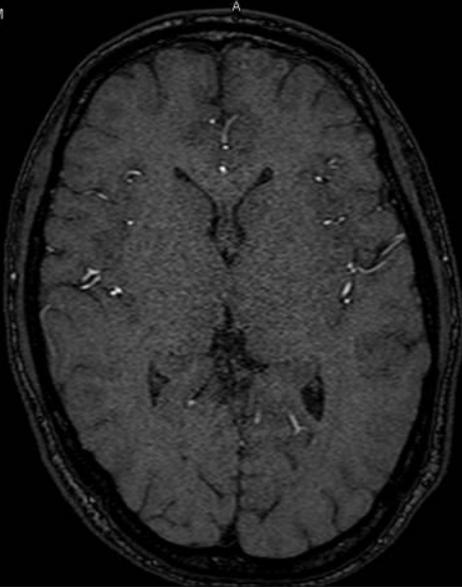
Sc 9  
T1FFEM  
SI 70



Sc 5  
T1FFEM  
SI 127



Sc 11  
T1FFEM  
SI 129



Sc 9  
T1FFEM  
SI 128



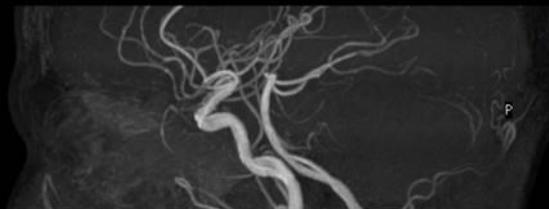
# TE

## 6.9

## 6.9 (PE-)

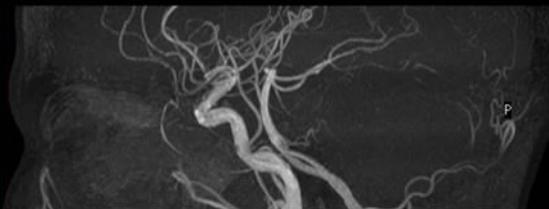
Sc 5  
T1FFEM  
Sl 1

H



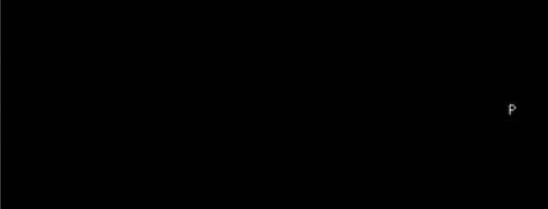
Sc 11  
T1FFEM  
Sl 1

H



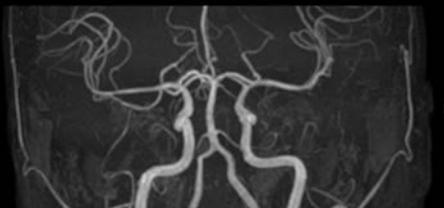
Sc 11  
T1FFEM  
Sl 1

H



Sc 5  
T1FFEM  
Sl 2

H



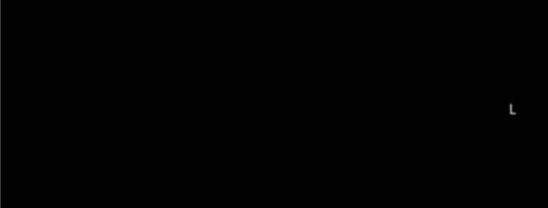
Sc 11  
T1FFEM  
Sl 2

H



Sc 11  
T1FFEM  
Sl 2

H



Sc 5  
T1FFEM  
Sl 3

A



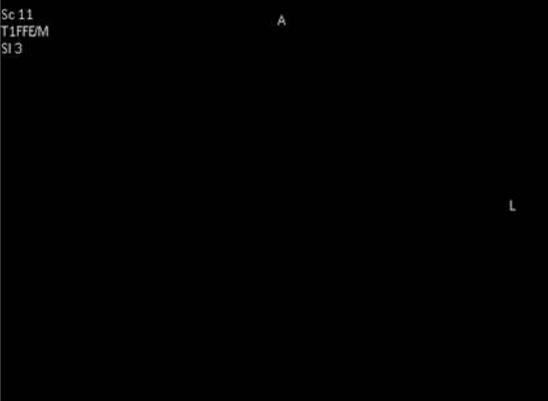
Sc 11  
T1FFEM  
Sl 3

A



Sc 11  
T1FFEM  
Sl 3

A



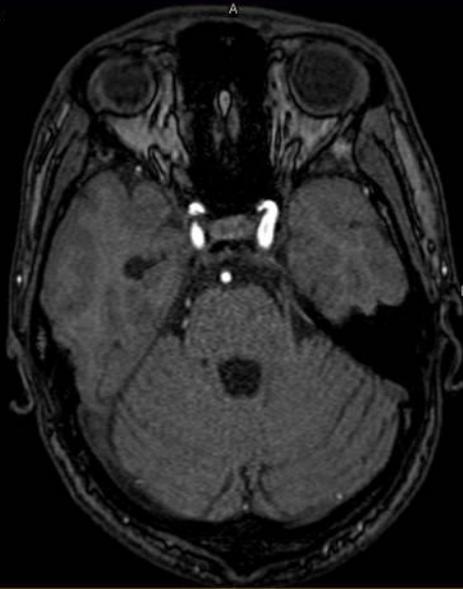
TE

6.9

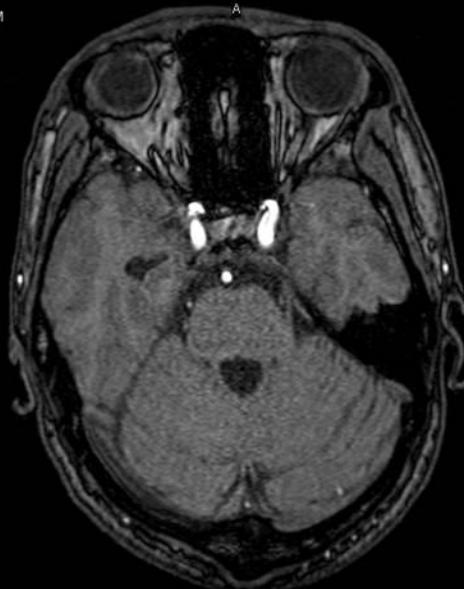
6.9 (FC-)

2.2 (FC-)

