



MR磁敏感成像 (SWI)

原理及其在脑部的应用

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漆剑频



SWI的基本原理

(susceptibility weighted imaging)



SWI是一项反映组织**磁化属性**的新的对比度增强技术，主要提供了传统的 T_1 WI、 T_2 WI、质子密度以及弥散成像之外的另一种对比度。

- ◆ 原始数据有两套，同时得到**强度图像**（Magnitude image）和**相位图像**（Phase image）。
- ◆ 包含脂肪、铁、去氧血红蛋白等物质的组织磁化属性与背景组织明显不同，在强度图像的后处理中使用**相位蒙掩**（phase mask）技术提高对磁敏感效应物质的显示，使其在SWI图像**相位对比**明显增强，因此称**SWI**。



磁敏感效应较强的物质

主要包括去氧血红蛋白、正铁血红蛋白、含铁血黄素、铁沉积（铁蛋白）以及钙沉积等，引起空间相位的改变，这些物质在SWI图像上呈显著的低信号改变。



SWI的基本成像技术

- ◆ 磁场不均匀会给图像中的相位引入低频扰动，使得包含在相位图像中的有用信息难以得到充分利用。
- ◆ 为了去除这种影响，先在原始的K空间数据上施加一个中心矩阵为 64×64 的**低通滤波器**，用原始图像除以（复数除法）由滤波后的K空间数据产生的图像，从而去除原始相位图像中由于磁场不均匀产生的影响。
- ◆ 经过原始图像和低通滤波后图像的复数相除，得到**校正相位图（corrected phase image）**。

相位蒙掩 (phase mask) 及负相位加权处理

- ◆ 校正相位图用于创建相位掩模，进而抑制具有一定相位值的体素。
- ◆ 相位值从0到 π 的加权值设置为1，相位值小于0的加权值被线性的单位化到0至1区间，0对应相位值 $-\pi$ ，1对应相位值0。

相位蒙掩为： $f(x) = (\phi(x) + \pi) / \pi$

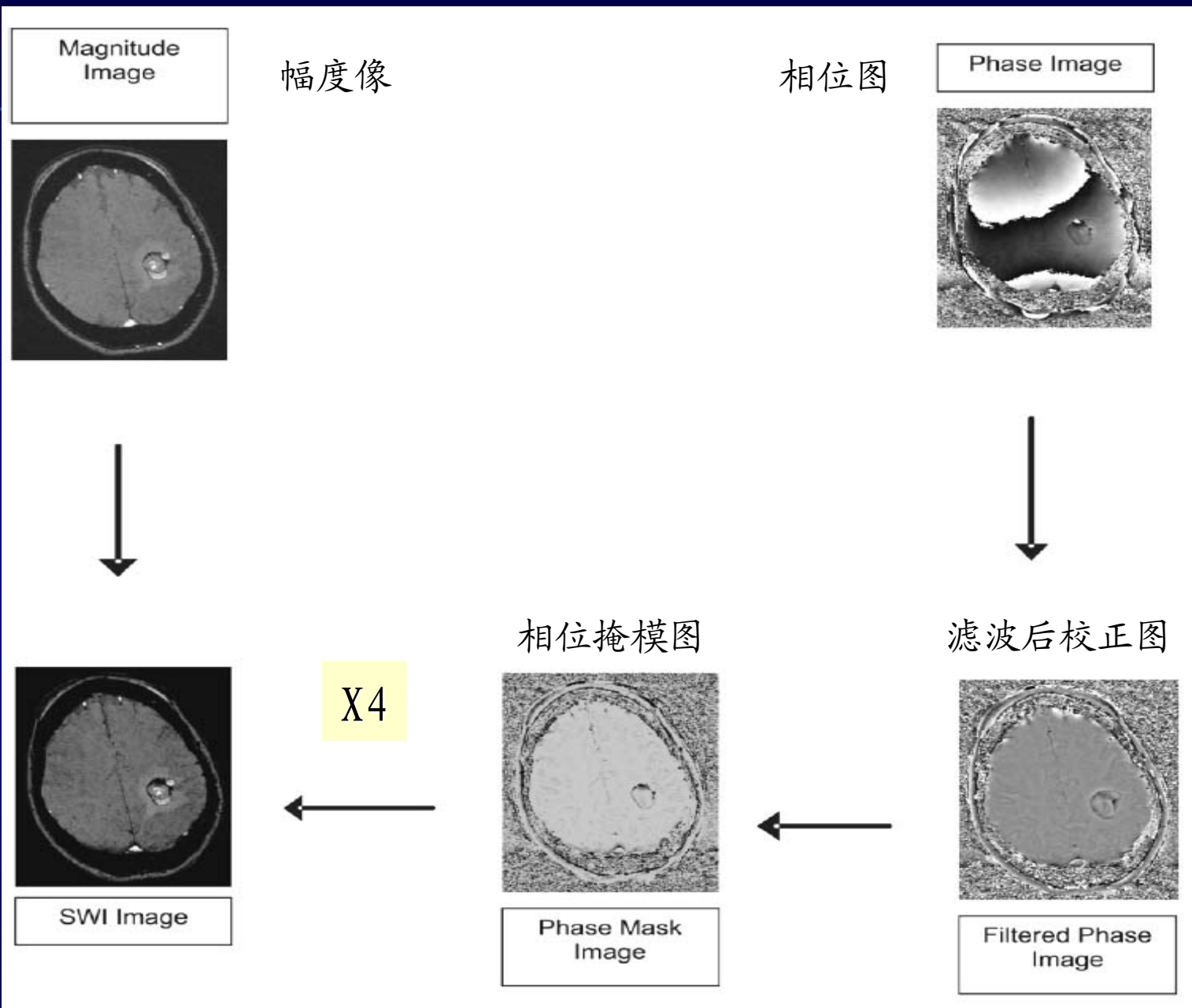
$\phi(x)$ 为兴趣区 x 的相位。

从该公式可以看出，相位值为 $-\pi$ 的体素将被完全抑制，而相位值为 $-\pi$ 至0之间的体素将被部分抑制。相位掩模的相位加权值为0到1之间，称为**负相位蒙掩**。



- ◆ 将幅度图像中的每个像素与对应的相位加权值进行多次相乘，由静脉产生的信号将被大幅度抑制，从而将静脉从原始图像分离出来。实验发现相乘4次得到的结果最为理想，对比噪声比最大。

----- 负相位加权



SWI图像数据采集处理步骤

三维成像及最小信号强度投影 (mIP)

◆ 高分辨率SWI成像参数:

3D-SPGR序列, FOV: 24*24, FA: 30, TR/TE
: 38/25ms, 层厚/间距: 1.5 ~ 2/0 mm,
Matrix: 512 × 384, NEX: 0.75

◆ 由于静脉血管表现为显著的低信号, 而且层面厚度很薄, 只有通过三维mIP显示才能显示完整的静脉血管形状。



SWI的主要技术特点

- ◆ 高分辨率三维梯度回波序列成像;
- ◆ 三个方向应用流动补偿技术;
- ◆ 薄层扫描避免信号丢失;
- ◆ 对原始相位图像进行高通滤波, 去除磁场不均匀对相位的影响;
- ◆ 生成相位蒙掩图突出某些组织的磁敏感属性;
- ◆ 在幅度图像应用负相位加权处理
- ◆ 最小信号强度投影 (mIP)

使用显著的相位对比来增强幅度图像的对比噪声比



临 床 应 用



在脑血管性病变的应用



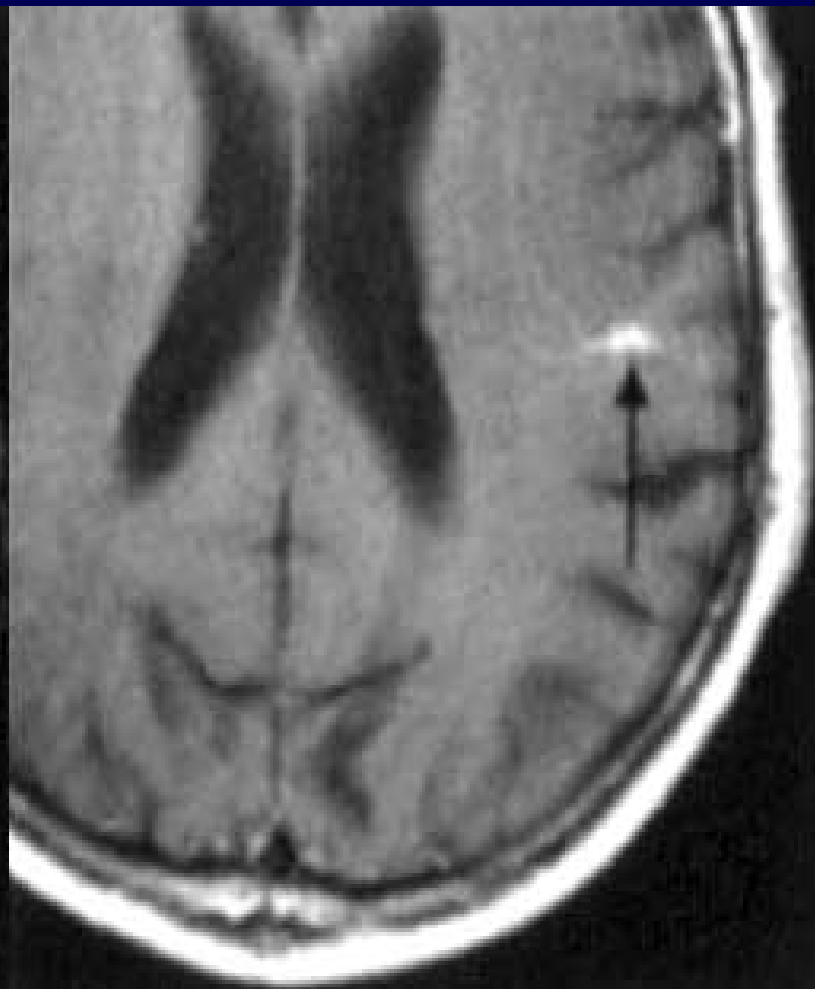
◆ 静脉血管畸形 (venous angioma)

