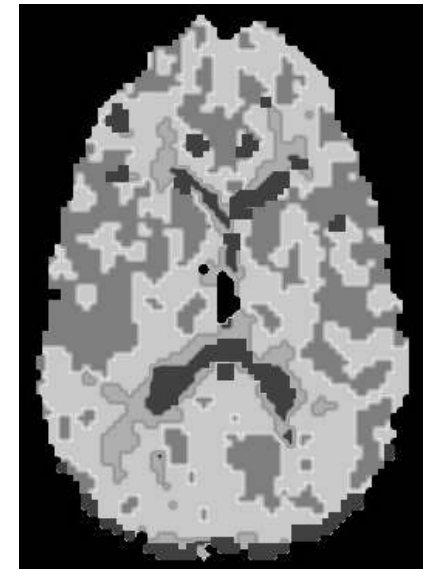
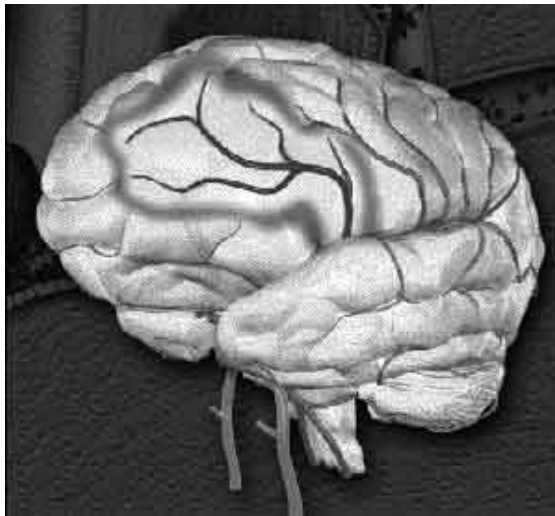


Imaging of Acute Ischemic and Hemorrhagic Stroke



Dr Richard Aviv

Associate Professor University of Toronto, Division of Neuroradiology,
Sunnybrook Health Sciences Center

Disclosures

- None

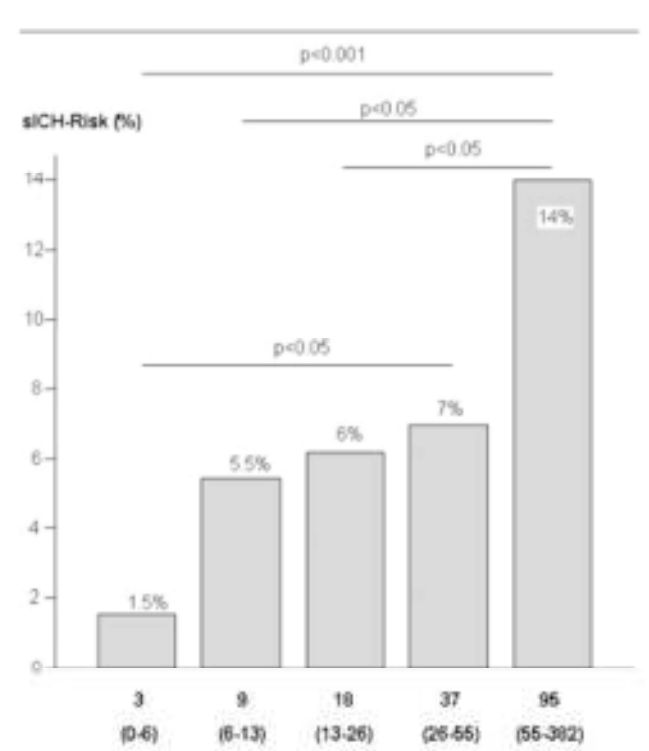
Objectives

- Stroke detection
- Typical scan protocols
- Methods of stroke detection
 - Limitations
 - Renal impairment
- Developments in imaging of Intracranial Hemorrhage
 - CTA detection of causes of secondary ICH detection
 - Spot Sign
- CT dose and dose reduction strategies

Detecting infarct

- Reassurance prior to treatment
- The larger the initial infarct
 - ↑ Risk of hemorrhagic transformation
 - Progressive increased risk with infarct size ¹

<10ml	10-100ml	>100ml
-------	----------	--------
 - ↑ Size of final infarct²
 - ↓ Final clinical outcome³



1) Ann Neurology 2008; 63:52 2) Patel S. JAMA 2001; 286:2830 3) Neurology 1996;47:366 4) NINDS NEJM 1995;33:1581

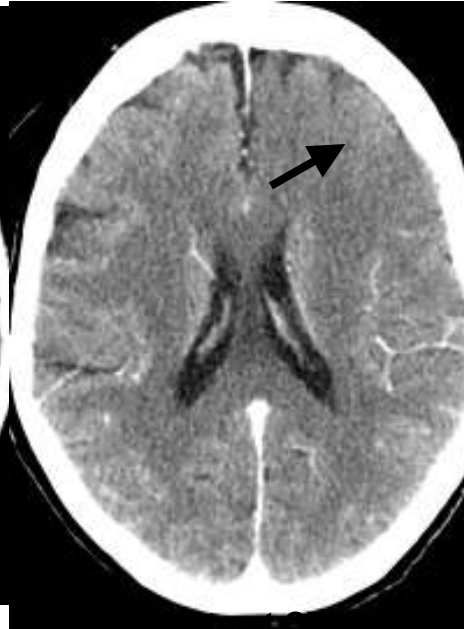
CT Stroke Protocol



Non-contrast CT



Angiogram 0.6mm



Perfusion Imaging



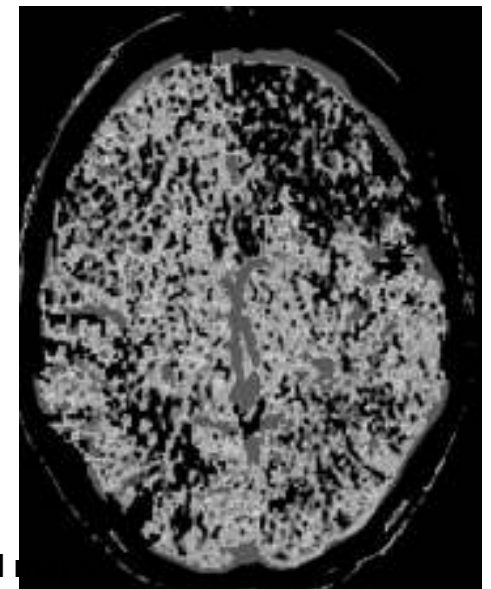
CTA-source images 3mm



MIP MPR

CT Scan time: 3-5 minutes

Contrast: 100-140 ml (Iodinated)



PWI

CT stroke detection

Proven performance (NINDS, ECASS^{3,4})