Sc 5  
T1FFEM  
SI 69



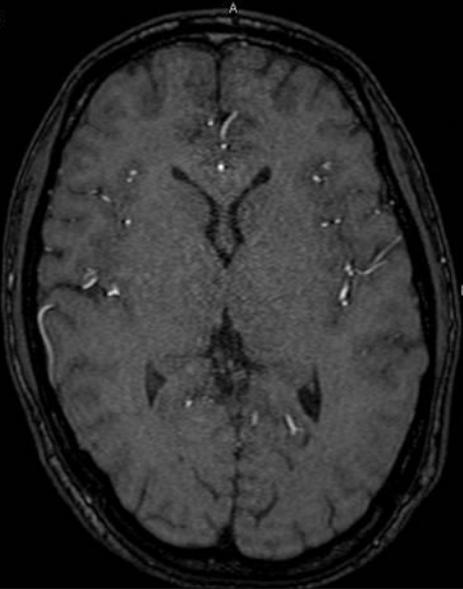
Sc 16  
T1FFEM  
SI 74



Sc 17  
T1FFEM  
SI 74



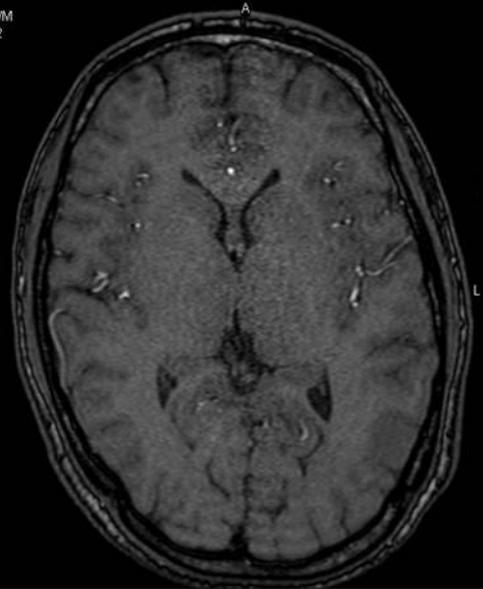
Sc 5  
T1FFEM  
SI 127



Sc 16  
T1FFEM  
SI 132



Sc 17  
T1FFEM  
SI 132



TE

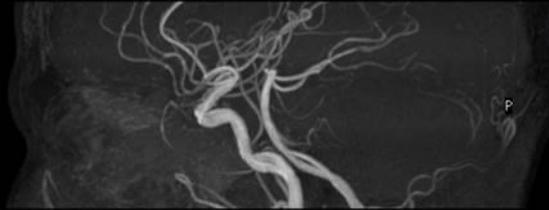
6.9

6.9(FC-)