SWI显示病变呈蜘蛛样改变，并显示丛状细如发丝的髓静脉，较增强MRI及MRA发现更多的髓静脉向粗大的引流静脉集中。

同济

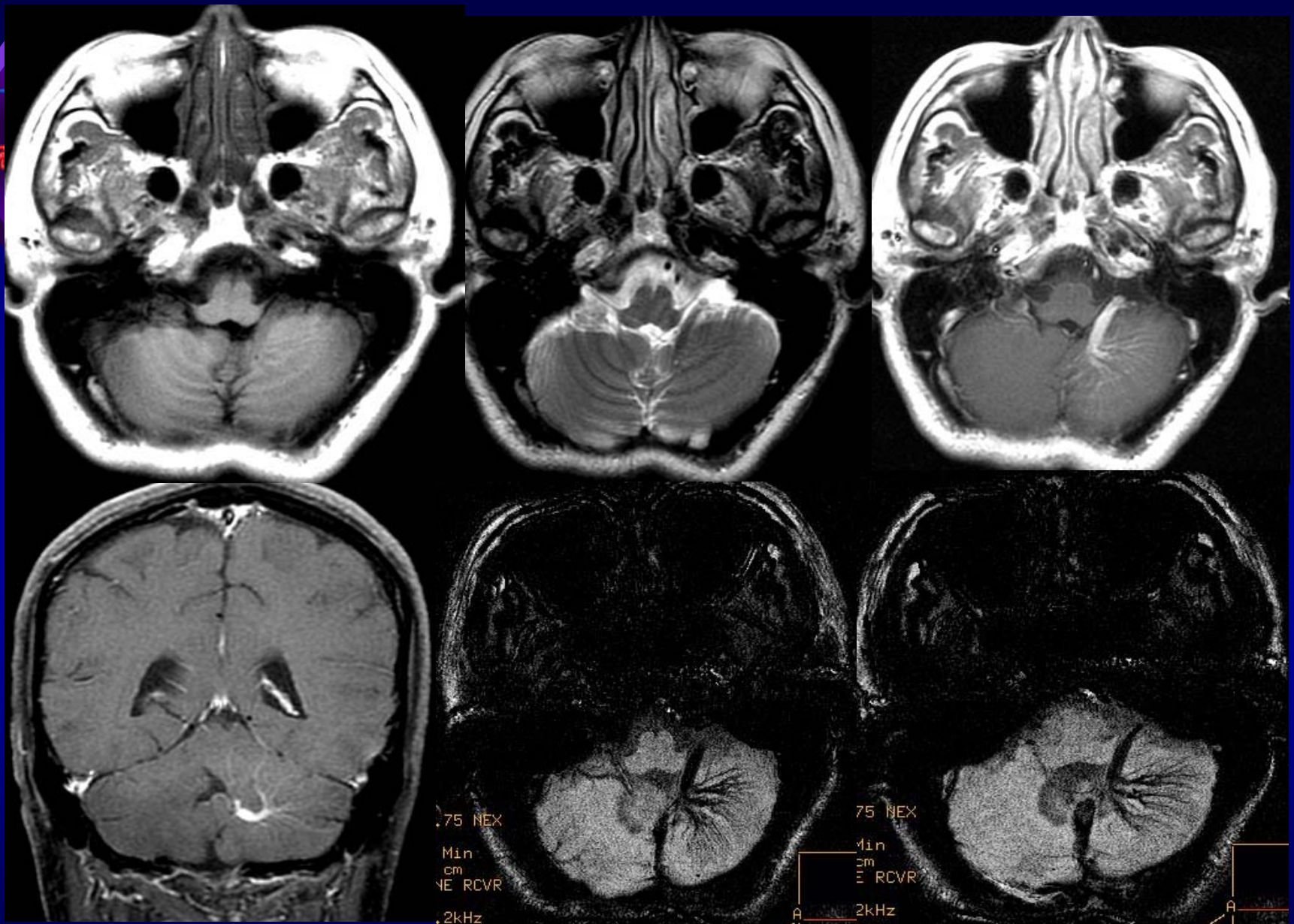


SWI

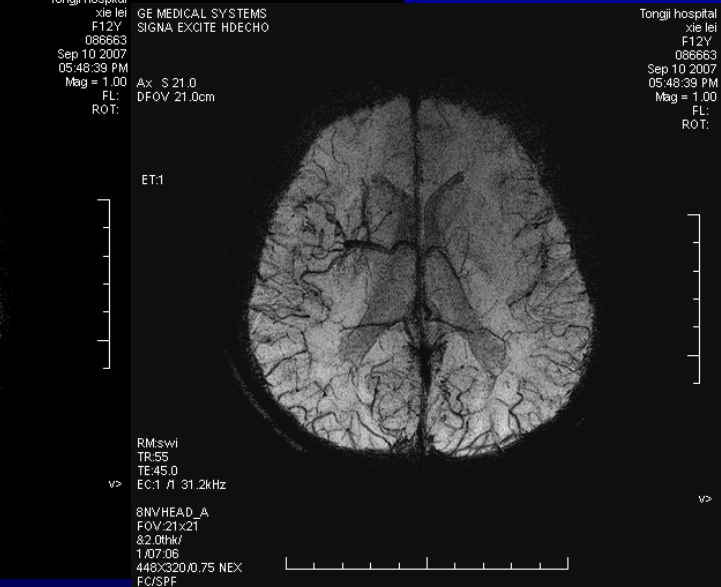
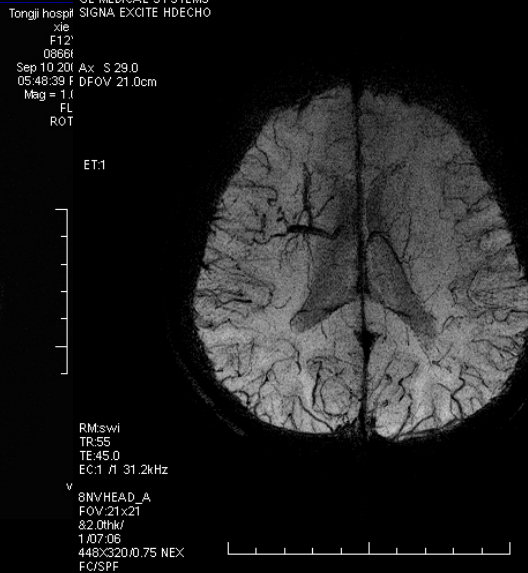
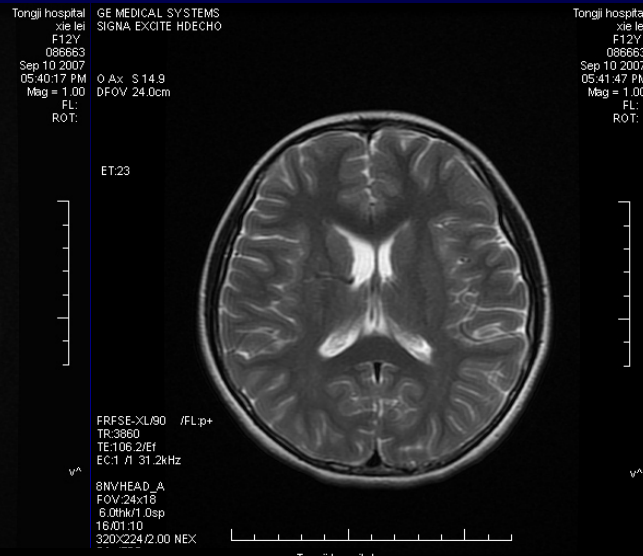
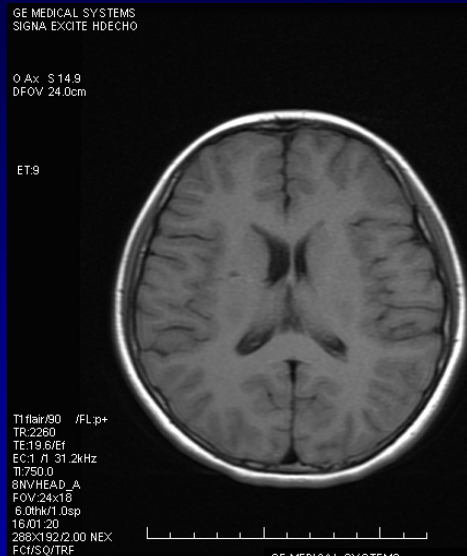


+C T1WI

Venous Angioma



Venous angioma

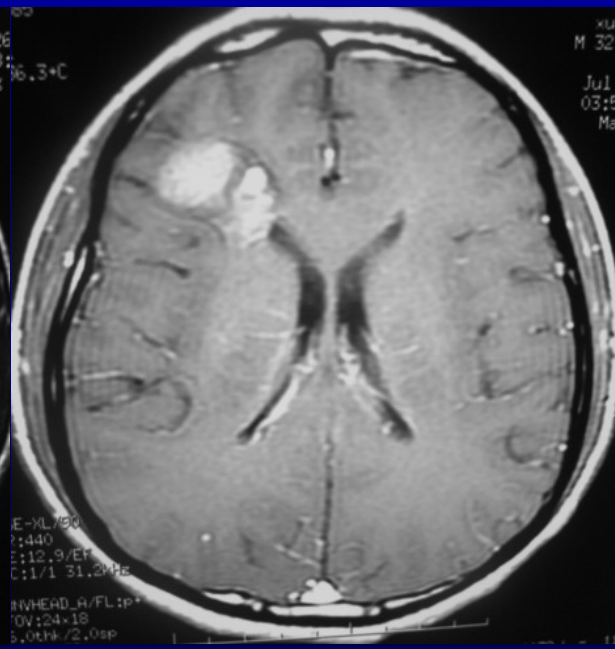
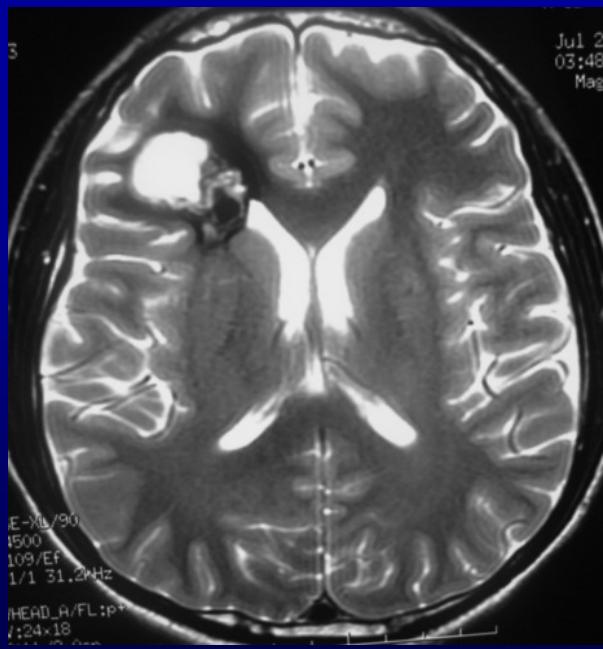
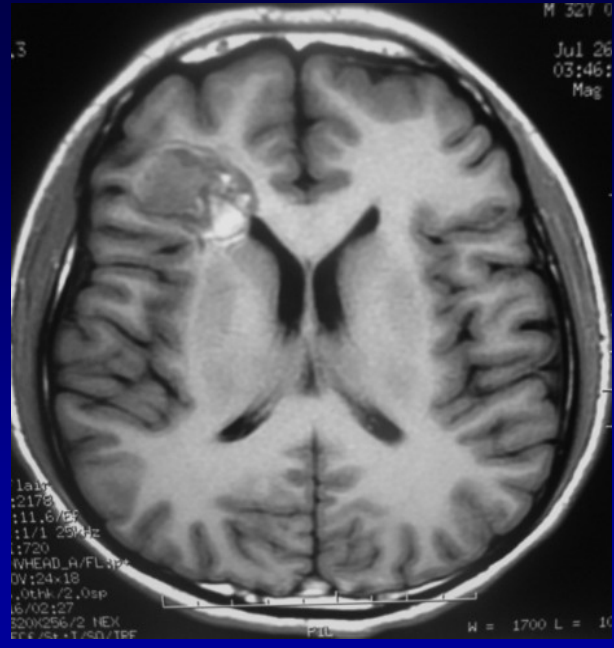
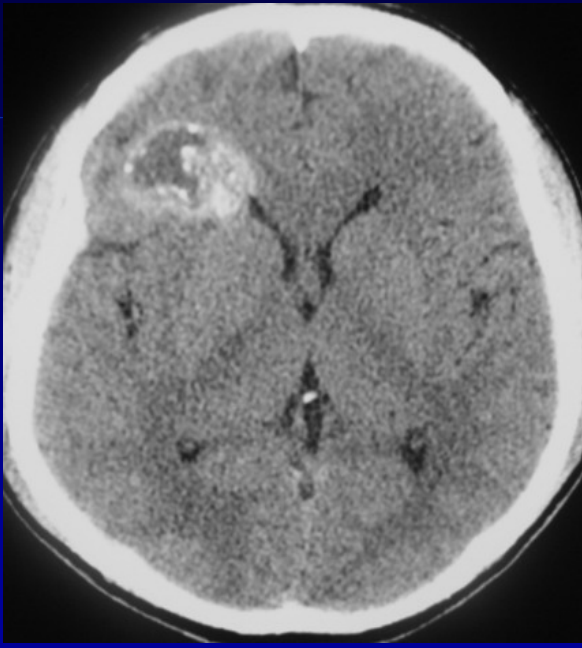


Venous angioma

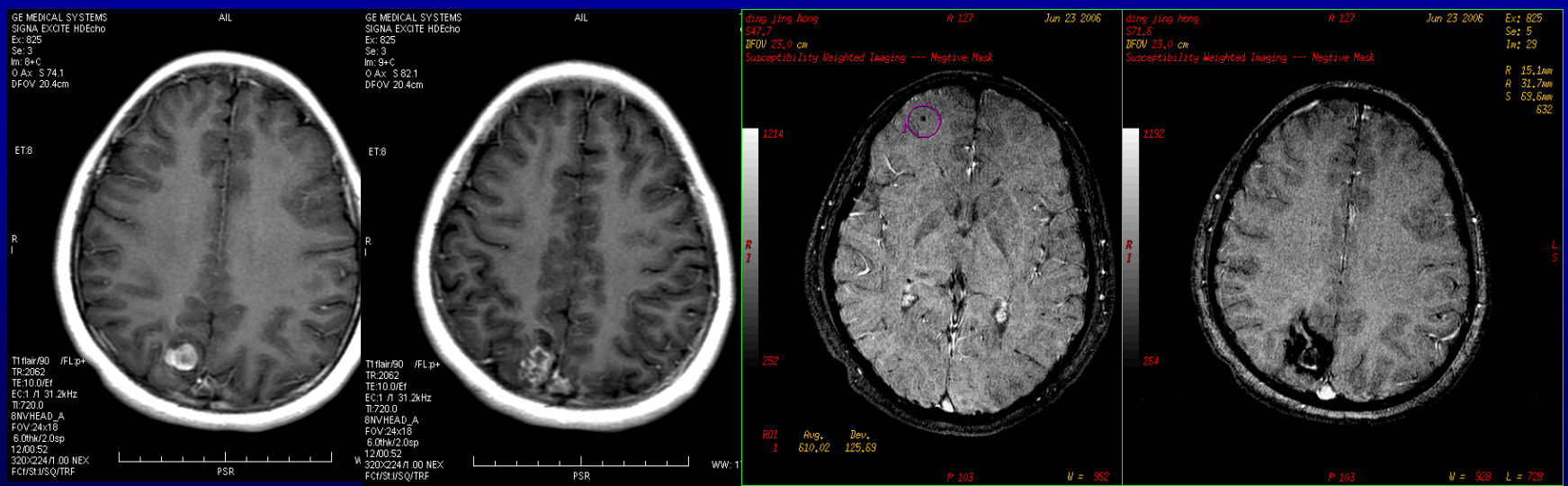
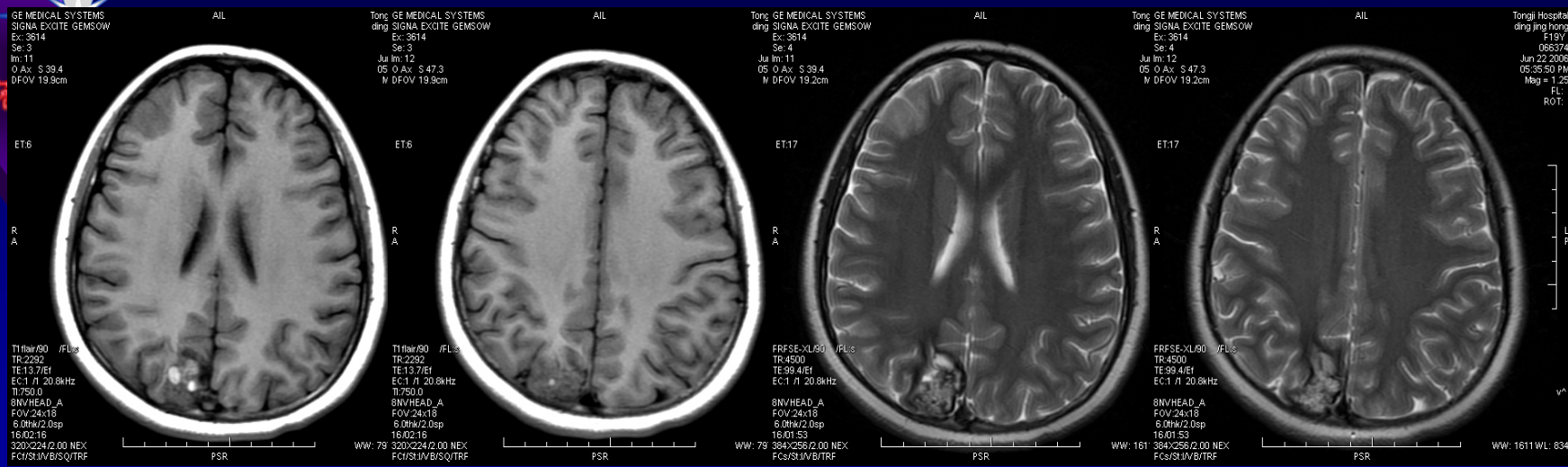
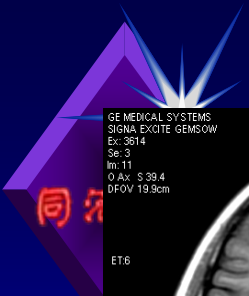