Sensitivity <3hrs 40-60%⁵

Specificity 85%, PPV 96%, NPV 27%

Earliest time to detection 45 minutes



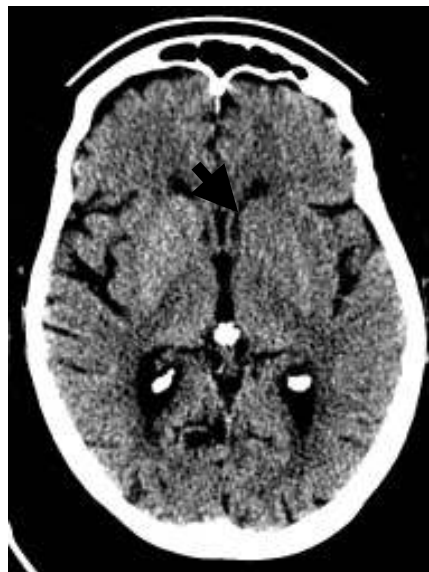
Loss of Lentiform nucleus¹



Loss of Insular ribbon² and grey/ white differentiation

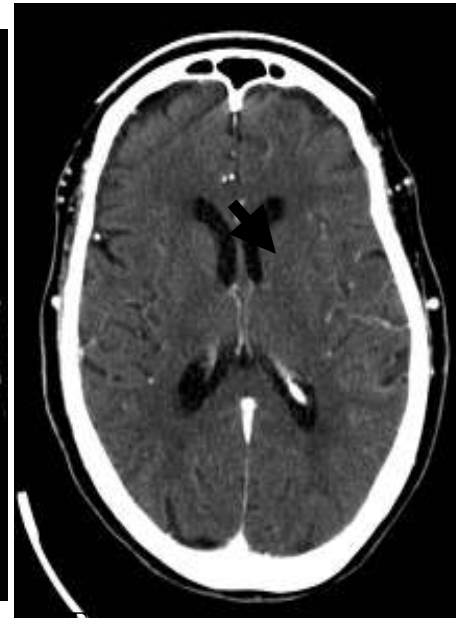
1) Radiology 1988;168:463 2) Radiology 1990;176:801; 3) NEJM 1995;33:1581 4) JAMA 1995;274:1017 5) JAMA 2001;286:2830

Strategies to improve CT detection

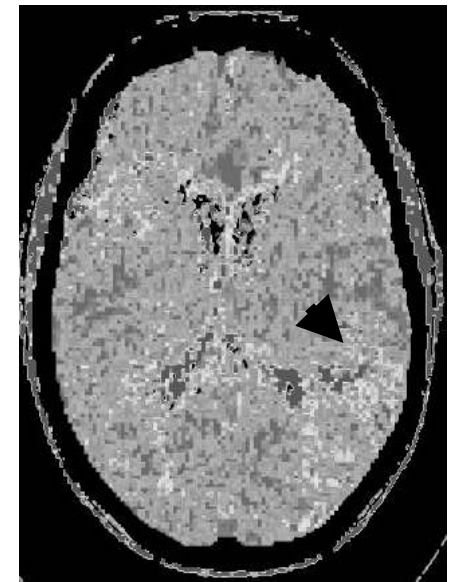


↑ Stroke window
sensitivity 20%⁶

WW 35 WL 35



↑ CTA-SI
sensitivity 20%⁷



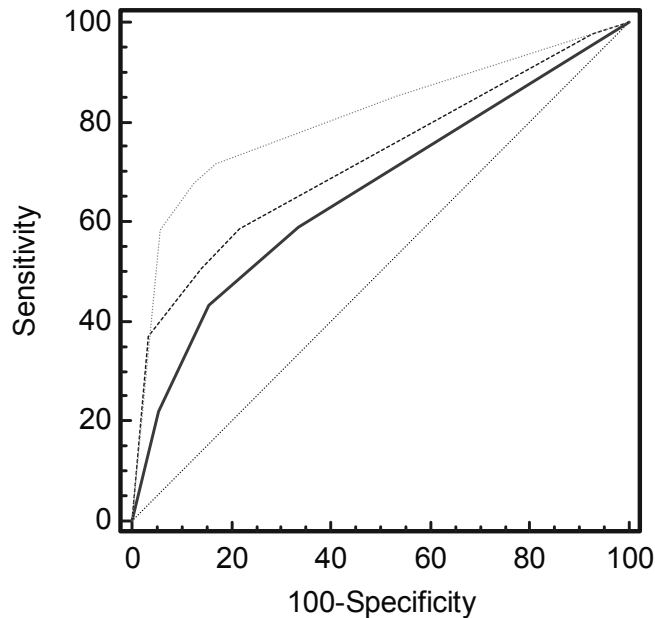
↑ CTP maps
sensitivity 20%⁸

Certainty of Stroke Diagnosis:
Incremental Benefit with CT Perfusion
over Noncontrast CT and CT
Angiography¹

- 191 acute stroke presentations
 - 4 blinded inexperienced reviewers
 - Combined clinical/ radiological outcome measure
 - LOC score for stroke presence: 1-5
 - Etiology
 - Stroke present 123 (64%)
 - TIA 35 (18%)
 - Mimic 32 (17%)

Diagnostic performance of multimodal CT protocol

Level of confidence ≥ 4	Sensitivity %	Specificity %
NC-CT	40.8	86.6
NC-CT+CTA-SI	50.8	86.2
NC-CT+ CTA-SI +CTP	70.6	86.8



AUC

NCCT 0.67

CTA 0.72

CTP 0.81

} P=0.001

Kappa: 0.3-0.4 to 0.4-0.6 to 0.6-0.8

Results from expert readers²⁻⁵:

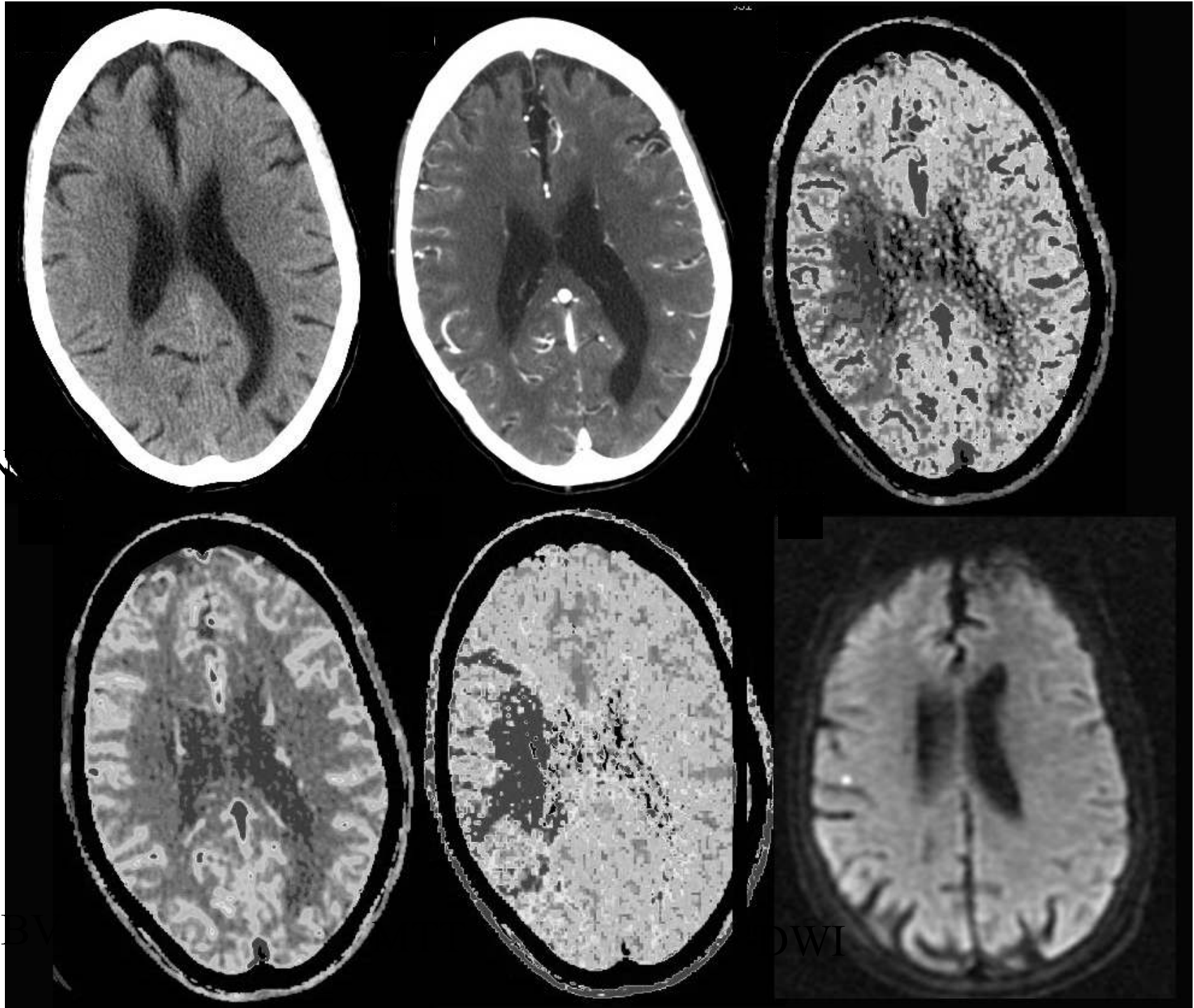
Sensitivity 0.79-0.90

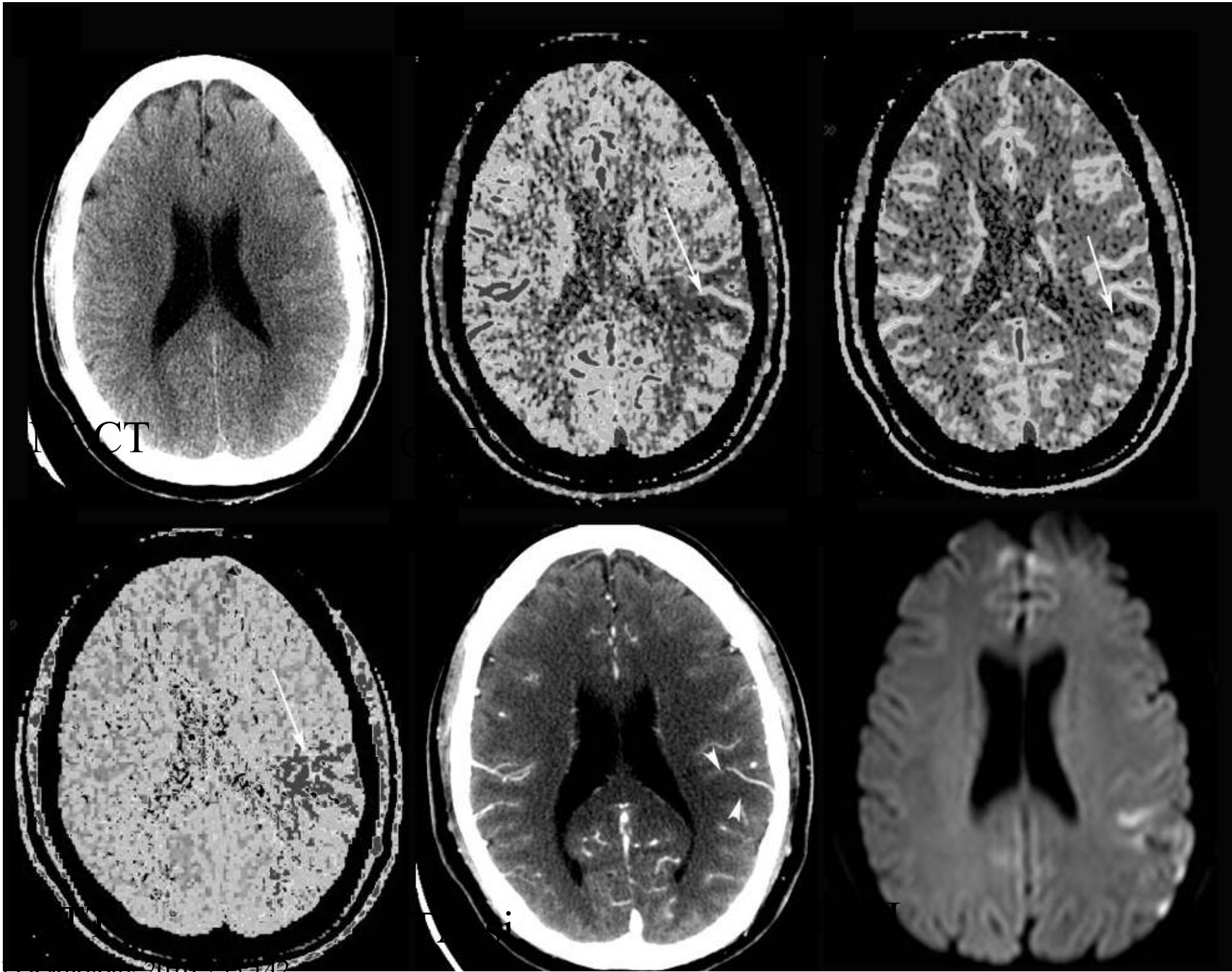
Specificity 0.68-0.79

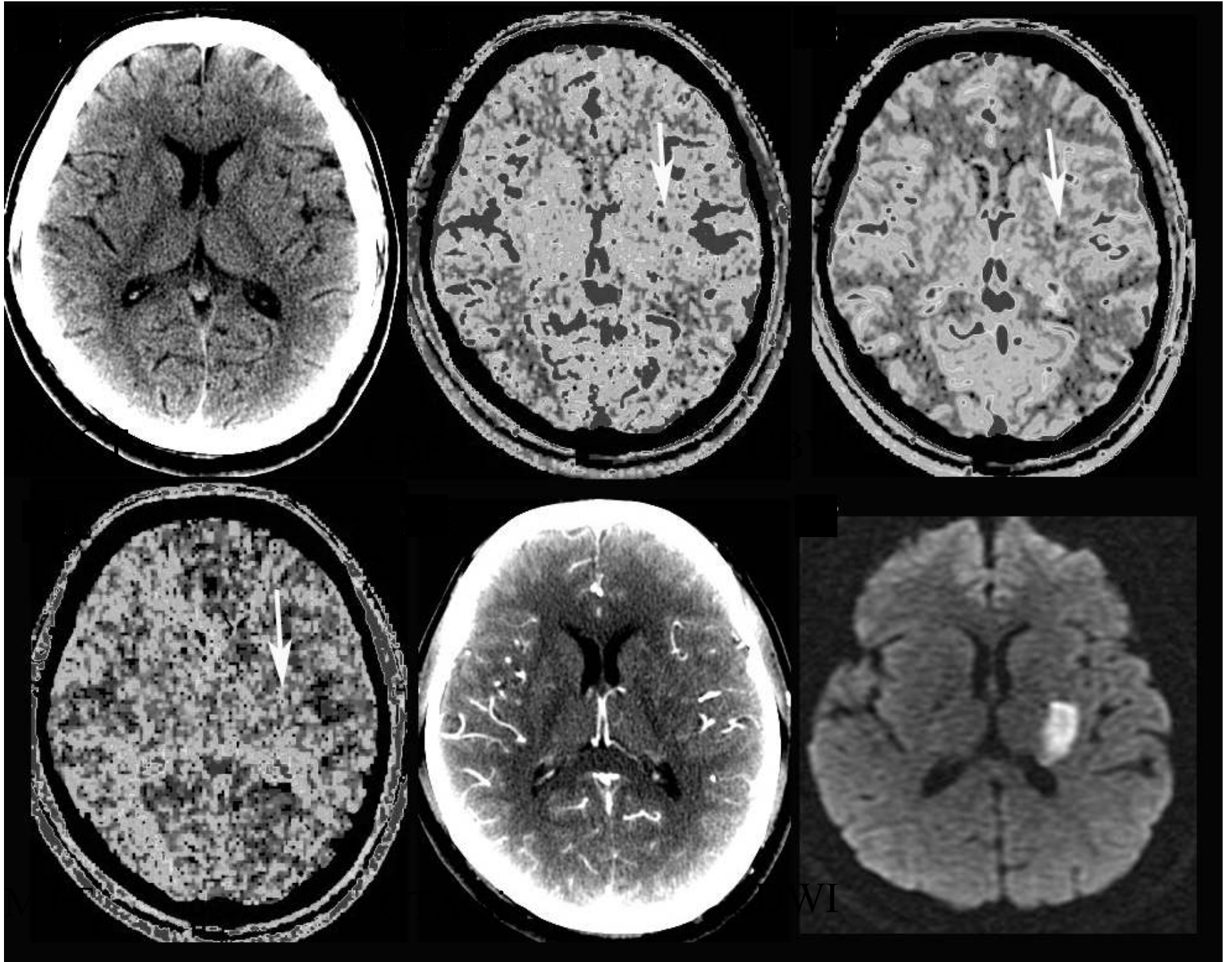
N

C

DWI



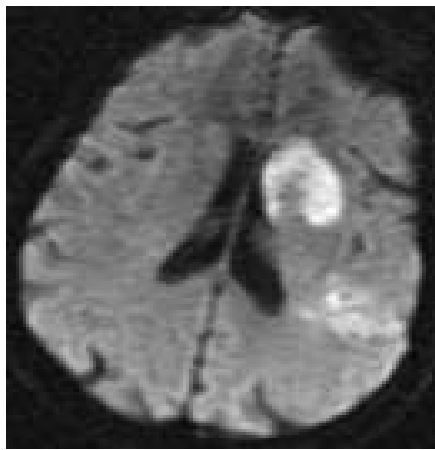




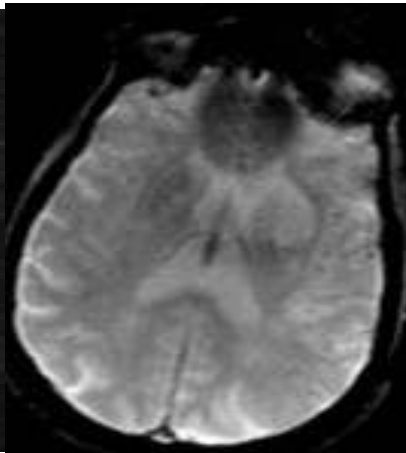
CTP Cost effectiveness

- 1. Penumbra based selection
 - reduced mortality
 - Improve functional outcome 0.59%
 - <4.5 hrs: Cost saving to hospital
 - 3-4.5hr: Reduce by 0.8% pts receiving ivTPA
- 2. CTP over NCCT
 - 3/12:
 - lower cost (-\$1716)
 - Greater QALY 0.004