2.2

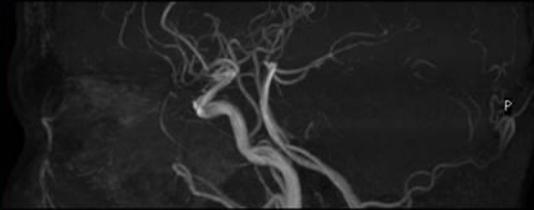
Sc 5  
T1FFEM  
Sl 1

H



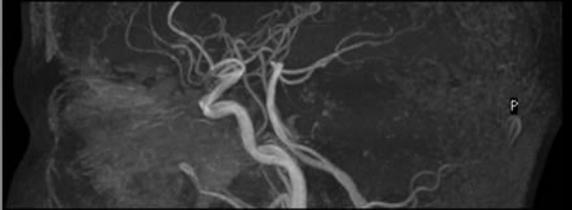
Sc 16  
T1FFEM  
Sl 1

H



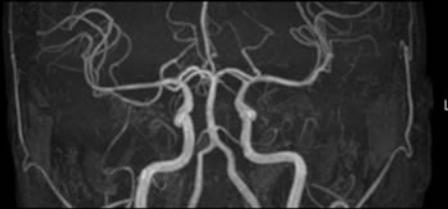
Sc 17  
T1FFEM  
Sl 1

H



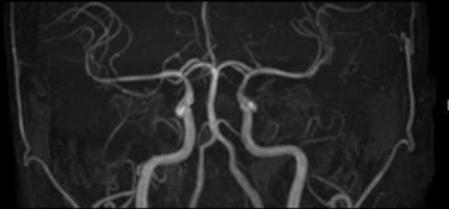
Sc 5  
T1FFEM  
Sl 2

H



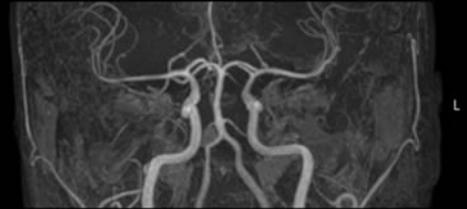
Sc 16  
T1FFEM  
Sl 2

H



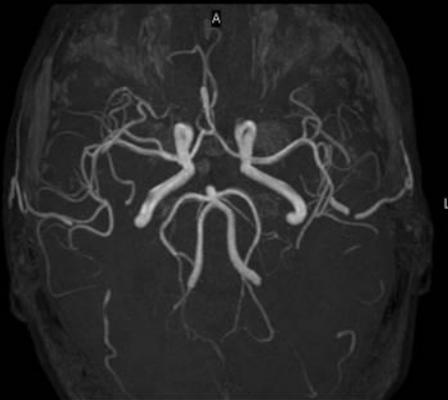
Sc 17  
T1FFEM  
Sl 2

H



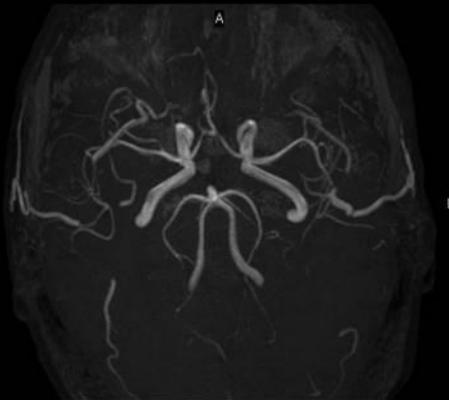
Sc 5  
T1FFEM  
Sl 3

A



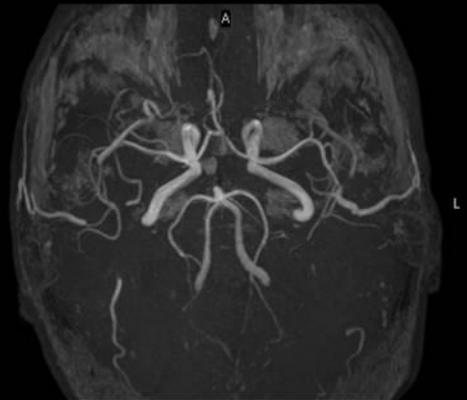
Sc 16  
T1FFEM  
Sl 3

A



Sc 17  
T1FFEM  
Sl 3

A



# TE

短いと位相分散の影響が少ない

逆位相を用いることで脂肪信号抑制

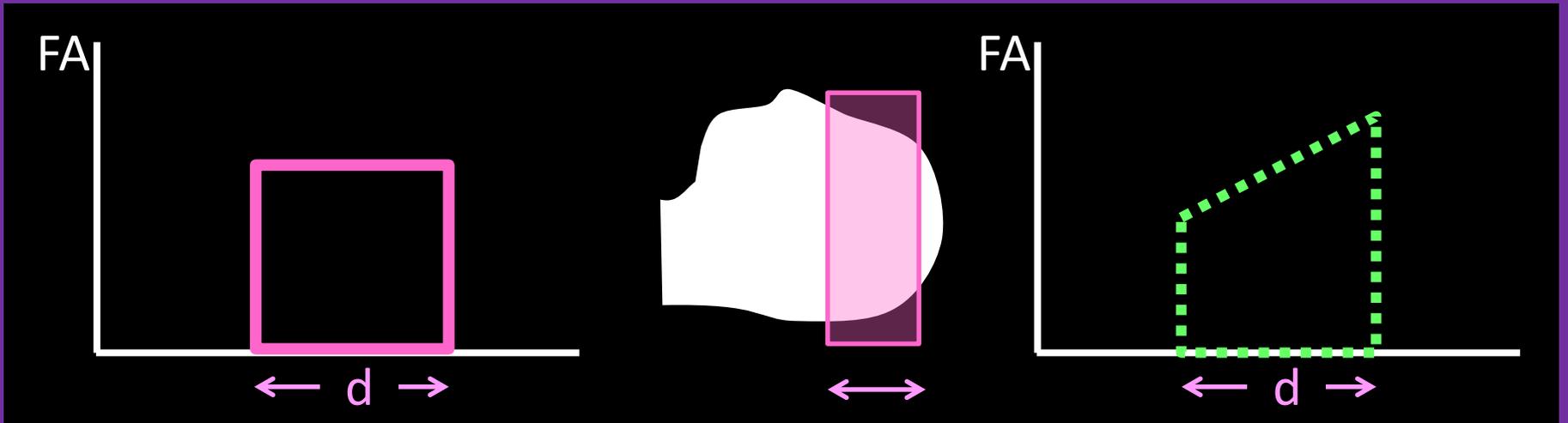
部分エコーの効果

位相補正の効果

# FA

## 飽和効果 背景・スラブ奥側

### 可変FA



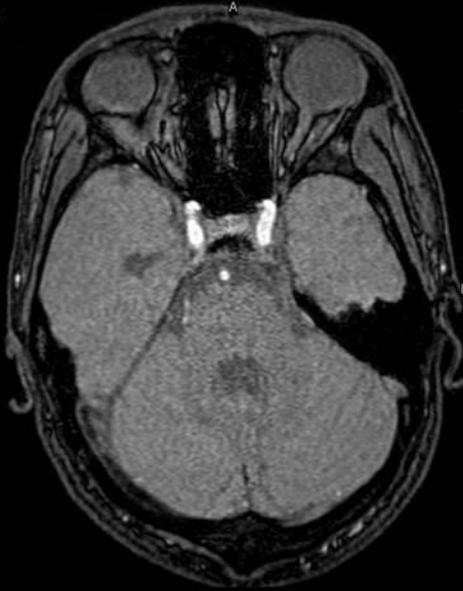
**FA**

10

20

30

Sc 12  
T1FFEM  
SI 71