◆海绵状血管瘤（Cavernoma）

SWI显示病灶信号不均，出血为低信号，瘤体呈不均匀高信号；并能发现更多血管瘤及细小出血灶。



海绵状血管瘤 (Cavernoma)



海绵状血管瘤 (Cavernoma)

GE MEDICAL SYSTEMS
SIGNA EXCITE GEMSOW
Ex: 14142
Se: 3
Im: 10
O Ax: S 51.3
DFOV 24.0cm

ASL

Tongji Hospit
liu bao z
F42
Ex: 14142
08971 Se: 4
Nov 08 2007 Im: 10
12:40:08 P O Ax: S 51.3
Mag = 1.0 DFOV 24.0cm
FL:
ROT:

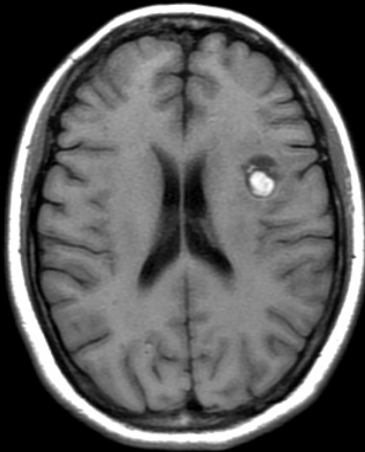
ASL

GE MEDICAL SYSTEMS
SIGNA EXCITE GEMSOW
Ex: 14142
Se: 4
Im: 12
O Ax: S 66.3
DFOV 24.0cm

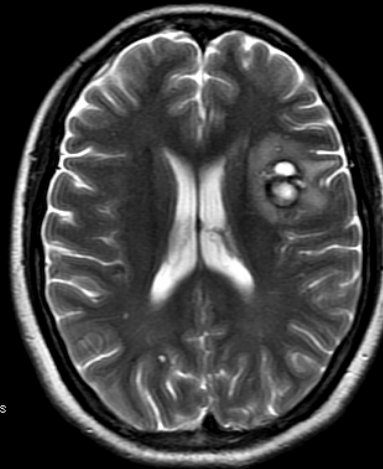
ASL

Tongji Hospital
liu bao zhi
F42Y
089718
Nov 08 2007
12:44:03 PM
Mag = 1.00
FL:
ROT:

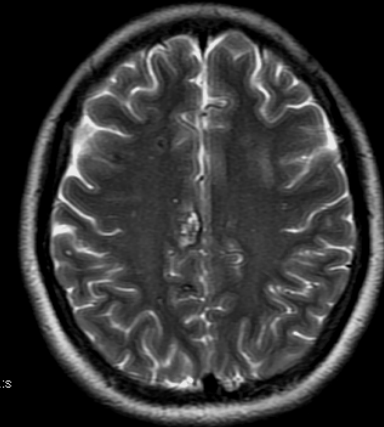
ET:8



ET:21



ET:21



T1flair/90 /FL:s
TR:2300
TE:13.0/ef
EC:1 /f 22.7kHz
TI:750.0
8NVHEAD_A
FOV:24x18
6.0thk/1.5sp
16.0/1.49
320x224/2.00 NEX
FCs/STJW/B/TRF/Z512

PIR

FRFSE-XL/90 /FL:s
TR:4800
TE:112.7/ef
EC:1 /f 27.8kHz
8NVHEAD_A
FOV:24x18
6.0thk/1.5sp
16.0/1.22
384x224/2.00 NEX
FCs/STJW/B/TRF/Z512

PIR

FRFSE-XL/90 /FL:s
TR:4800
TE:112.7/ef
EC:1 /f 27.8kHz
8NVHEAD_A
FOV:24x18
6.0thk/1.5sp
16.0/1.22
384x224/2.00 NEX
FCs/STJW/B/TRF/Z512

PIR

WW: 1076 WL: 652

GE MEDICAL SYSTEMS
SIGNA EXCITE HDECHO
Ex: 10149
Se: 302
Im: 9
O Ax: S 40.4
DFOV 24.0cm

ASR

SIGNA
Ex: 10149
Se: 302
Im: 5
O Ax: S 62.4
DFOV 24.0cm

PIR

GE MEDICAL SYSTEMS
088 SIGNA EXCITE HDECHO
Nov 09 2 Ex: 10149
01:37:3 Se: 302
Mag = Im: 3
O Ax: S 76.4
R DFOV 24.0cm

ASR

Tongji hospital
liu bao zhi
F42Y
089718
Nov 09 2007
01:37:34 PM
Mag = 1.00
FL:
ROT:

ET:1



ET:1



ET:1



RMresearch/swi/swi_asset
TR:56
TE:42.0
EC:1 /f 15.6kHz

PIR

RMresearch/swi/swi_asset
TR:56
TE:42.0
EC:1 /f 15.6kHz

PIR

RMresearch/swi/swi_asset
TR:56
TE:42.0
EC:1 /f 15.6kHz

PIR

8NVHEAD ONE RCVR
FOV:24x24
82.0thk/
1.08:40
448x384/0.75 NEX
FC

PIR

8NVHEAD ONE RCVR
FOV:24x24
82.0thk/
1.08:40
448x384/0.75 NEX
FC

PIR

WW: 830 WL: 652
FC

PIR

WW: 830 WL: 662
FC

毛细血管扩张症 (Telangiectasis)