 - Number needed to screen to avoid 1 DSA was 2
 - Lifetime
 - Lower cost (-\$2058)
 - Greater QALY 0.008

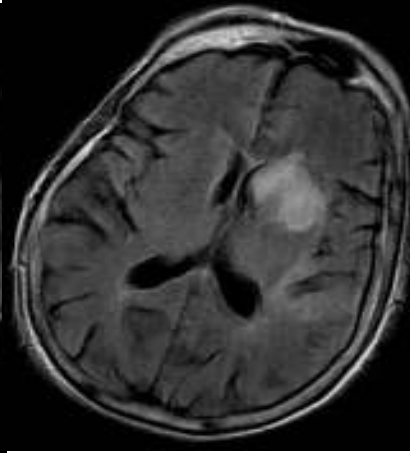
MRI Stroke Protocol



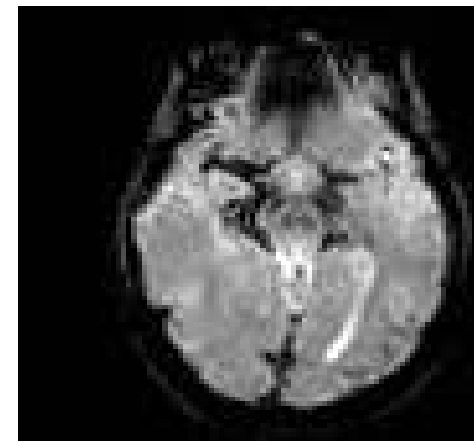
Diffusion weighted Imaging



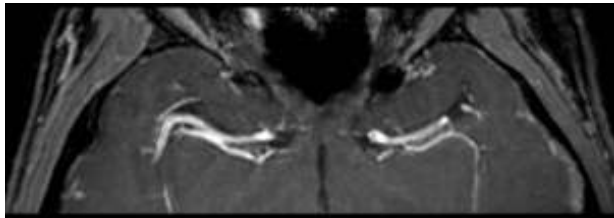
Gradient Echo



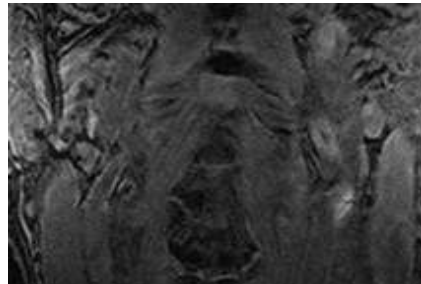
FLAIR



Perfusion Imaging



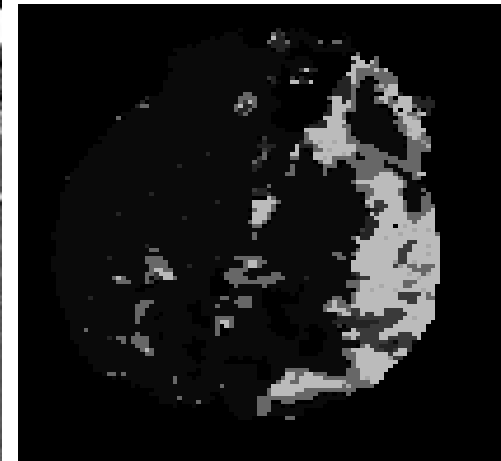
MR Angiography



Plaque sequence



MIP MPR

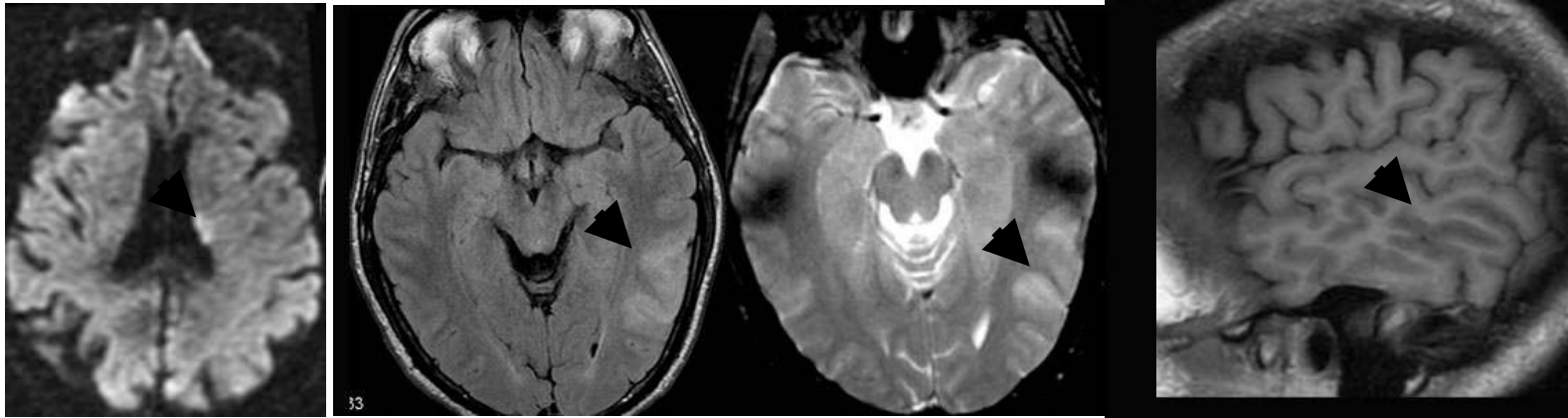


Perfusion maps

MRI Scan time: 10-15 minutes

Contrast: 15 ml (Gadolinium)