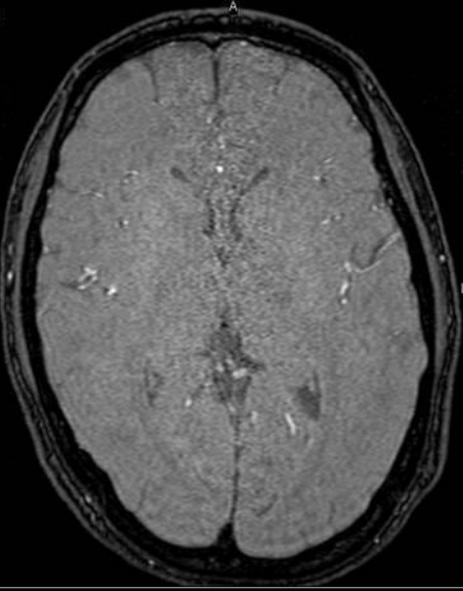
Sc 5  
T1FFEM  
SI 69



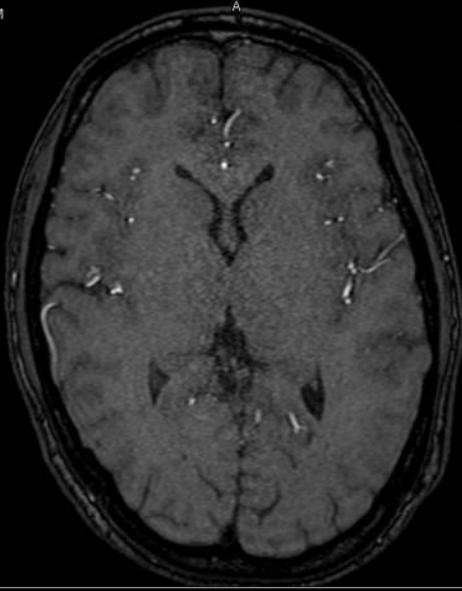
Sc 13  
T1FFEM  
SI 72



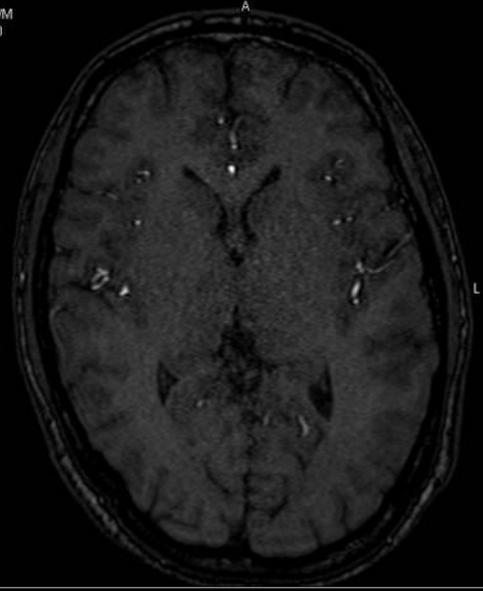
Sc 12  
T1FFEM  
SI 129



Sc 5  
T1FFEM  
SI 127



Sc 13  
T1FFEM  
SI 130



# FA

## 10

## 20

## 30

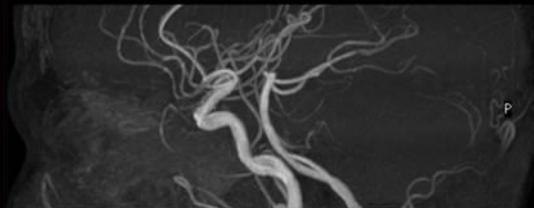
Sc 12  
T1FFEM  
Sl 1

H



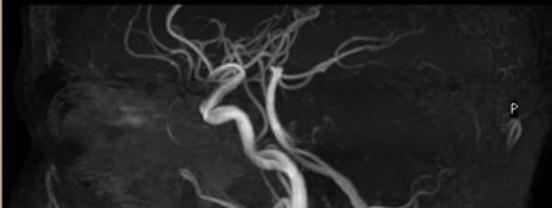
Sc 5  
T1FFEM  
Sl 1

H



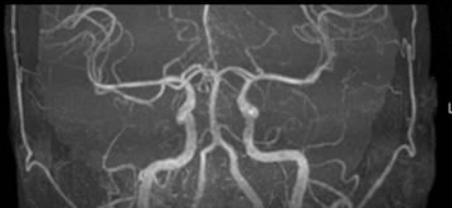
Sc 13  
T1FFEM  
Sl 1

H



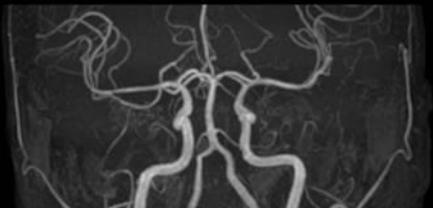
Sc 12  
T1FFEM  
Sl 2

H



Sc 5  
T1FFEM  
Sl 2

H



Sc 13  
T1FFEM  
Sl 2

H



Sc 12  
T1FFEM  
Sl 3

A



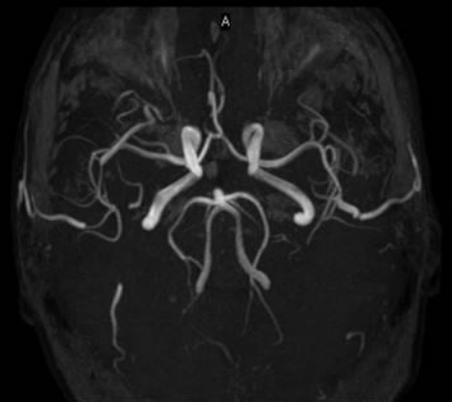
Sc 5  
T1FFEM  
Sl 3

A



Sc 13  
T1FFEM  
Sl 3

A



**FA**

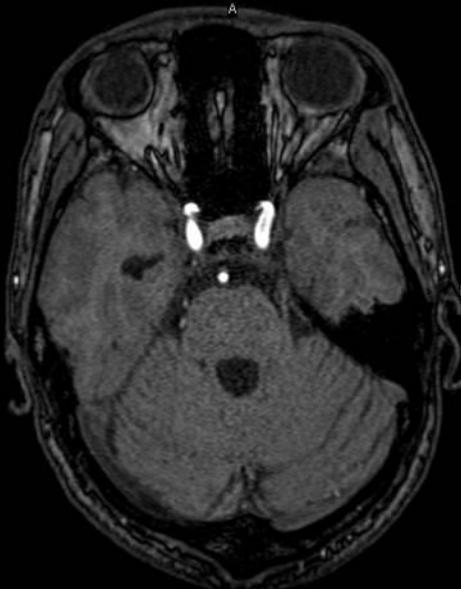
TONE(+)

TONE(-)