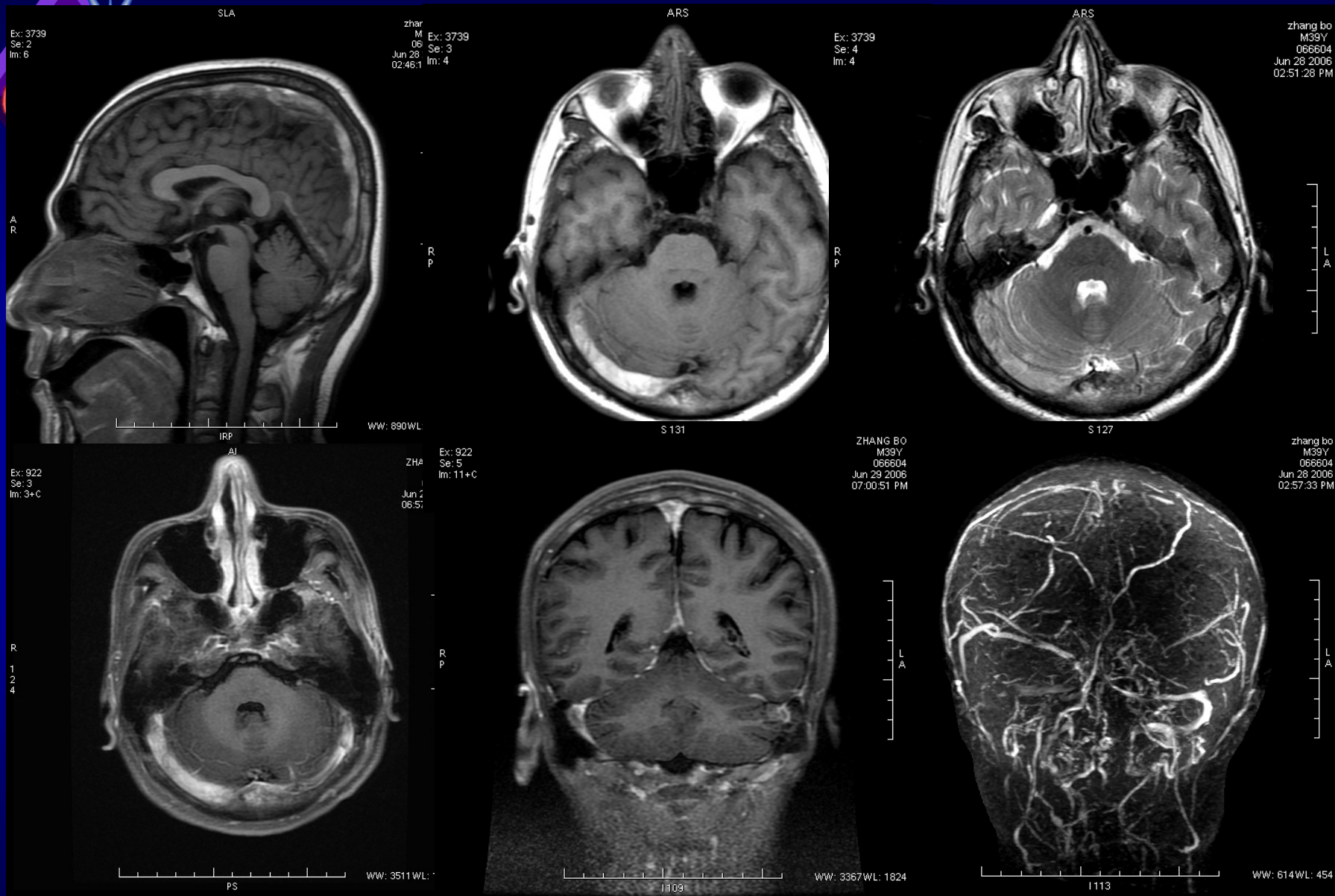


◆ 静脉窦血栓形成

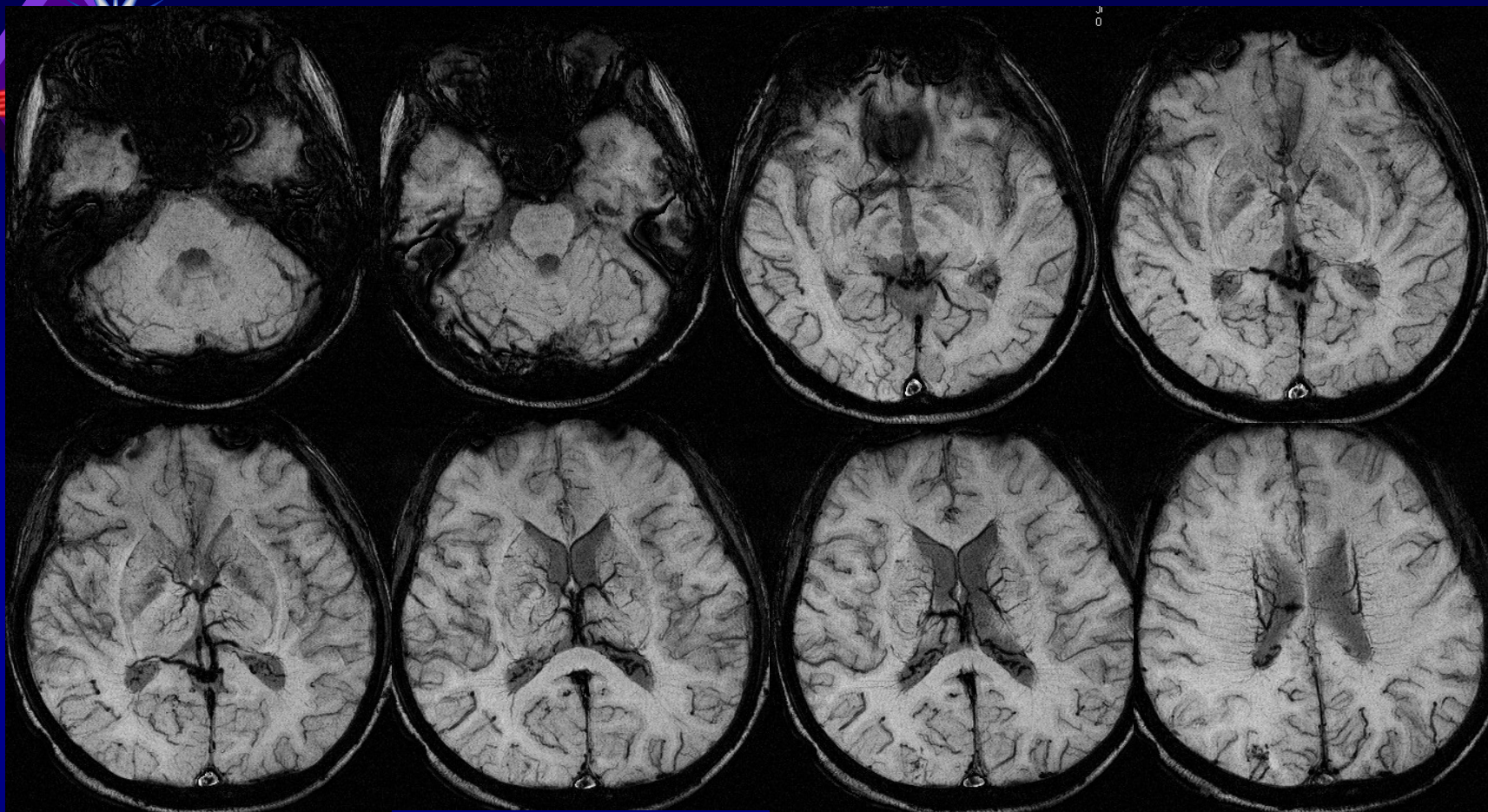
MRV见患侧乙状窦不显影，增强扫描见广泛充盈缺损形成。

DWI及T1WI及T2WI仅发现脑内少量水肿与腔梗，并未发现出血。

SWI见深部引流静脉及脑表面静脉网广泛增粗扩张迂曲，并发现早期出血灶



右侧乙状窦急性血栓形成1d

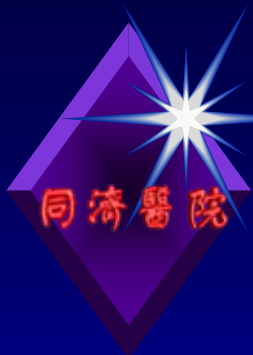


右侧乙状窦急性血栓形成
SWI见深部扩张的静脉\右顶枕叶交界处早期出血



◆ 高血压脑部微血管病变

SWI显示基底节区及皮层下多发细小出血灶。



GE MEDICAL SYSTEMS
 SIGNA EXCITE HDECHO
 Ex: 6580
 Se: 1005
 Im: 9
 Ax: 132.0
 DFOV: 21.0cm

A 105

ET:1

R
1
0
2

RMswi
 TR:55
 TE:45.0
 EC:1 / 1 31.2kHz

8NVHEAD_A
 FOV:21x21
 82.0thk/
 1.0mm
 GE MEDICAL SYSTEMS
 SIGNA EXCITE HDECHO
 Ex: 6580
 Se: 9
 Im: 13
 O Ax: 124.8
 DFOV: 24.0cm

ASR

ET:1

R
P
I

GR/20 /FL:p+
 TR:500
 TE:15.0
 EC:1 / 1 12.5kHz

8NVHEAD_A
 FOV:24x18
 5.0thk/0.5sp
 20/02:32
 256x192/1.00 NEX
 St:SlF/Z512/SPF

PIL

Tongji hospital GE MEDICAL SYSTEMS
 yin xiao he SIGNA EXCITE HDECHO
 F60Y Ex: 6580
 080854 Se: 1005
 May 25 2007 Im: 2
 08:25:26 P Ax: 14.0
 Mag = 1.0 DFOV: 21.0cm
 FL:
 ROT:

A 105

ET:1

R
1
0
2

RMswi
 TR:55
 TE:45.0
 EC:1 / 1 31.2kHz

v: 8NVHEAD_A
 FOV:21x21
 82.0thk/
 1.0mm
 GE MEDICAL SYSTEMS
 SIGNA EXCITE HDECHO
 Tongji hospital yin xiao he Ex: 6580
 Se: 9
 F60Y Im: 9
 080854 O Ax: 12.9
 May 25 2007 DFOV: 24.0cm
 08:17:31 PM
 Mag = 1.00
 FL:
 ROT:

ASR

ET:1

R
P
I
L
A
S

GR/20 /FL:p+
 TR:500
 TE:15.0
 EC:1 / 1 12.5kHz

v> 8NVHEAD_A
 FOV:24x18
 5.0thk/0.5sp
 20/02:32
 256x192/1.00 NEX
 St:SlF/Z512/SPF

WW: 2151 WL: 1404

PIL

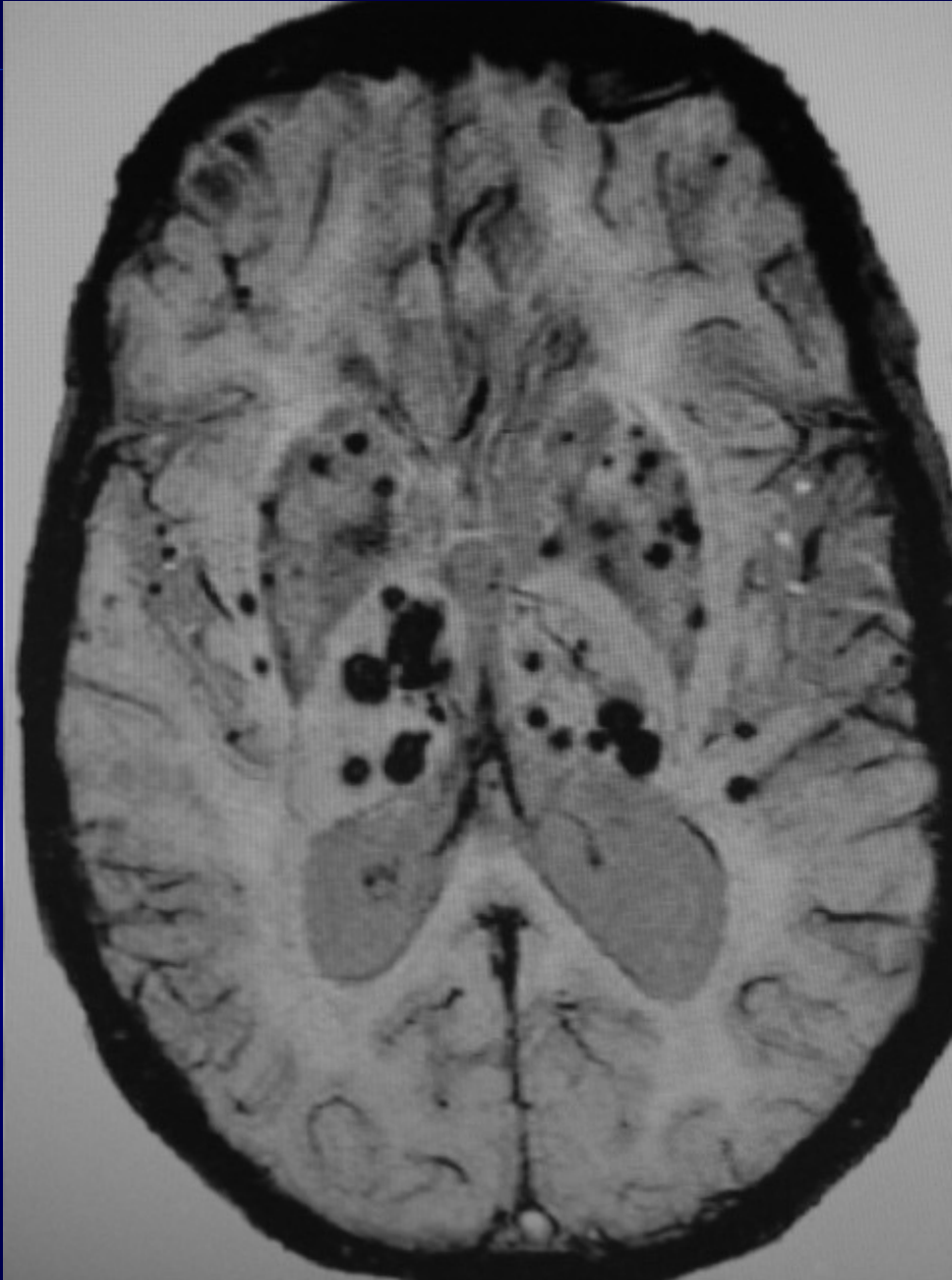
Tongji hospital yin xiao he
 F60Y
 080854
 May 25 2007
 08:25:26 PM
 Mag = 1.00
 FL:
 ROT:

Tongji hospital yin xiao he
 F60Y
 080854
 May 25 2007
 08:17:31 PM
 Mag = 1.00
 FL:
 ROT:

L
A
S

WW: 2161 WL: 1390

Hypertension - 皮层下微出血

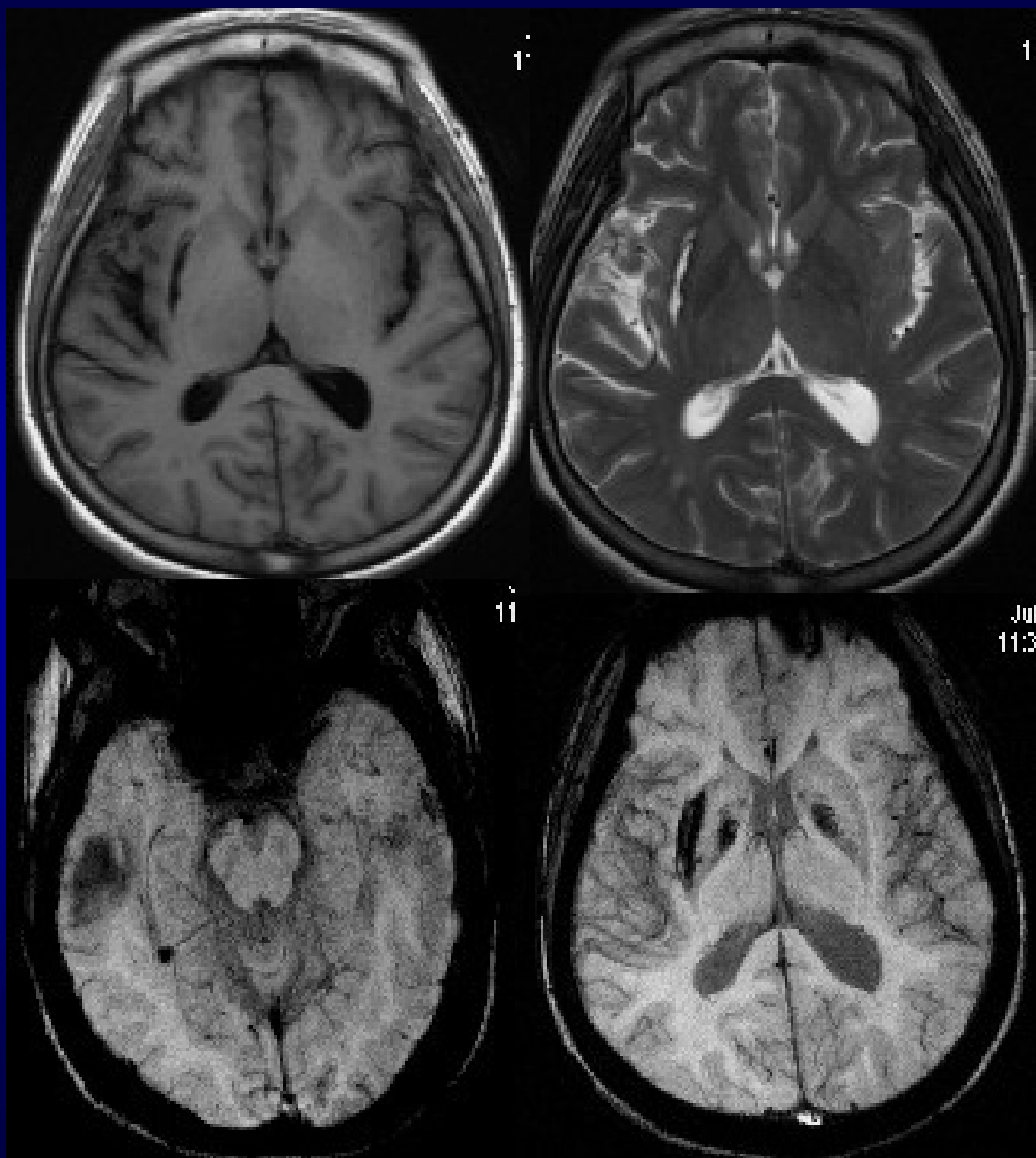


Hypertension
多发散在出血灶



◆脑梗死并发出血

发现早期梗死灶内的早期出血，指导临床治疗。陈旧性梗死灶内大小不等的片状及团状极低信号，提示病变曾经出血。

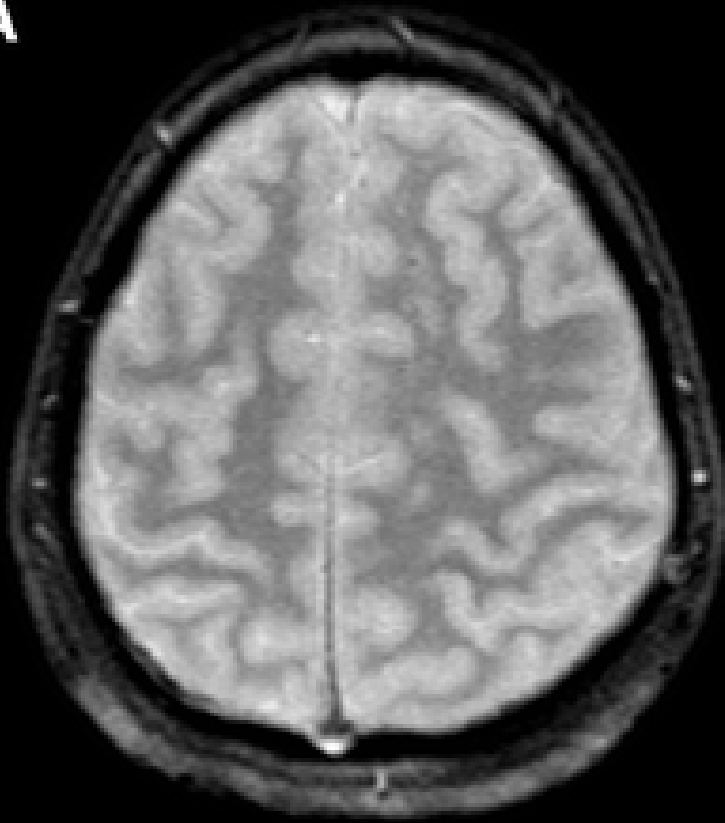




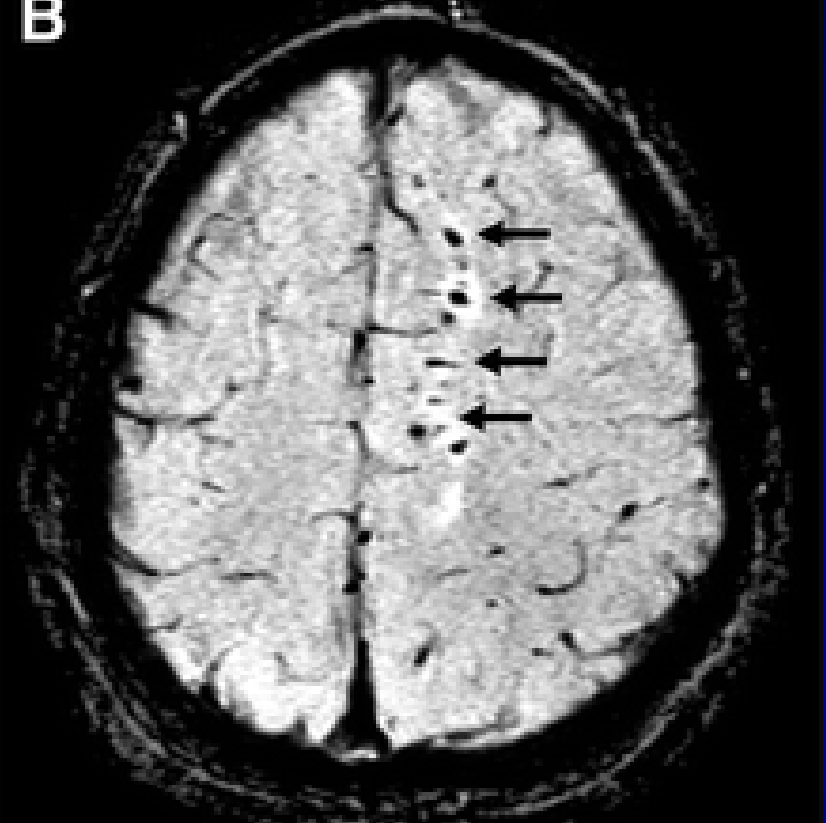
◆在脑外伤的应用

显示弥漫性轴索损伤在灰白质交界处的多发小出血灶，较常规MRI敏感。

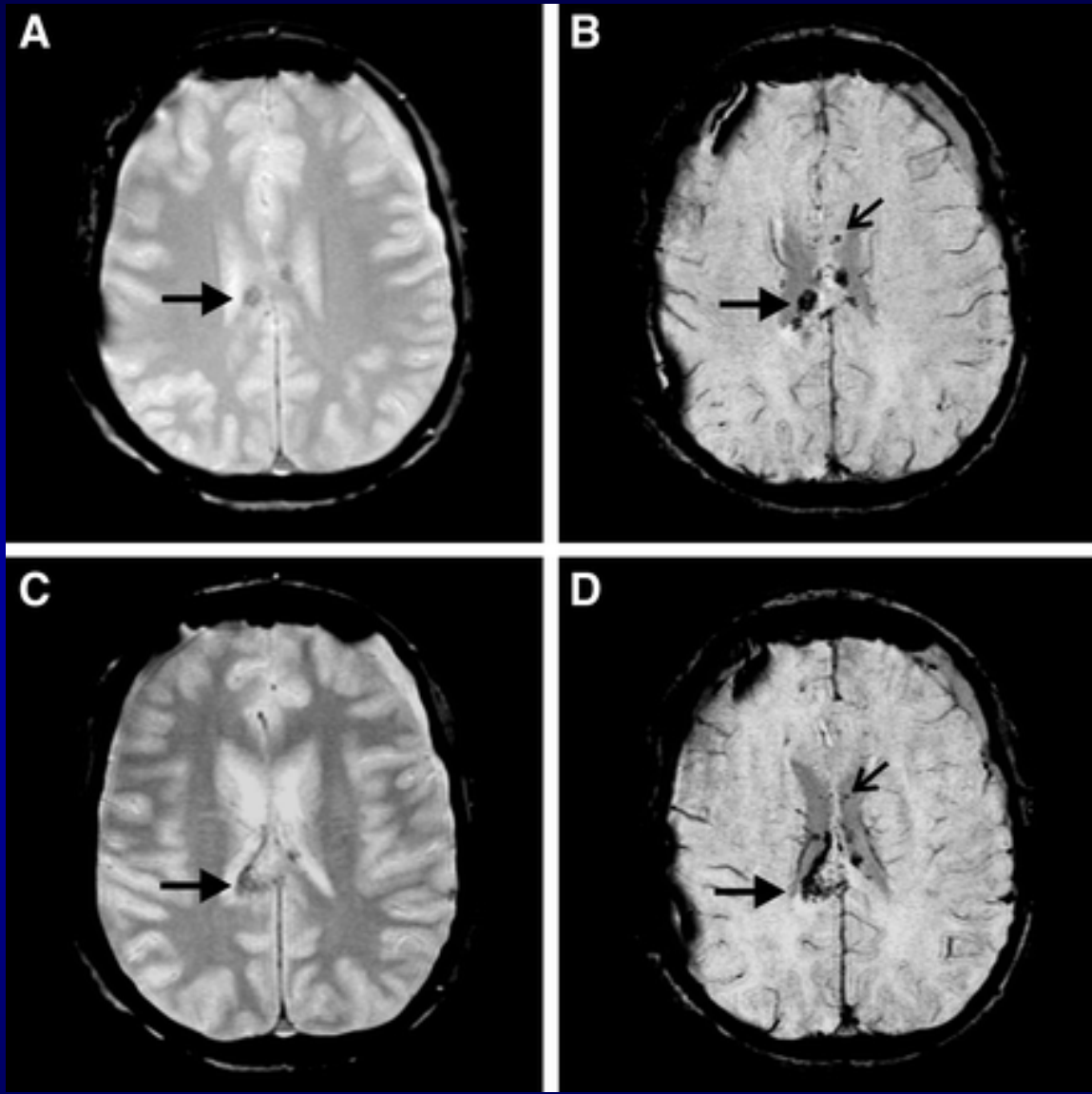
A



B



Radiology, 2003. Tong KA



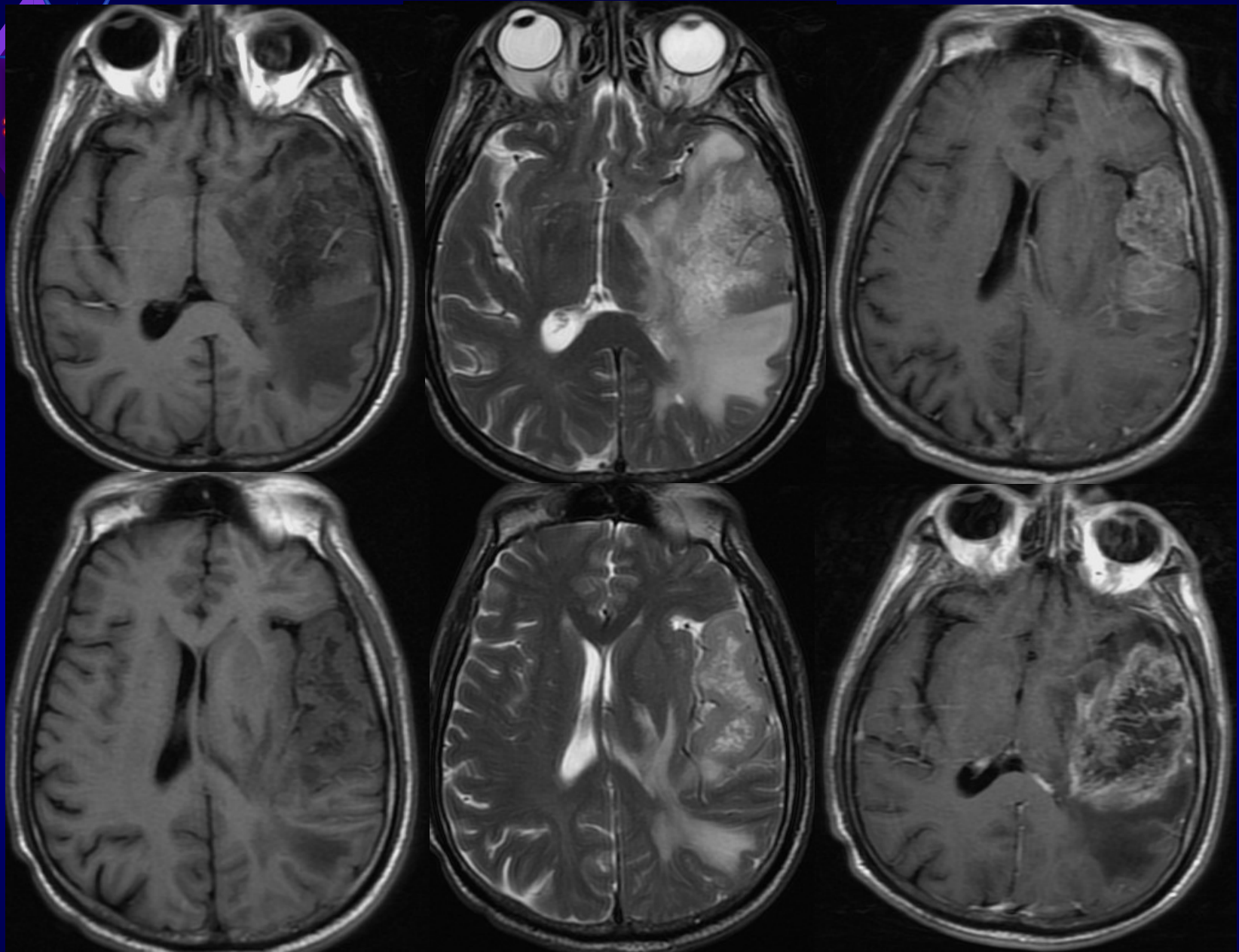
Radiology, 2003. Tong KA



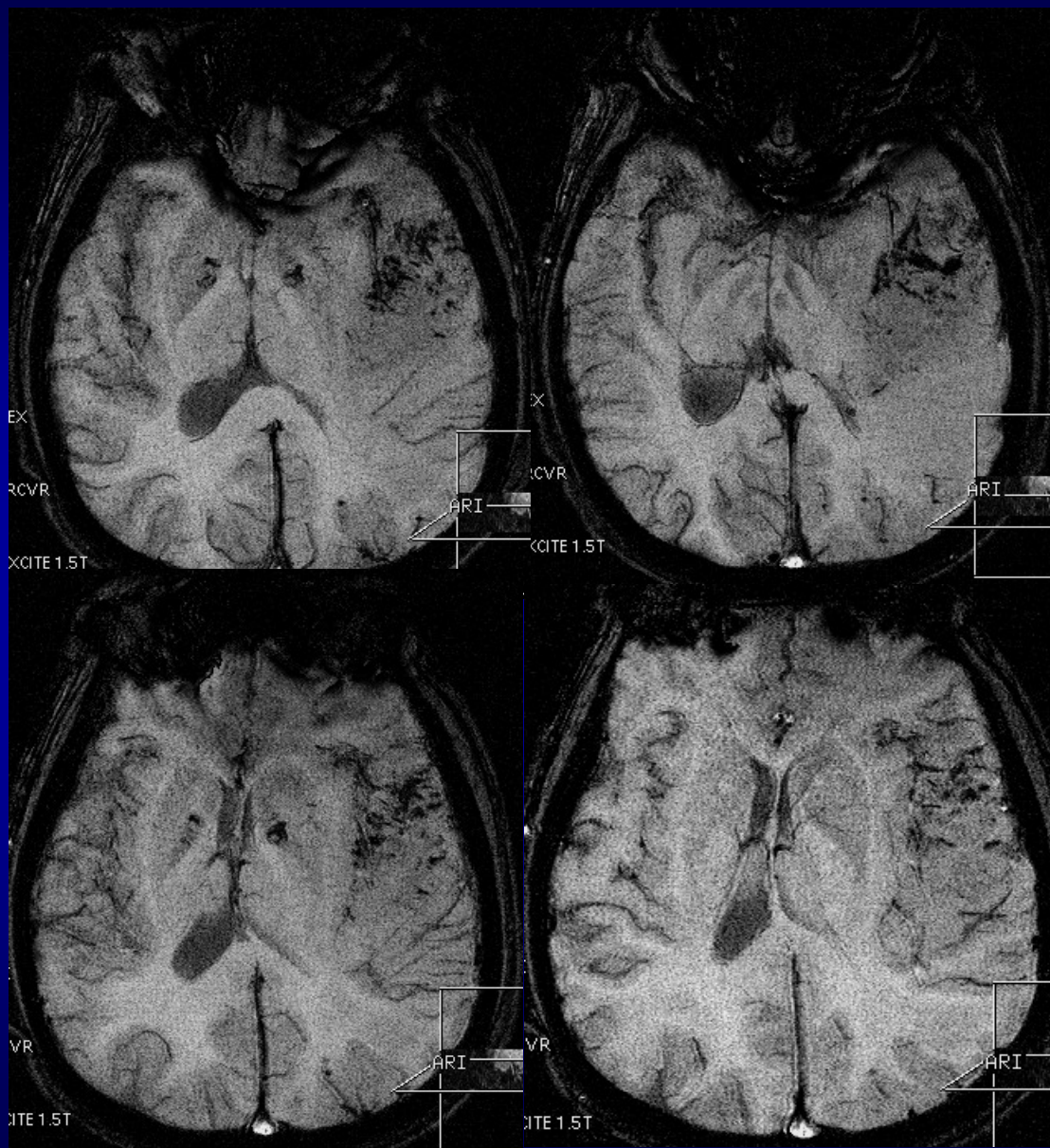
◆在脑肿瘤的应用

显示肿瘤出血及内部静脉血管

结构及小出血灶



Malignant astrocytoma



SWI
显示肿瘤内血管及出血



脑部矿物质沉积及变性等病变的应用

Wilson disease

豆状核变性

Parkinson disease

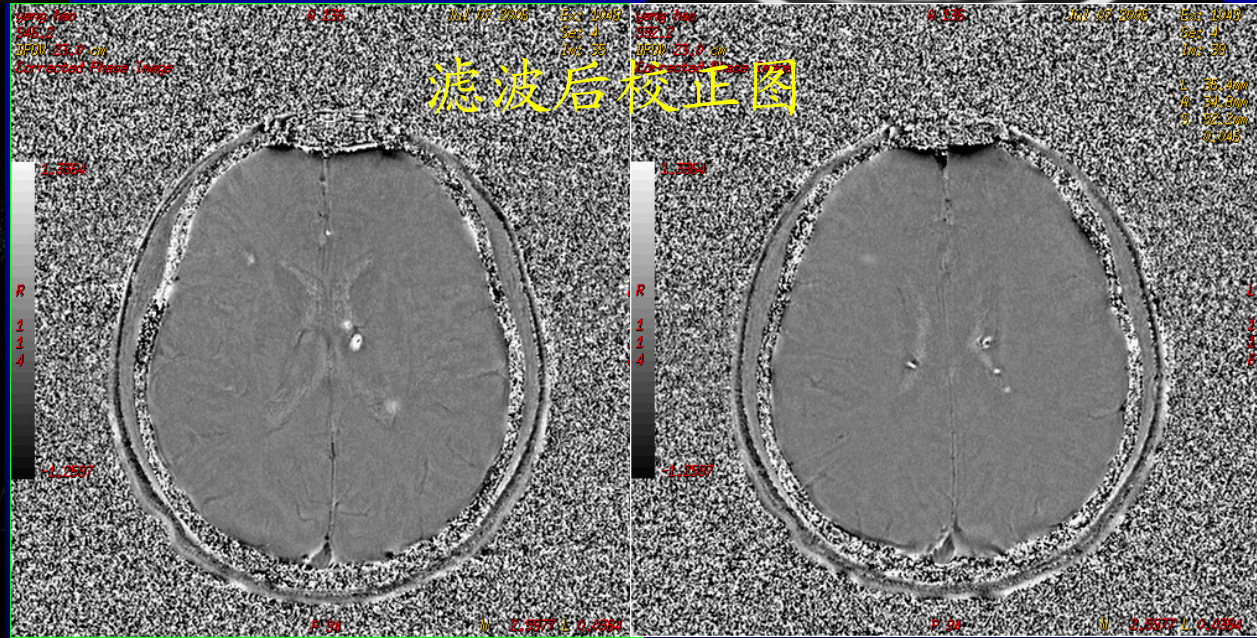
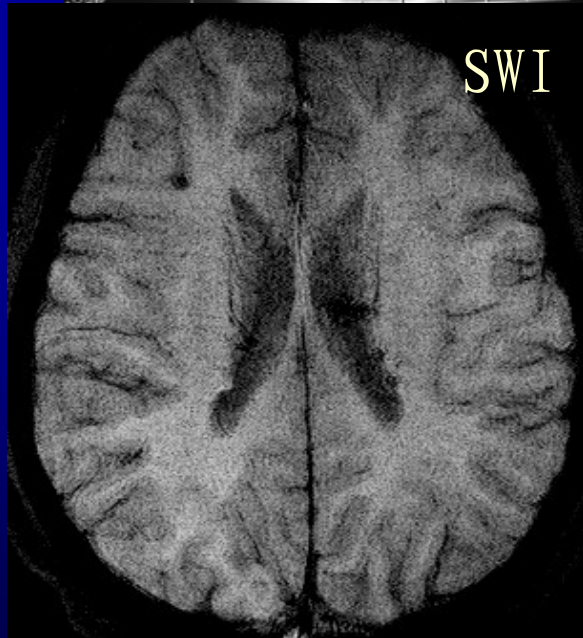
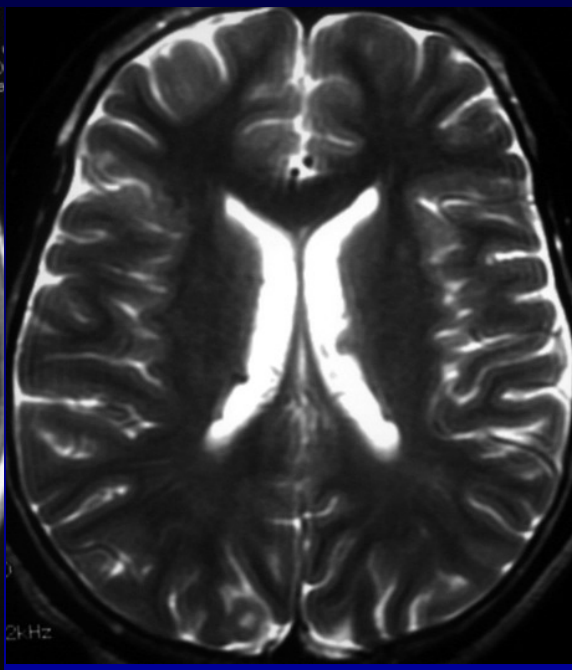
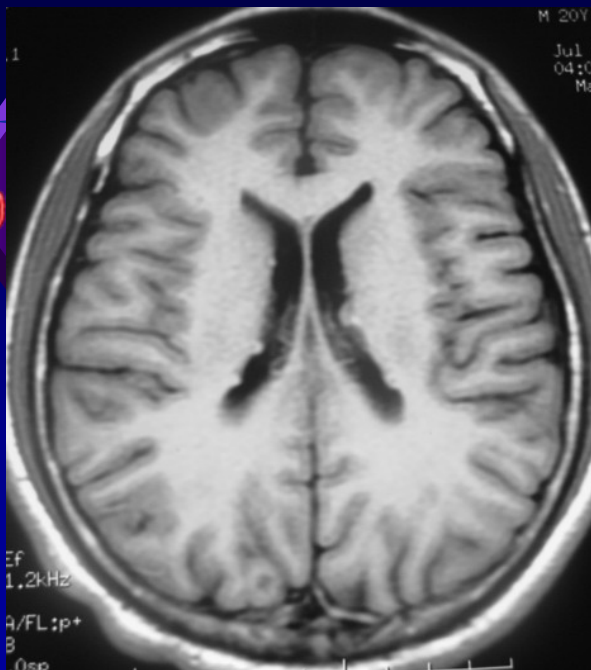
帕金森氏综合征

Alzheimer disease

老年性痴呆症

Tuberous Sclerosis

结节性硬化



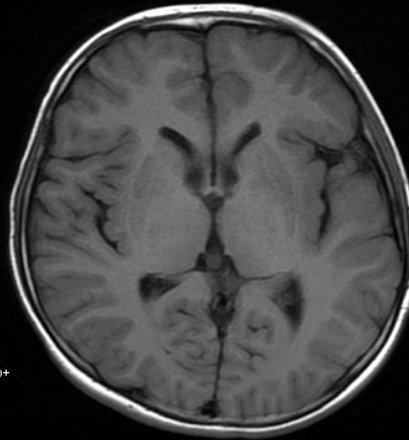
M, 20y. Epilepsy 结节性硬化



GE MEDICAL SYSTEMS
SIGNA EXCITE HDECHO

Ax: S 5.6
DFOV: 24.0cm

ET:6

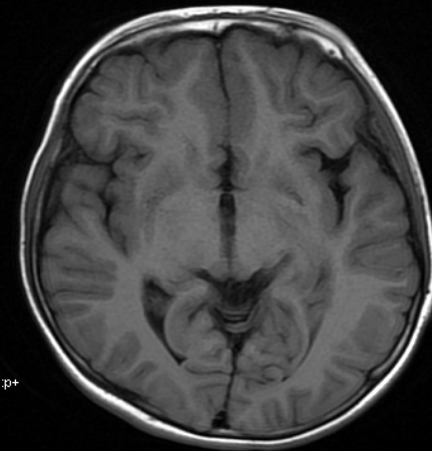


T1 flair/90 /FL.p+
TR:2162