MRI stroke detection

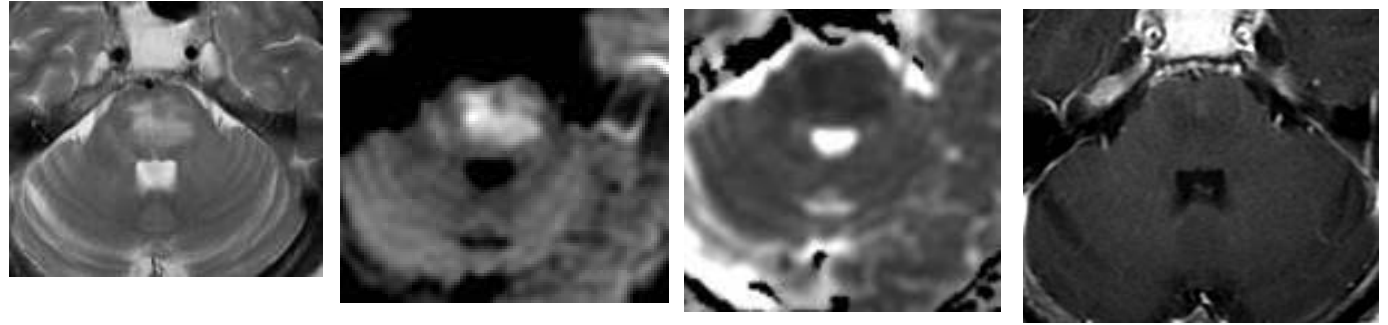


- Performance
 - Conventional MRI
 - Sensitivity similar to NCCT <3hrs
 - Usually <24hrs all T2 and 50% T1 abnormal
 - DWI
 - Sensitivity 88-100%
 - Specificity 95-100%
 - False negatives
 - 5% DWI in 24 hrs¹
 - 10* more likely posterior fossa
 - Small subcortical infarcts²
 - False positives
 - Abscess, cellular tumor, encephalitis, CJD, seizure

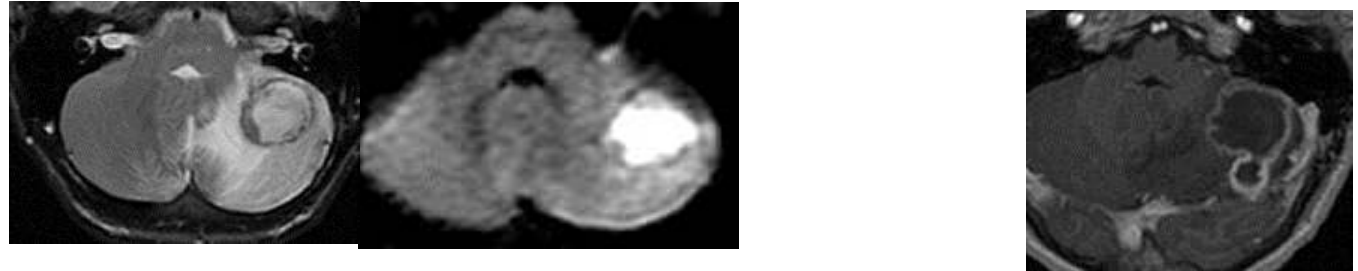
1) AJNR 2000;21:1434 2) Ay H. Neurology 1999;52:1784

False positive Diffusion

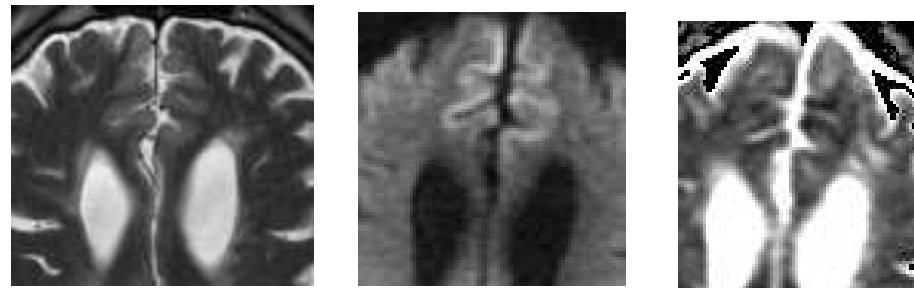
Glioma/ cellular tumor



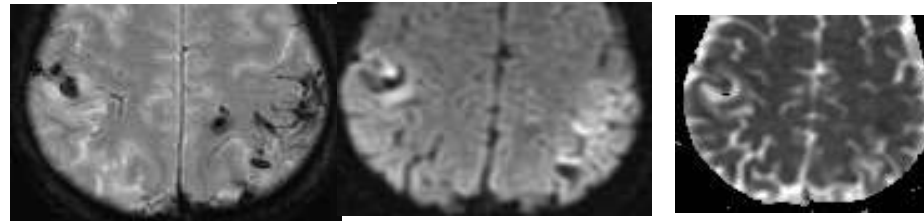
Abscess



Encephalitis/ CJD



Seizure/ Venous thrombosis



T2

DWI

ADC

T1+c

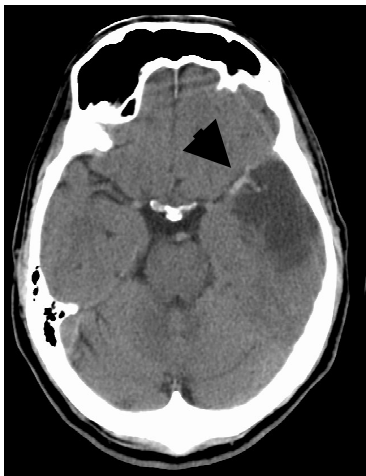
Brain swelling ¹



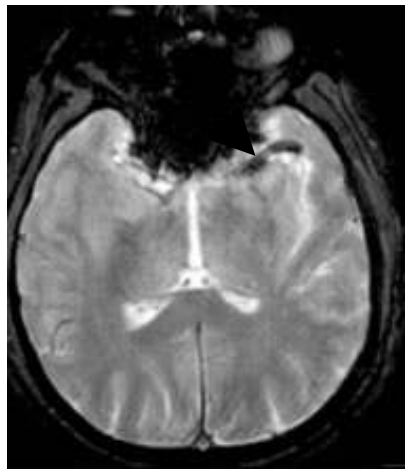
CT

- Increased CBV
- Unstable state
- 60% infarct

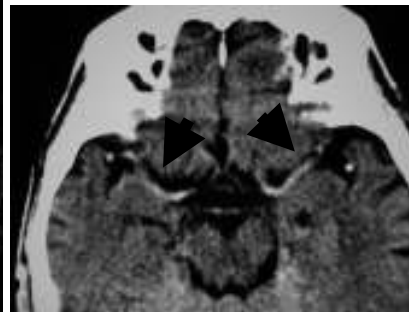
Hyperdense/ hypointense MCA sign²



CT



GRE



Pseudo-hyperdense sign

- 35-50% MCA strokes²
- Predicts
 - >100ml at risk
 - Poorer response to tPA
 - Mortality 5-45%
- Survivors poor outcome³
 - Sensitivity 78%
 - Specificity 93%

Beware: HCT, CA⁺⁺

Eye sign

- High PPV for side of infarct 93%¹
- Caveat
 - Brainstem & thalamic lesions
 - Post-ictal states
- Predicts poor outcome²
 - Mortality 44% vs 12% if absent