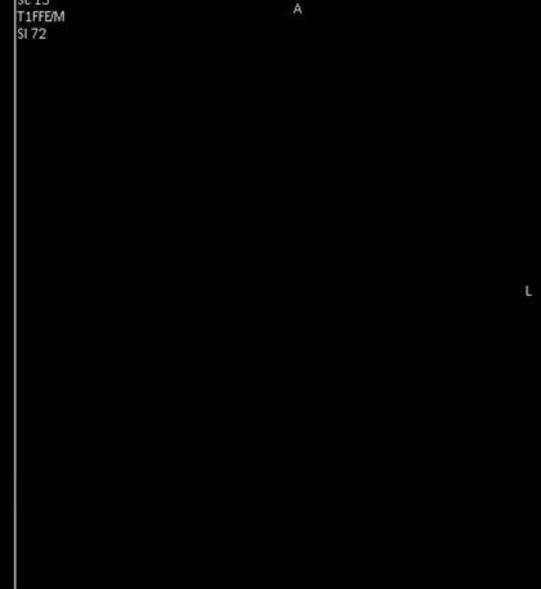
Sc 5  
T1FFE/M  
SI 69



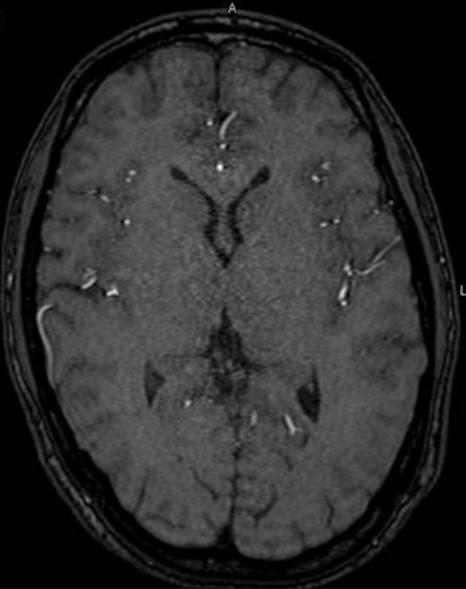
Sc 15  
T1FFE/M  
SI 73



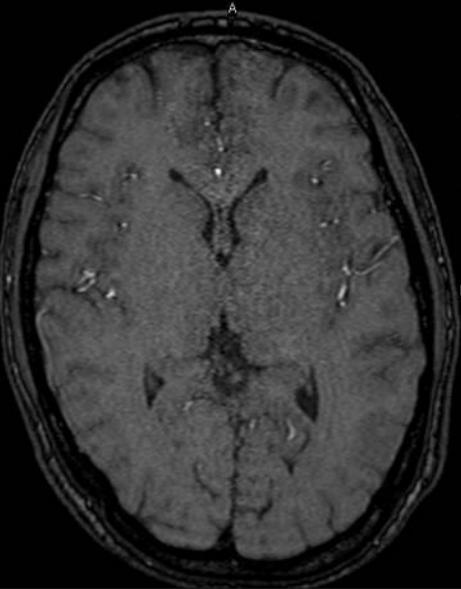
Sc 13  
T1FFE/M  
SI 72



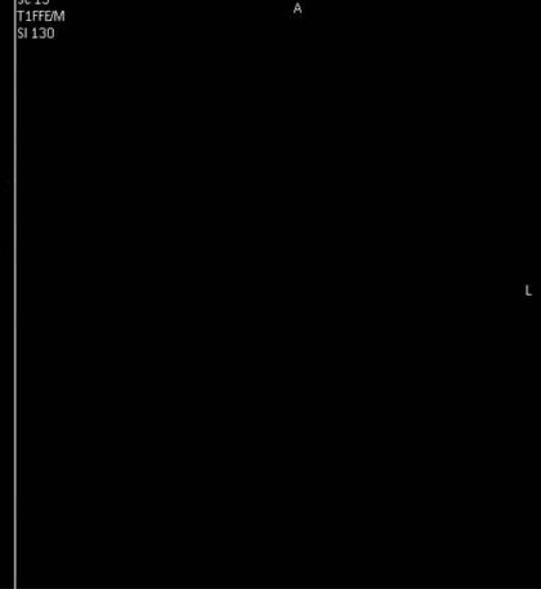
Sc 5  
T1FFE/M  
SI 127



Sc 15  
T1FFE/M  
SI 131



Sc 13  
T1FFE/M  
SI 130



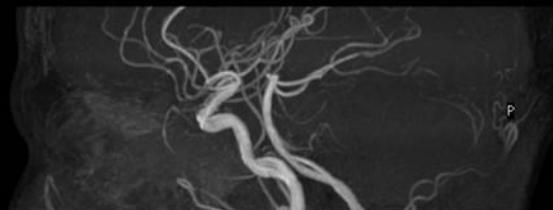
# FA

## TONE(+)

## TONE(-)

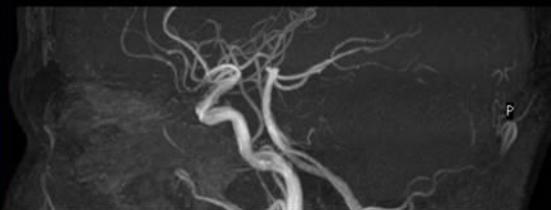
Sc 5  
T1FFE/M  
SI 1

H



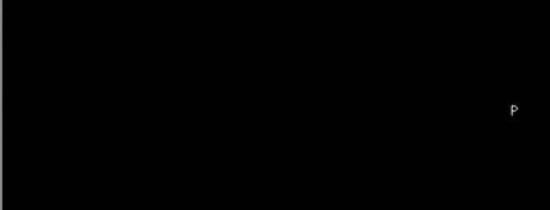
Sc 15  
T1FFE/M  
SI 1

H



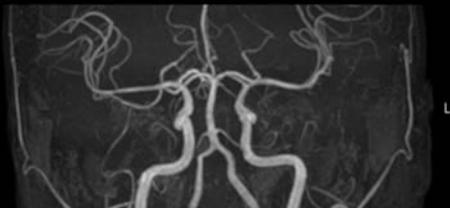
Sc 13  
T1FFE/M  
SI 1

H



Sc 5  
T1FFE/M  
SI 2

H



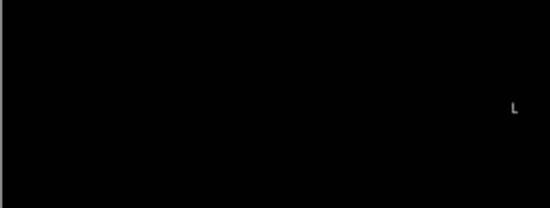
Sc 15  
T1FFE/M  
SI 2

H



Sc 13  
T1FFE/M  
SI 2

H



Sc 5  
T1FFE/M  
SI 3

A



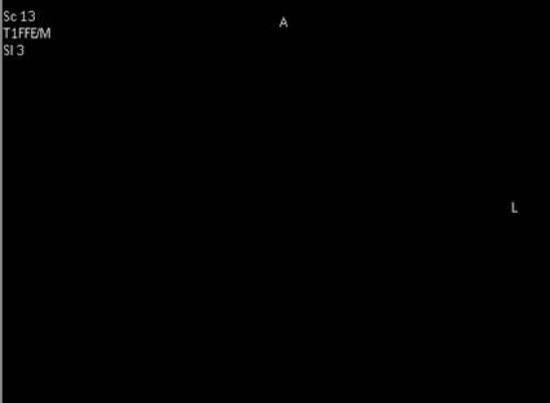
Sc 15  
T1FFE/M  
SI 3

A



Sc 13  
T1FFE/M  
SI 3

A



# FA



背景信号の飽和効果が高い  
血液信号の飽和もあり得る