TE:21.1/Ef
EC:1 /1 25kHz
TI:720.0
8NV/HEAD_A
FOV:24x18
6.0thk/1.0sp
16.02.26
320x256/2.00 NEX
FCs/STL/SQ/TRF

Tongji hospital
chu chun
M13Y
0706271
Jun 27 2007
08:29:59 PM
Mag = 1.00
FL:
ROT:

Ax: I 1.4
DFOV: 24.0cm

ET:6

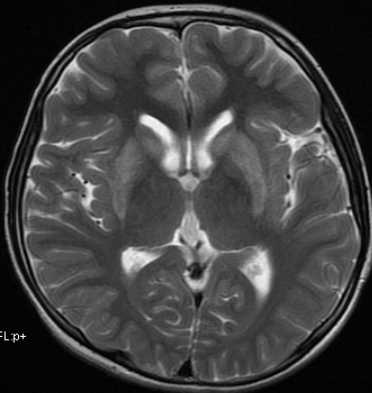


T1 flair/90 /FL.p+
TR:2162
TE:21.1/Ef
EC:1 /1 25kHz
TI:720.0
8NV/HEAD_A
FOV:24x18
6.0thk/1.0sp
16.02.26
320x256/2.00 NEX
FCs/STL/SQ/TRF

Tongji hospital
chu chun
M13Y
0706271
Jun 27 2007
08:29:59 PM
Mag = 1.00
FL:
ROT:

Ax: S 5.6
DFOV: 24.0cm

ET:19



GE MEDICAL SYSTEMS
SIGNA EXCITE HDECHO

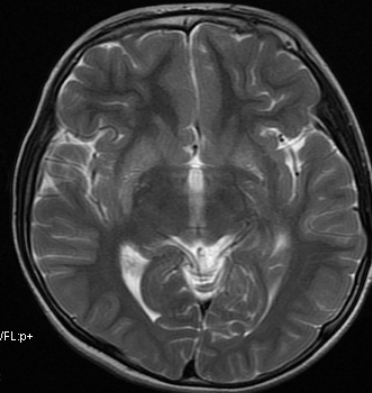
Ax: S 5.6
DFOV: 24.0cm

ET:19

FRFSE-XL/90 /FL.p+
TR:4500
TE:109.5/Ef
EC:1 /1 31.2kHz
8NV/HEAD_A
FOV:24x18
6.0thk/1.0sp
16.01.53
384x256/2.00 NEX
FCs/STL/ED/TRF

Tongji hospital E MEDICAL SYSTEMS
chu chun GNA EXCITE HDECHO
M13Y
0706271
Jun 27 2007
08:32:34 PM x 11.4
Mag = 1.00 FOV: 24.0cm
FL:
ROT:

T:19



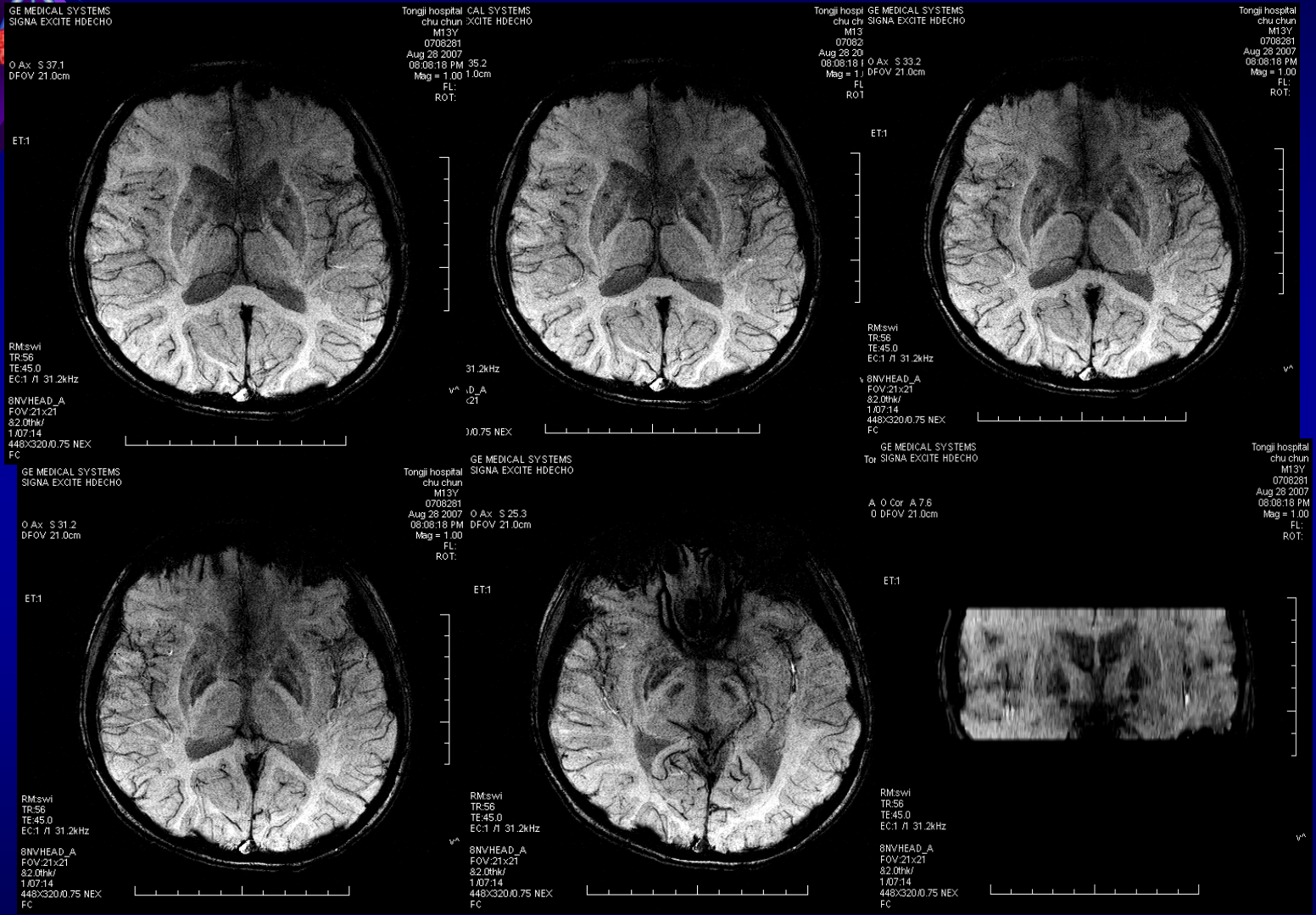
FRFSE-XL/90 /FL.p+
TR:4500
TE:109.5/Ef
EC:1 /1 31.2kHz
8NV/HEAD_A
FOV:24x18
6.0thk/1.0sp
16.01.53
384x256/2.00 NEX
FCs/STL/ED/TRF