CT Fogging

9 July

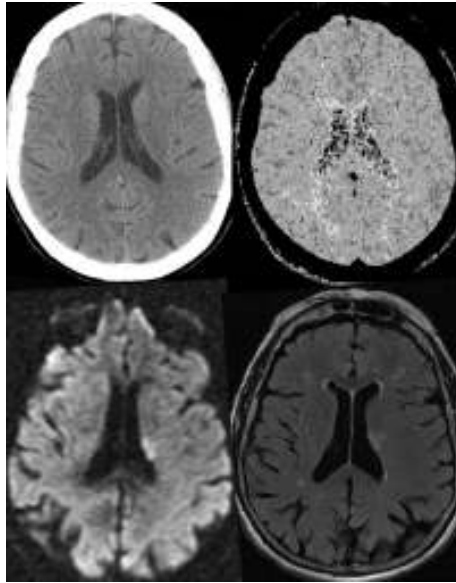


14 July

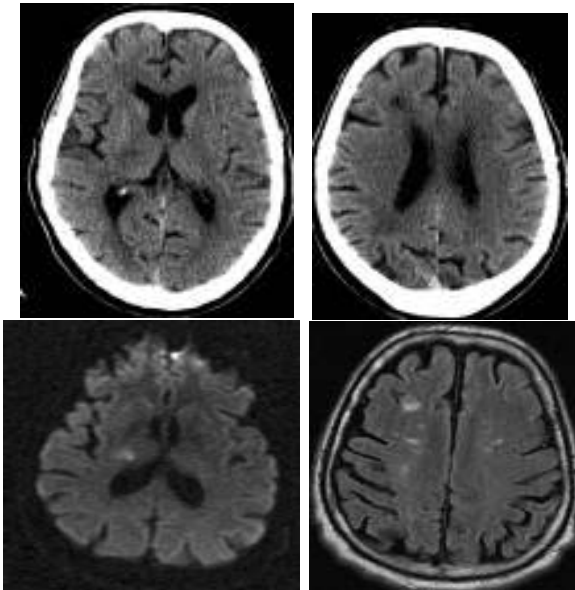


- Pseudonormalisation 2-3 weeks
- Mechanism is uncertain
- Edema reversal, microhemorrhage, ischemic related demyelination or macrophage infiltration

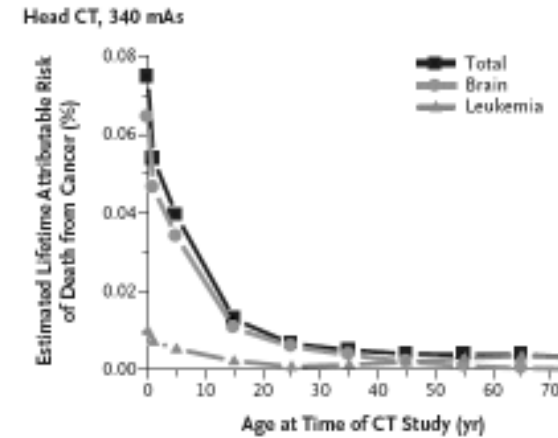
CT limitations-1



Small Lesion Profile



Microangiopathic change



Radiation dose - cancer risk ¹

Head CT 1/3 of all CT exams

1) NEJM 2007;357:2277

- **Renal impairment CIN (25% ↑Cr)**

- **N=831 pts** ^{1,2}
 - CIN 3%
 - No Cr available at time of scan CIN 1.8-2%
 - No renal failure
- **N=575 NCCT/CTA/CTP±DSA vs 343 control AIS patients**
 - CIN 5% vs 10% control group³
- **N=348 CTA for ICH**
 - CIN 6% (contrast not risk factor in multi-variate analysis), 2.6% significant renal impairment vs 1.4% control (p=0.3)⁴
- **N=2034 for outpatient PCT 66 (3%) sCR**
 - 94% history of renal disease- 2 (0.1%) no risk factors⁵
- **N=640 ER presentation 35 (5.5%) sCR**
 - 75% risk factors for renal insufficiency- 8 (1.3%) no risk factors⁶
- **N=241 All CTA (x=139cc) prior to blood results available**
 - 24% CTA and 22% control pts abn delayed baseline CR
 - CIN 3% CTA vs 4% control⁷

- CIN <5% (closer to 2-3%)

- CIN Misnomer- contrast not needed

Guidelines for ER patients

- **CAR¹:**
 - **Evaluate risk factors. If absent no risk for renal failure** ^{2,3}
 - **Risk factors present**
 - **Known renal impairment/single kidney**
 - **Diabetes, age>70, sepsis/hypotension**
 - **Dehydration/ organ transplantation/ chemotherapy**
 - **Cardiovascular disease (HT, CHD, PVD, CAD)**
 - **Consider**
 - **Visipaque (iso-osmolar): Class B data**
 - **Assess hydration: 300-500ml crystalloid bolus**
 - **Stop Metformin resume once renal function known and normal**
- **ACR⁴:**
 - **Risk of CIN is not an absolute but a relative (and often weak relative) contraindication to contrast.**
- **ESUR⁵:**
 - **Emergent situation waive Cr measurement**
 - **If procedure deferrable with no harm to pt- get Cr**

CT limitations-2

Spatial coverage

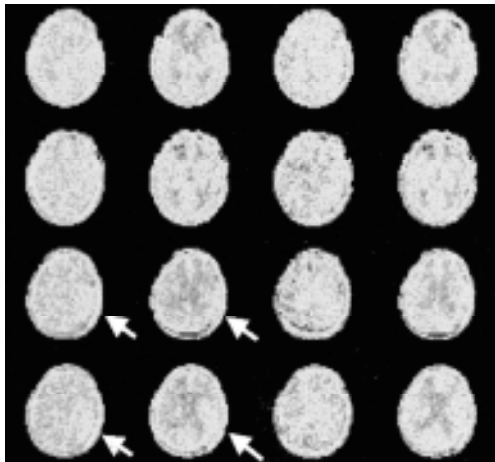
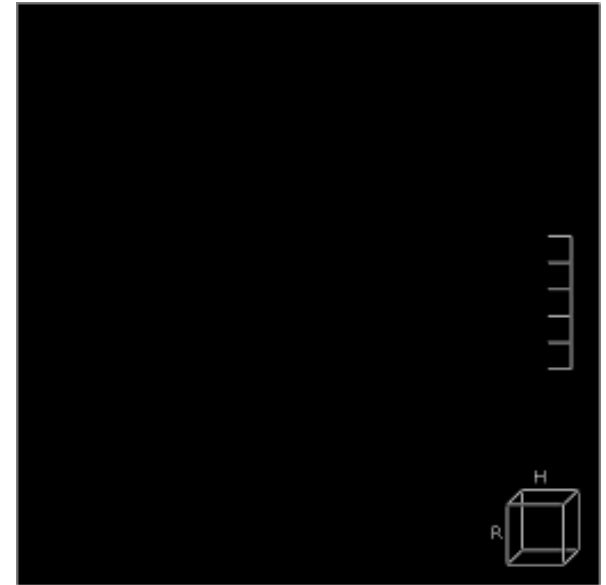


Table toggle³



320 slice scanner- whole brain coverage



Courtesy J Barfett

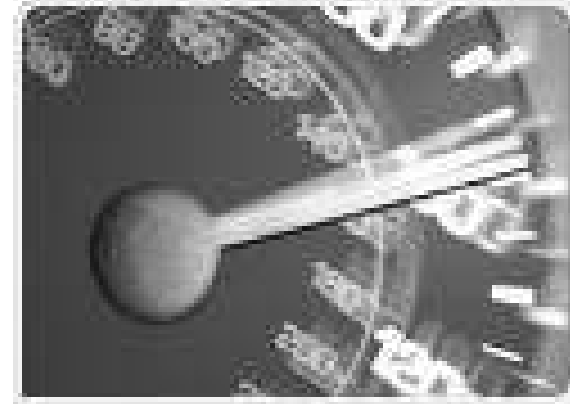
MRI limitations



Scan Environment



Contraindications 10%



Access/ Speed

Nephrogenic Systemic fibrosis¹

Described 2000

Gadolinium and impaired renal function

Skin thickening/ brawny pigmentation

Extremity fibrosis

Nearly all organs involved



1) Lancet 2000;356:1000

Emerging Applications

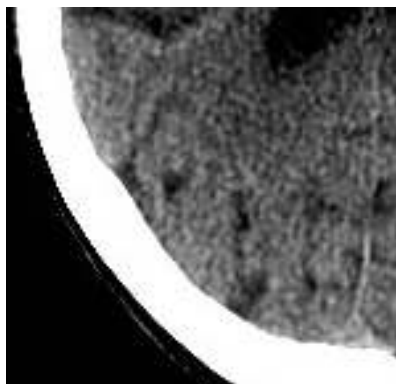
Prediction of hematoma expansion in ICH

- NCCT Sensitivity 77%, Specificity 84% for predicting underlying cause ¹
- AHA guidelines limitations
- Risk of structural lesion in ICH is between 2-3% Basal Ganglia and up to 11% in all locations ^{2,3}