背景信号の飽和効果が低い

可変FAの効果

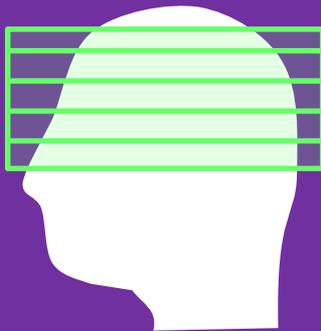
# slab

## メリット

2D-TOF

撮像時間

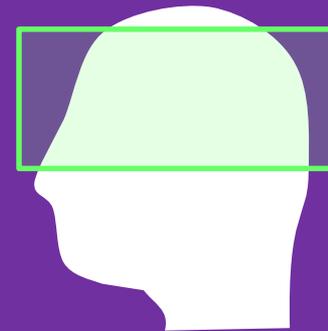
低流速



3D-TOF

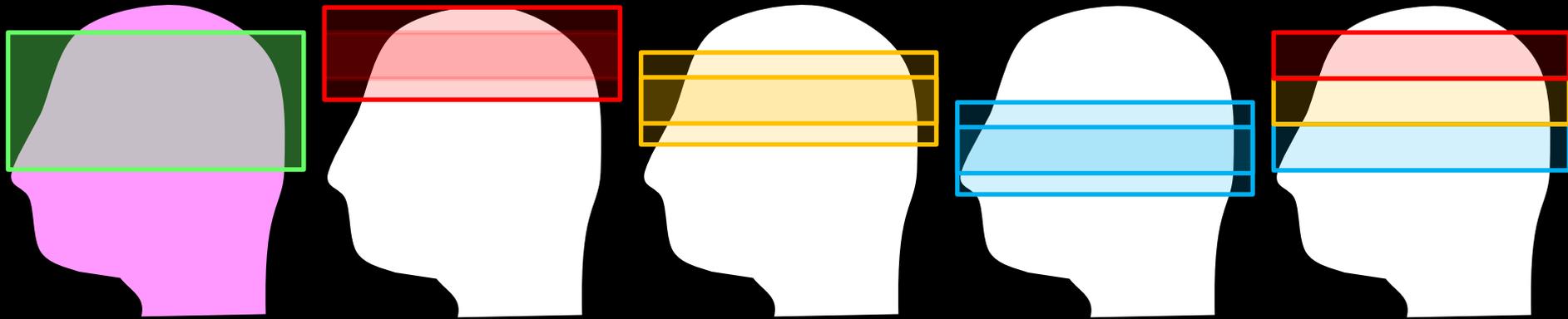
SNR

空間分解能



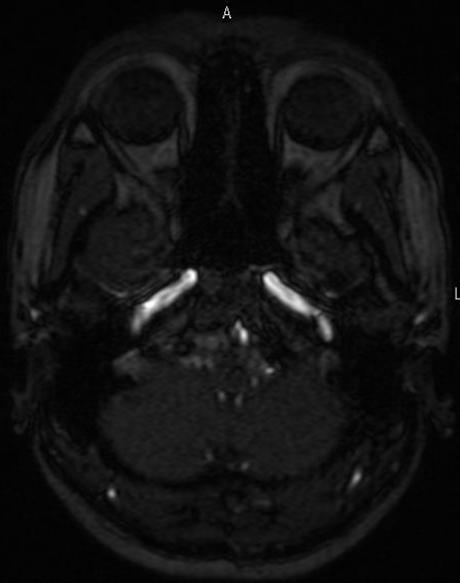
# slab

## 飽和効果 マルチスラブ

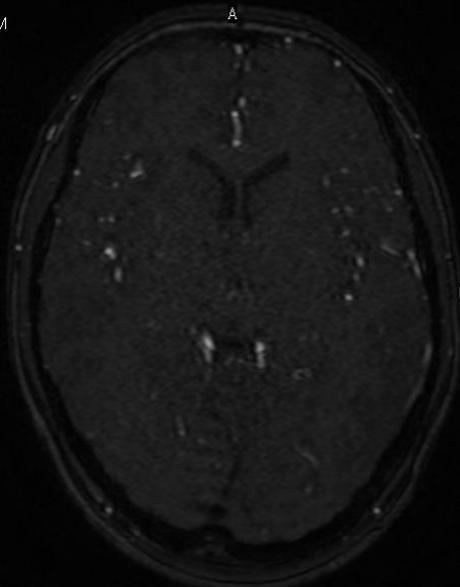


# 2D

c 6  
1FFE/M  
120



Sc 6  
T1FFE/M  
SI 48



## 2D

Matrix size :  $0.78 \times 1.3$

Slice th. :  $2.0/-0.5\text{mm}$

Number of slice : 66

TR/TE :  $25/5.2\text{msec}$

FA :  $45^\circ$

Scan time : 03:08

## 3D

Matrix size :  $0.63 \times 0.98$

Slice th. :  $1.0\text{mm}$

Number of slice : 200

TR/TE :  $23/6.9\text{msec}$

FA :  $20^\circ$

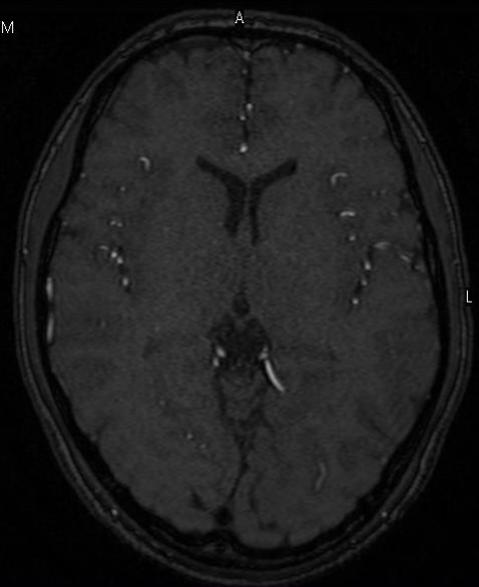
Scan time : 05:08

# 3D

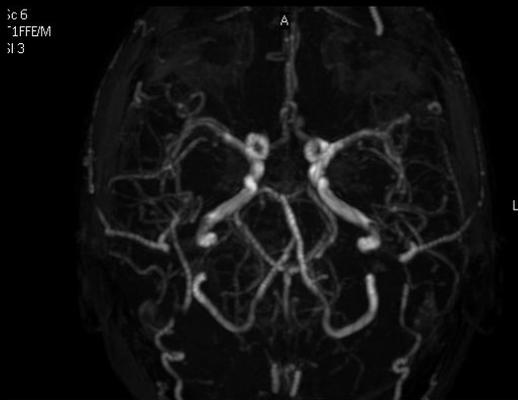
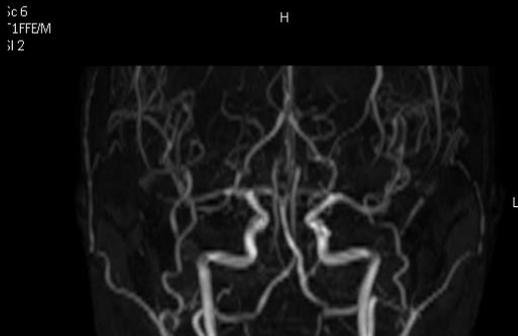
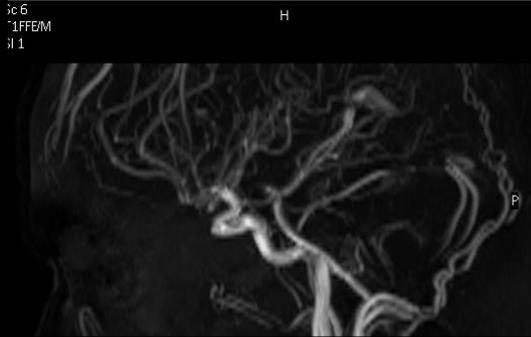
Sc 4  
T1FFE/M  
SI 61