Tongji hospital
chu chun
M13Y
0706271
Jun 27 2007
08:32:34 PM
Mag = 1.00
FL:
ROT:

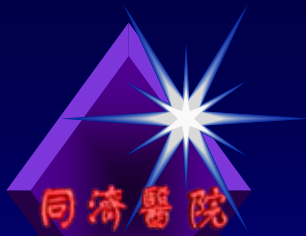
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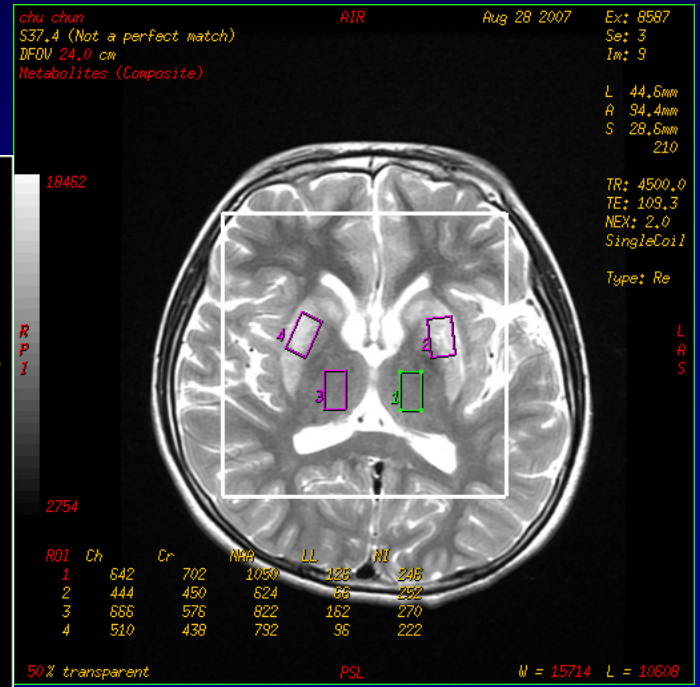
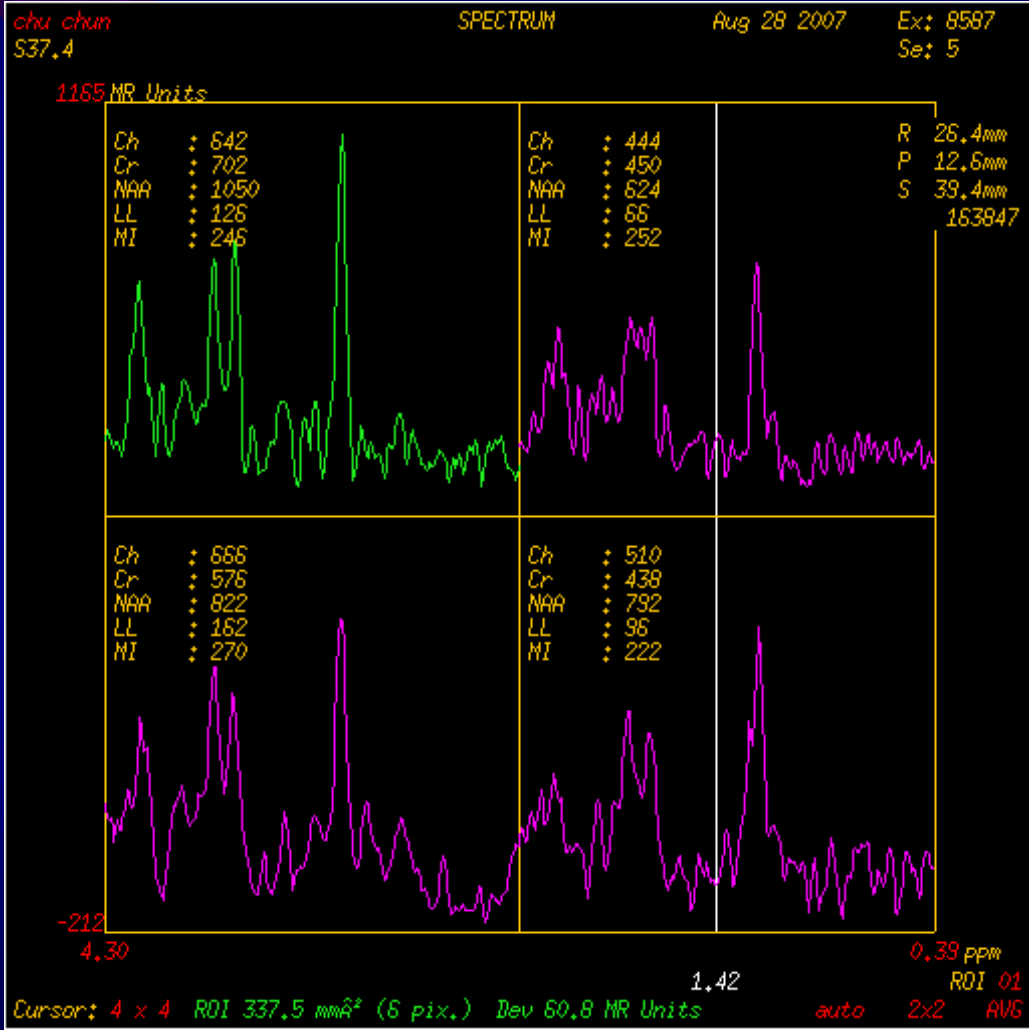
Wilson Disease
豆状核变性