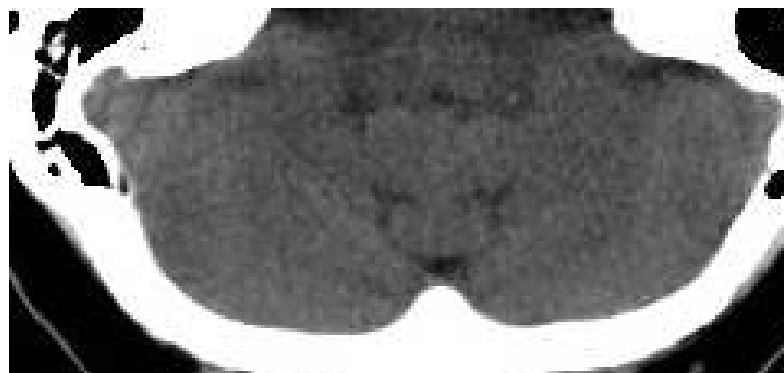
Dural fistula



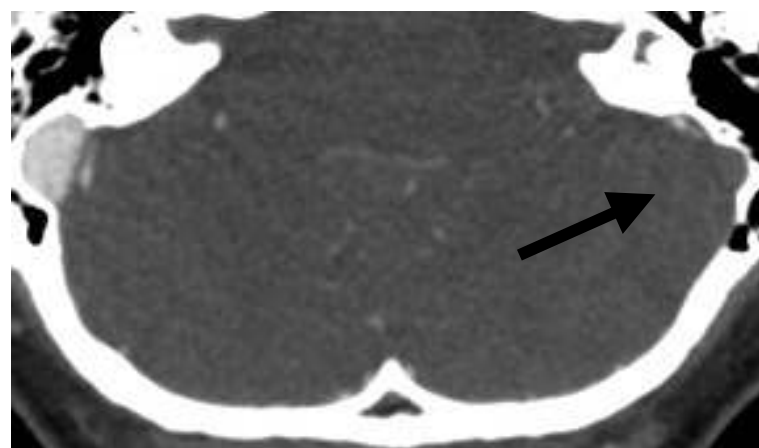
Vascular malformation



Sinus thrombosis



NCCT



CTA

CTA detection of secondary ICH

- **Retrospective series**
- **N=623; ≤ 24 hrs;**
 - 91/623 (15%)
 - CTA Sens 96%; Spec 99; Accuracy 98%
- **N=78; 49 ± 14 yrs;**
 - 22/78 (28%)
 - CTA Sens 96%; Spec 100; Accuracy 99%
- **N=44;**
 - 24/44 (54%)
 - CTA Sens 92%; Spec 92; Accuracy 92%
 - Kappa 0.81-0.91
- **N=43; ER attendance < 40 yrs;**
 - 27/43 (63%)
 - CTA Sens 96%; Spec 100; Accuracy 98%

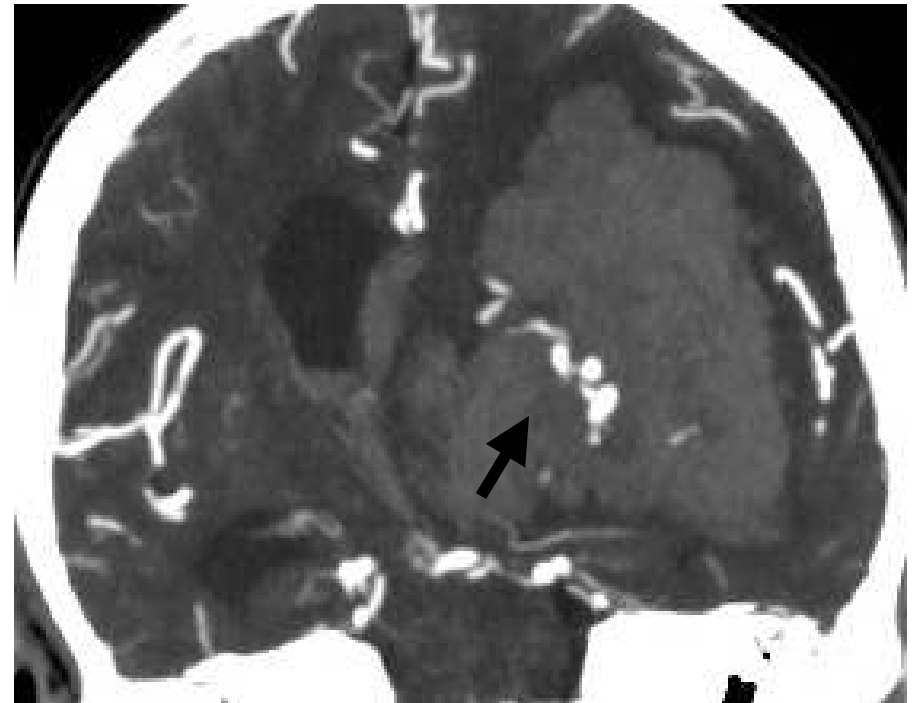
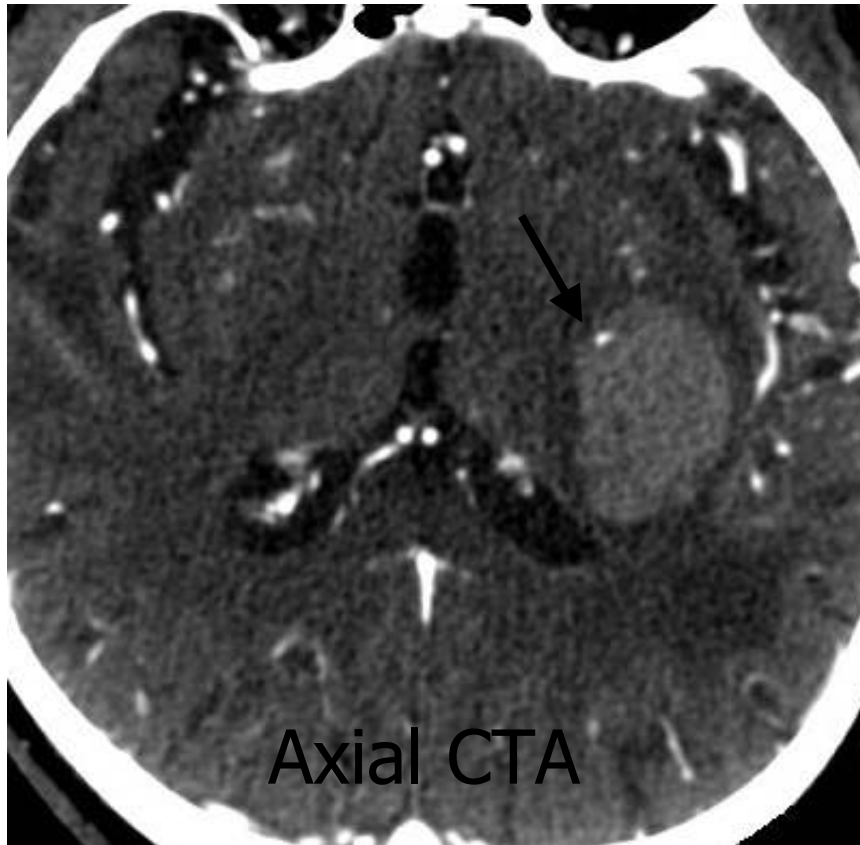
Sensitivity 92-96%; Specificity 92-100%; Accuracy 92-98%