Sc 4  
T1FFE/M  
SI 147



# 2D



## 2D

Matrix size :  $0.78 \times 1.3$

Slice th. :  $2.0/-0.5\text{mm}$

Number of slice : 66

TR/TE :  $25/5.2\text{msec}$

FA :  $45^\circ$

Scan time : 03:08

## 3D

Matrix size :  $0.63 \times 0.98$

Slice th. :  $1.0\text{mm}$

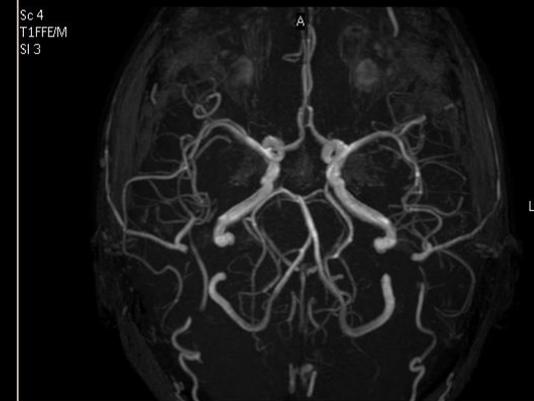
Number of slice : 200

TR/TE :  $23/6.9\text{msec}$

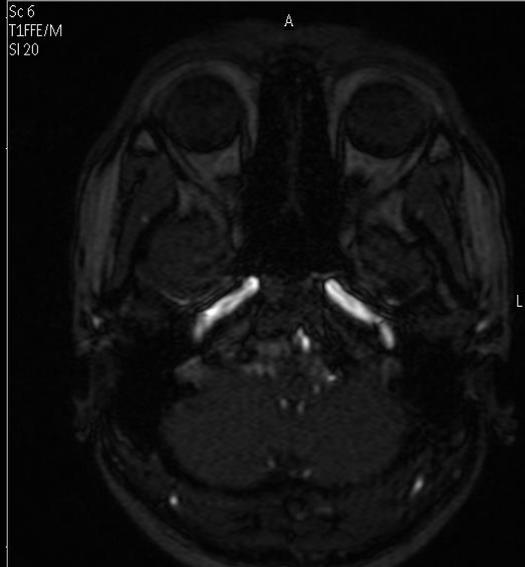
FA :  $20^\circ$

Scan time : 05:08

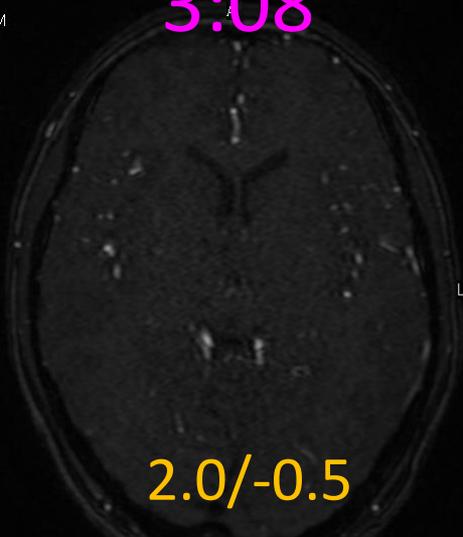
# 3D



# 2D



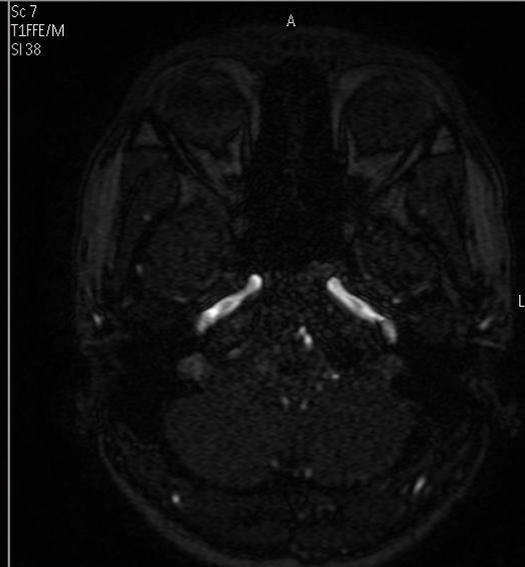
Sc 6  
T1FFE/M  
SI 48



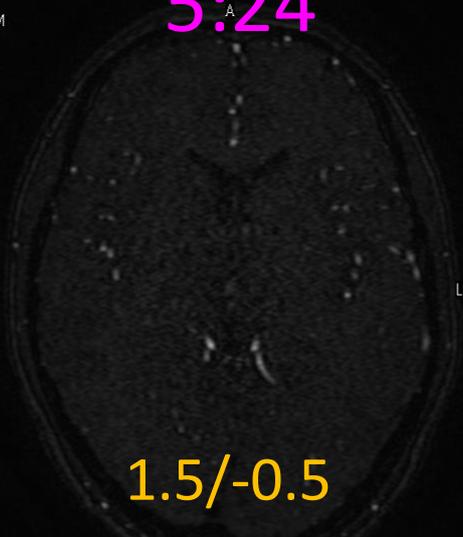
3:08

2.0/-0.5  
0.78 × 1.3

# 2D HR



Sc 7  
T1FFE/M  
SI 91



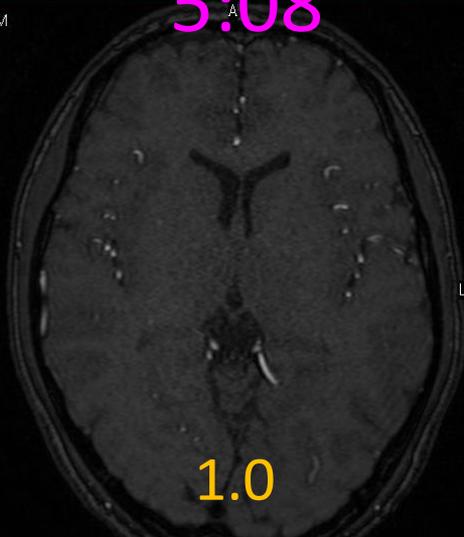
5:24

1.5/-0.5  
0.63 × 1.05

# 3D



Sc 4  
T1FFE/M  
SI 147



5:08

1.0  
0.63 × 0.98

# 2D

# 2D HR

# 3D

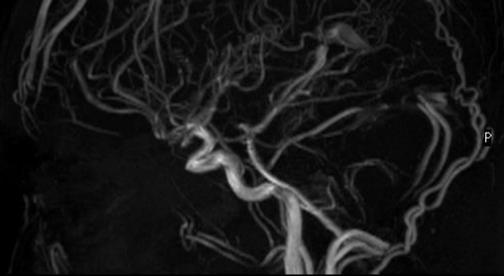
Sc 6  
T1FFE/M  
SI 1

H



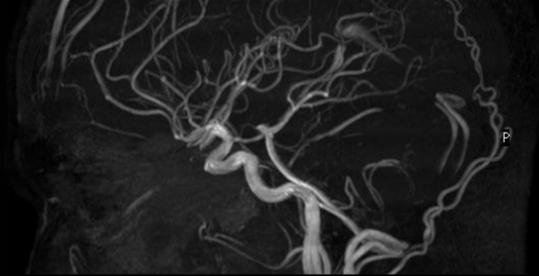
Sc 7  
T1FFE/M  
SI 1

H



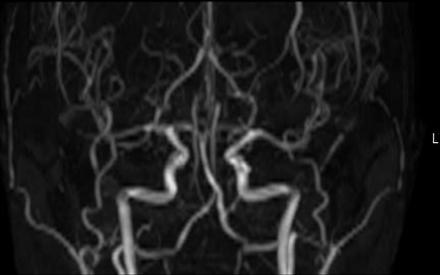
Sc 4  
T1FFE/M  
SI 1

H



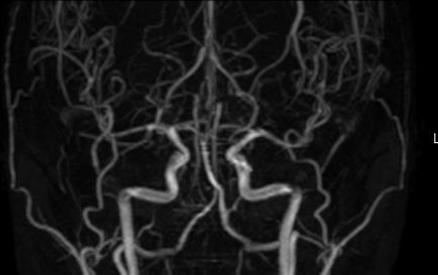
Sc 6  
T1FFE/M  
SI 2

H



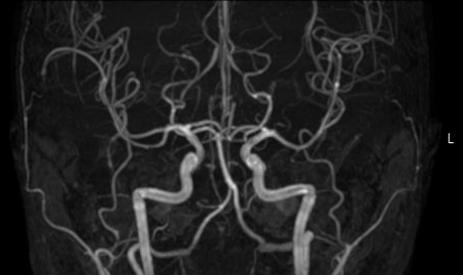
Sc 7  
T1FFE/M  
SI 2

H



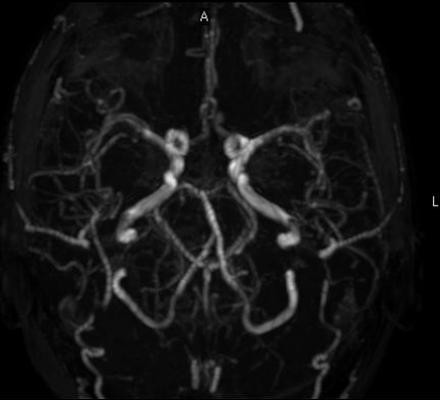
Sc 4  
T1FFE/M  
SI 2

H



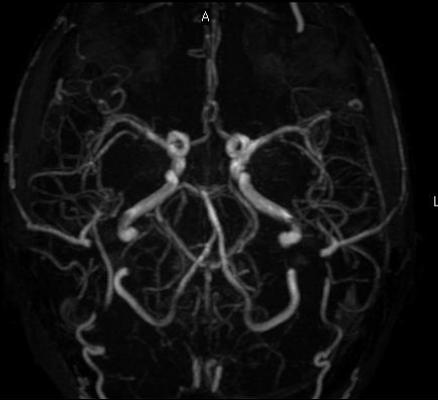
Sc 6  