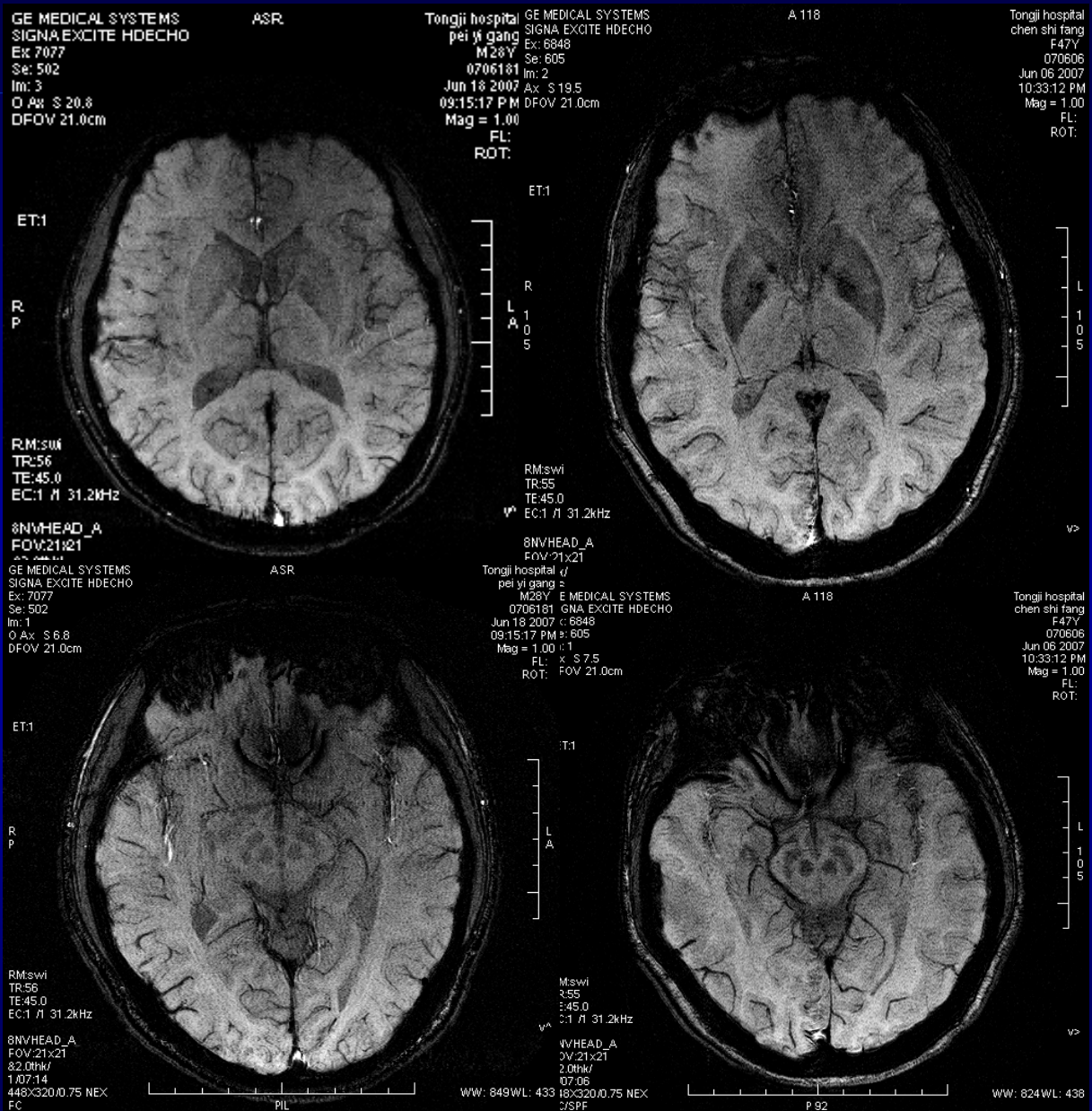
Wilson Disease 豆状核变性



同济醫院



Wilson Disease
豆状核变性

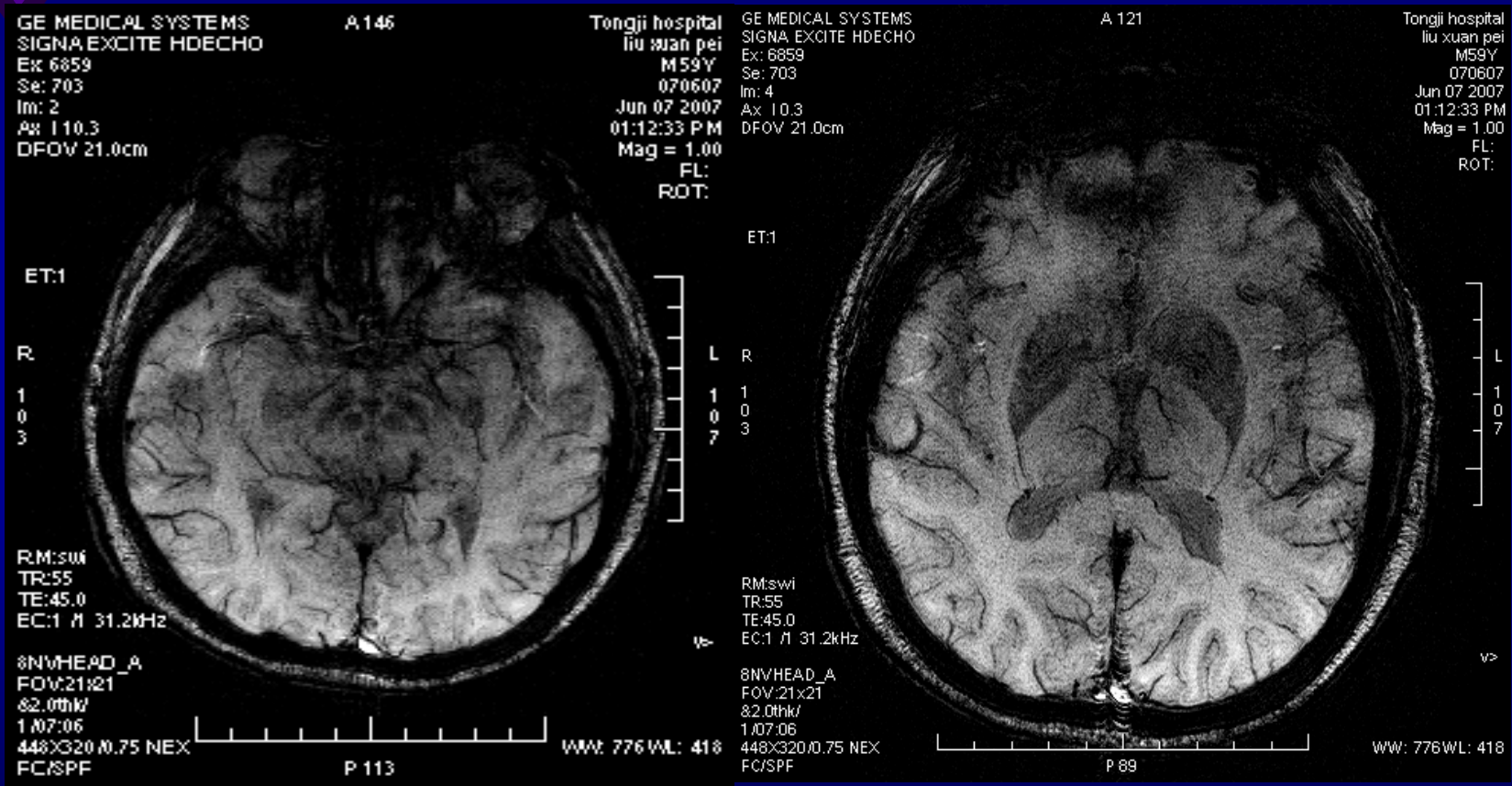


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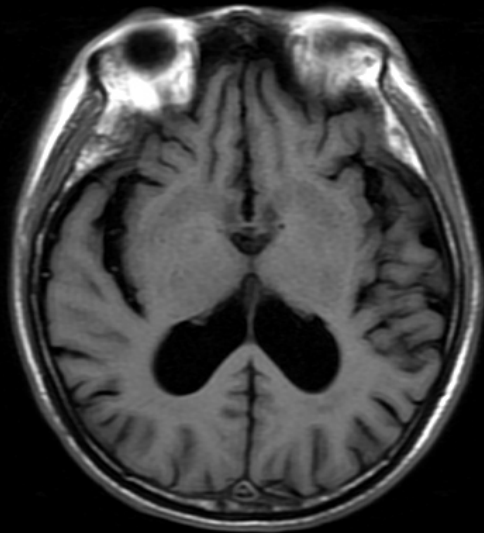
正常人脑随年龄增长的铁沉积

帕金森氏患者红核黑质基底节区异常铁沉积

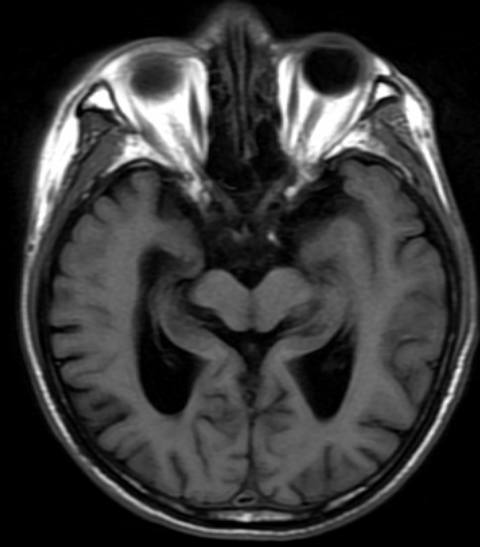




Tongji hos
zhang tong
lin
M61
061
Jul 07 2
09:17:04

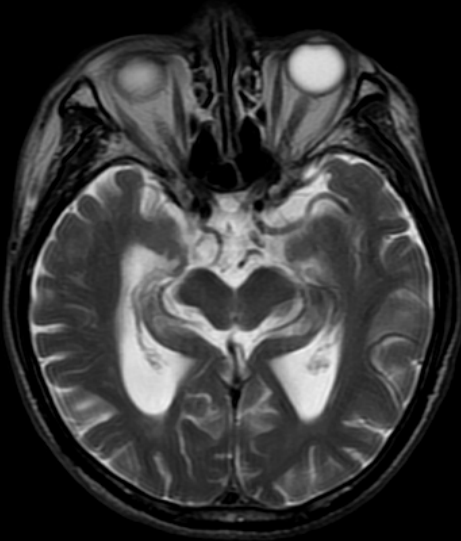


Tongji hospital
zhang tong lin
M65Y
061052
Jul 07 2006
09:17:04 AM



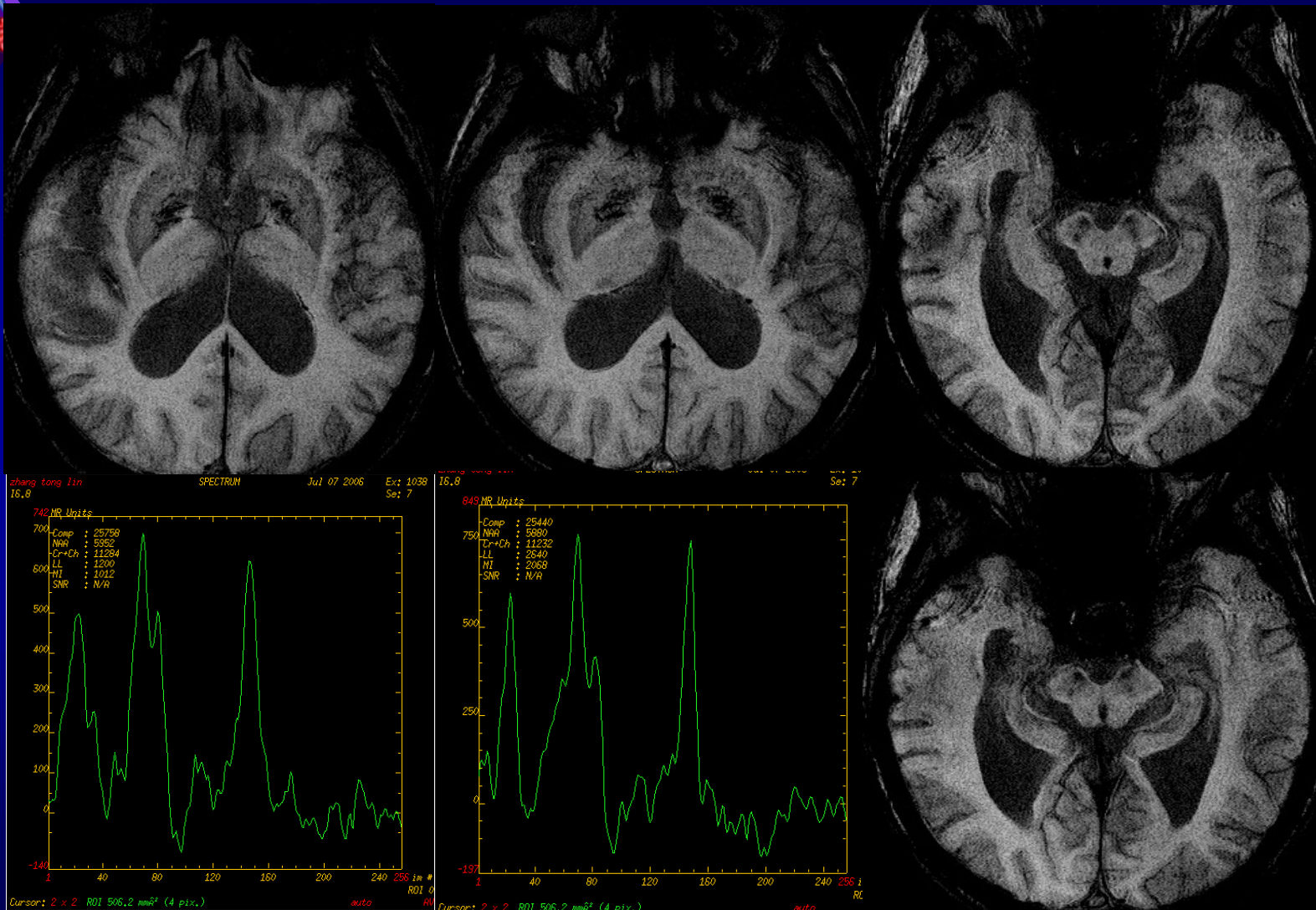
帕金森氏综合征

Tongji hospital
zhang tong lin
M65Y
061052
Jul 07 2006
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Tongji hospital
zhang tong lin
M65Y
061052
Jul 07 2006
09:18:35 AM

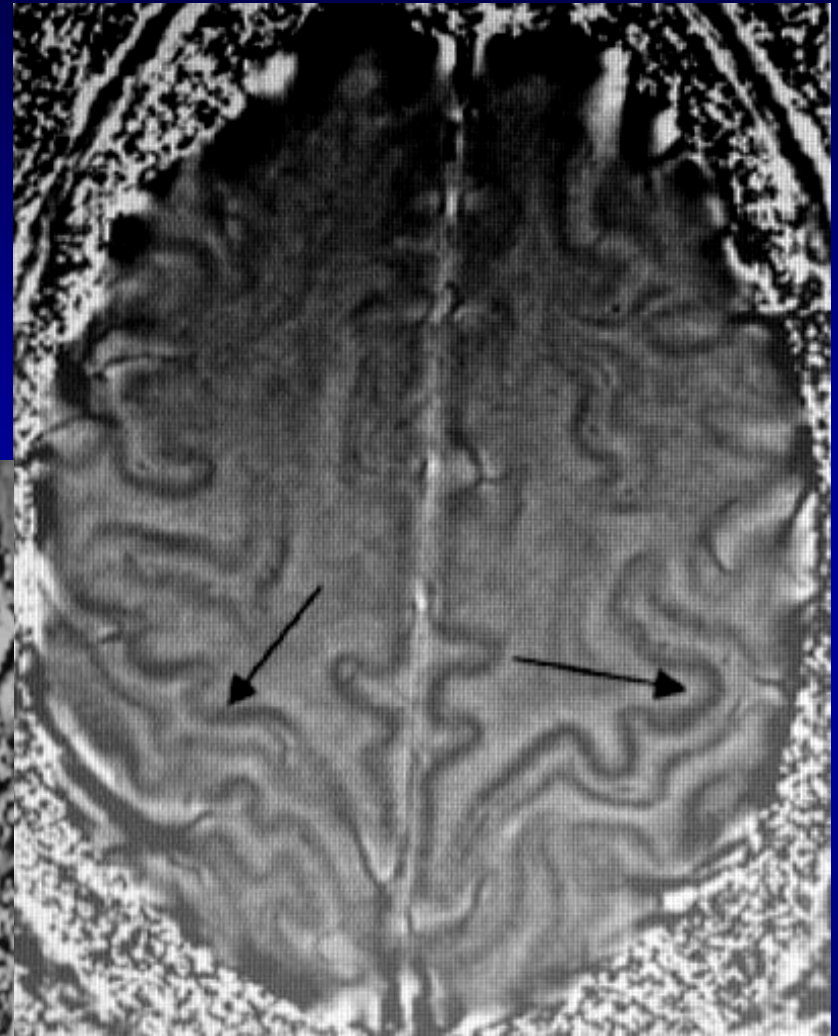
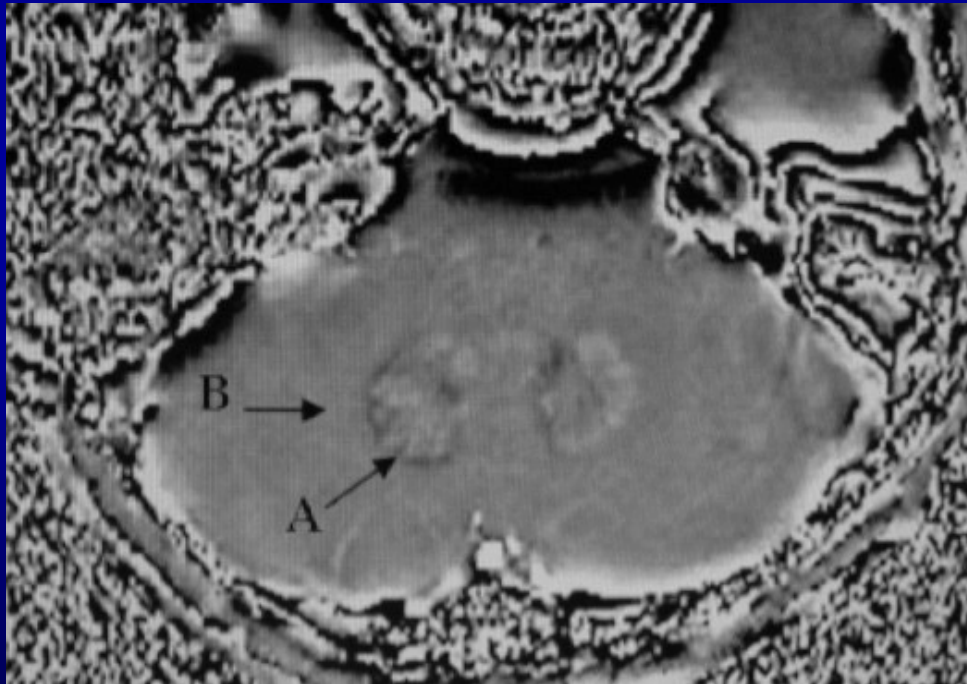




帕金森氏综合征



老年性痴呆症





小 结

SWI的临床应用

- ①低流量血管畸形及血管瘤的显示;
- ②高血压多发微出血的显示;
- ③肿瘤内血管和出血的显示;
- ④脑外伤DAI的显示;
- ⑤急性脑梗死并发出血;
- ⑥铁异常沉积的显示及定量分析;



謝 謝