T1FFE/M  
SI 3

A



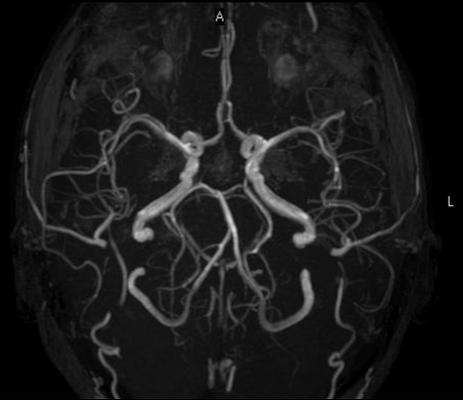
Sc 7  
T1FFE/M  
SI 3

A



Sc 4  
T1FFE/M  
SI 3

A



**slab**

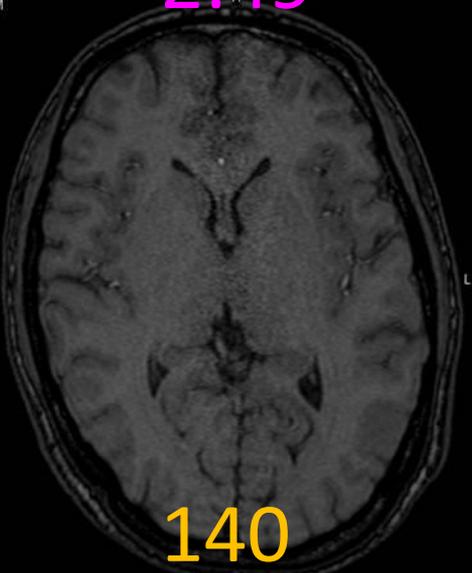
1

Sc 18  
T1FFE/M  
SI 74



2:49

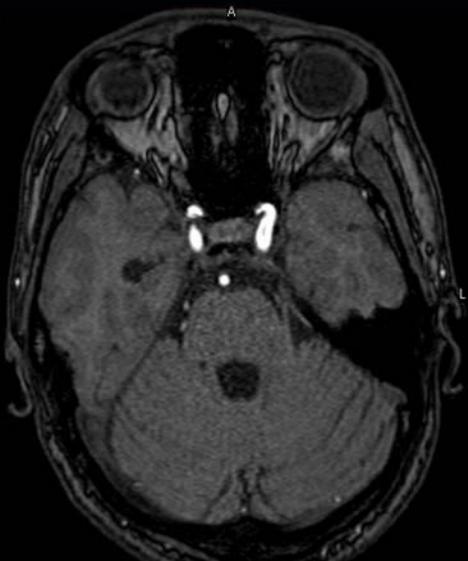
Sc 18  
T1FFE/M  
SI 132



140

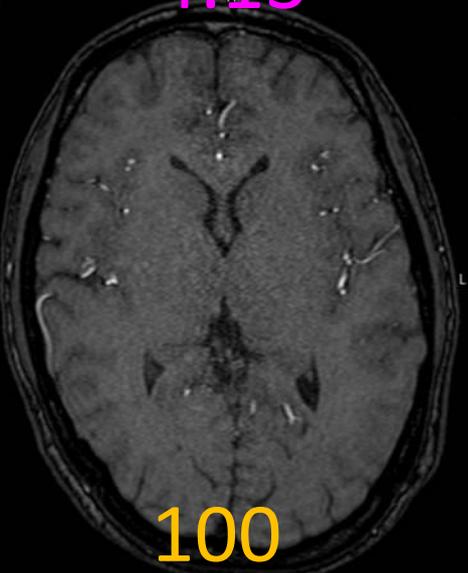
3

Sc 5  
T1FFE/M  
SI 69



4:13

Sc 5  
T1FFE/M  
SI 127



100

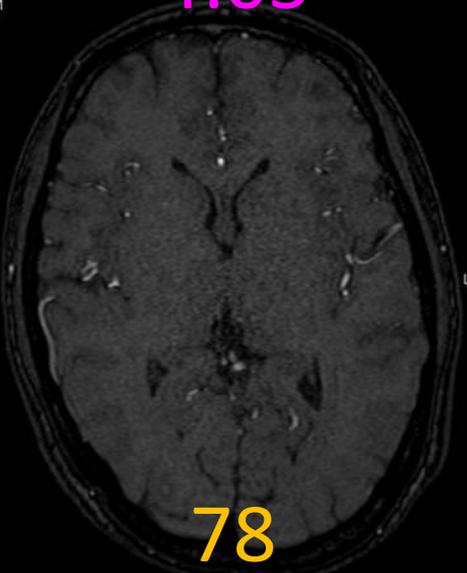
5

Sc 19  
T1FFE/M  
SI 74



4:05

Sc 19  
T1FFE/M  
SI 132



78

# slab

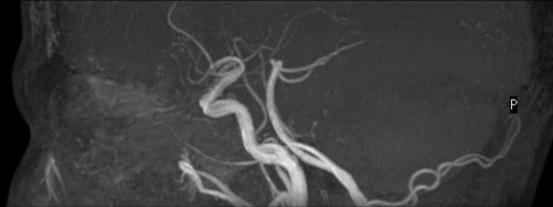
## 1

## 3

## 5

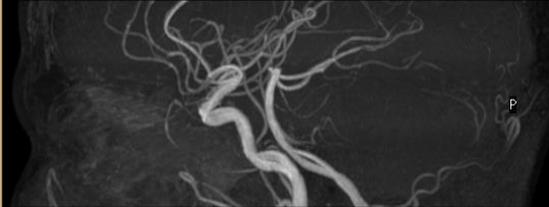
Sc 18  
T1FFE/M  
Sl 1

H



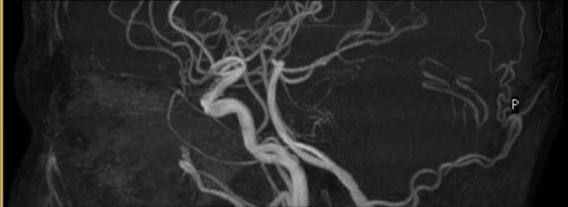
Sc 5  
T1FFE/M  
Sl 1

H



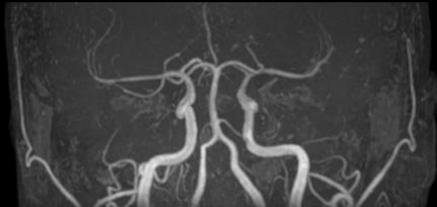
Sc 19  
T1FFE/M  
Sl 1

H



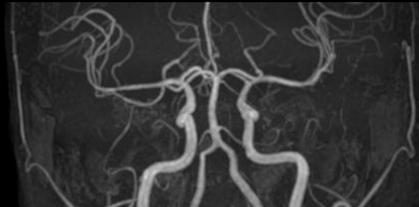
Sc 18  
T1FFE/M  
Sl 2

H



Sc 5  
T1FFE/M  
Sl 2

H



Sc 19  
T1FFE/M  
Sl 2

H



Sc 18  
T1FFE/M  
Sl 3

A



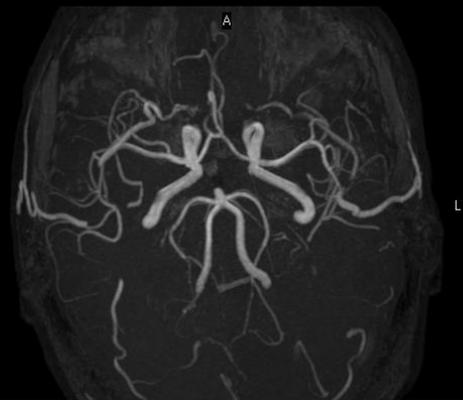
Sc 5  
T1FFE/M  
Sl 3

A



Sc 19  
T1FFE/M  
Sl 3

A



# slab

通常検査においては3D撮像が優る

マルチスラブの効果

# MTC - FS

## MTC

自由水

高分子  
結合水

オンレゾナンス  
オフレゾナンス

## FS (SPIR)

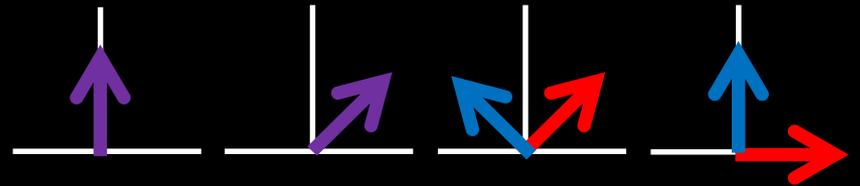
3.5ppm

水

油

## FS (ProSet)

水・油



# まとめ

## 流れに関する基礎

流速・同期撮像・流入効果・位相スピン効果

## 撮像パラメータと効果

TR・TE・FA・slab

ご清聴ありがとうございました