CTA Spot Sign Definition

- Single or multiple, serpiginous or spot-like foci of contrast density
- Normal NCCT
- No visible communication outside hematoma
- Density $\sim 2^*$ greater than hematoma

CTA Spot Sign Definition

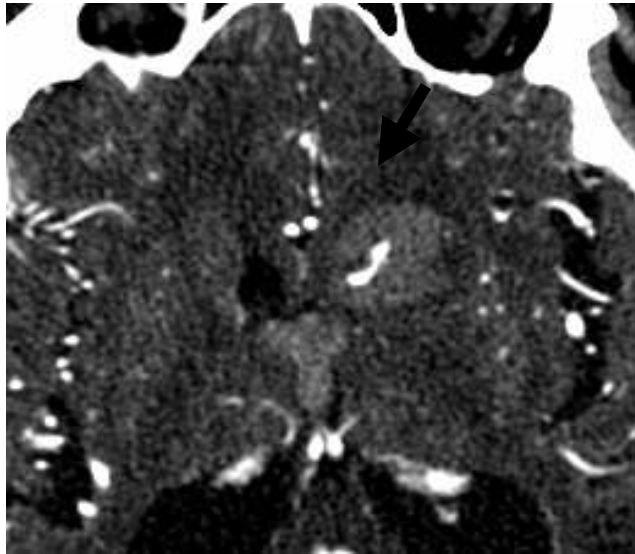
- Single or multiple, serpiginous or spot-like foci of contrast density



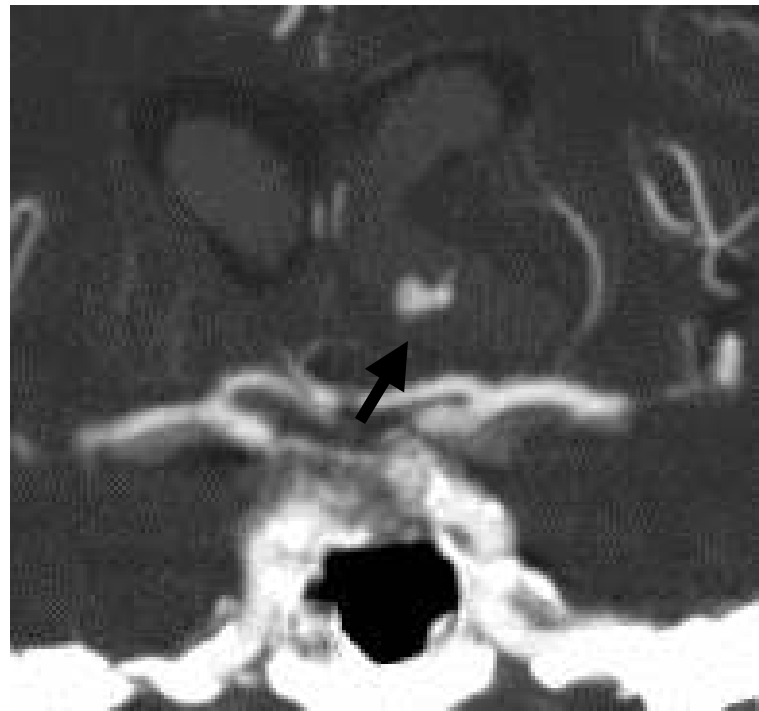
Appearance of contrast extravasation differs according to scan orientation.

CTA Spot Sign Definition

- Single or multiple, serpiginous or spot-like foci of contrast density



Axial CTA

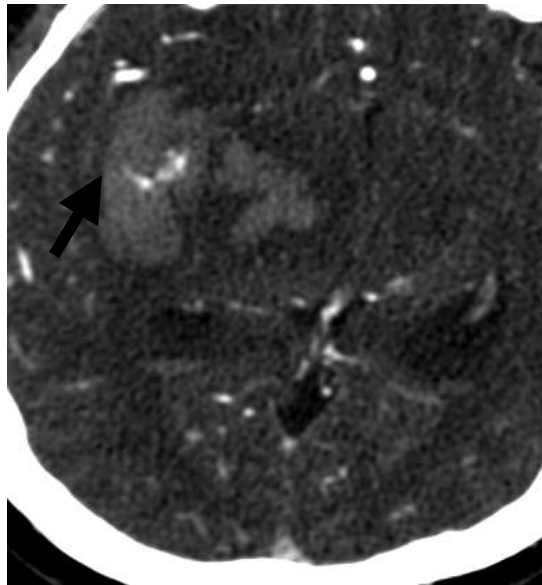


Coronal CTA Reformat

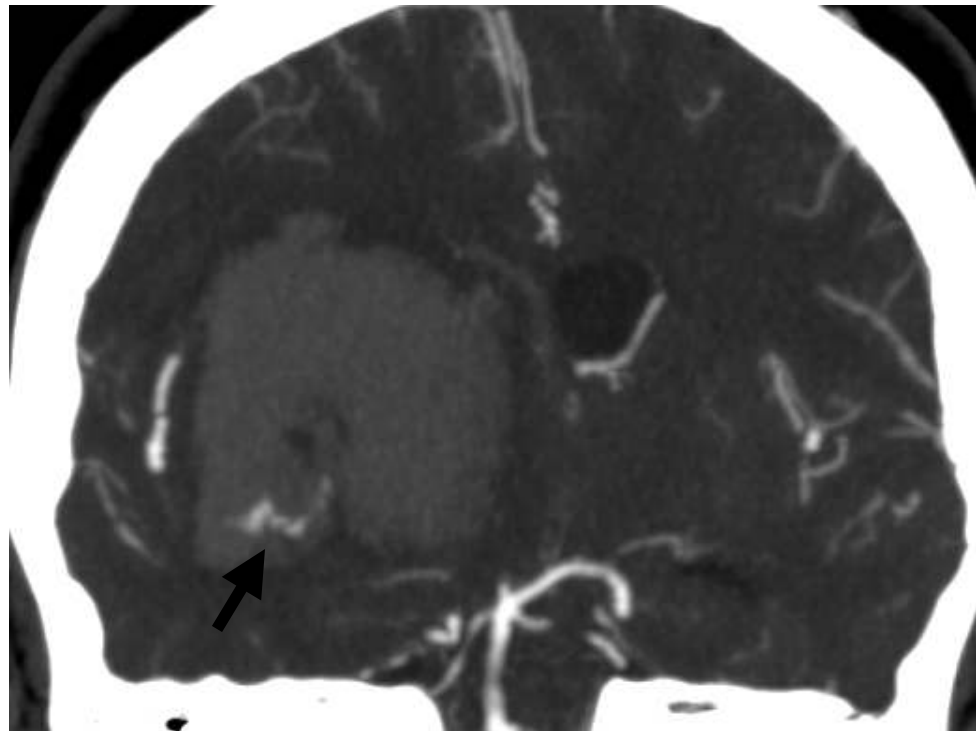
Appearance of contrast extravasation differs according to scan orientation.

CTA Spot Sign Definition

- Single or multiple, serpiginous or spot-like foci of contrast density



Axial CTA



Coronal CTA Reformat

Appearance of contrast extravasation differs according to scan orientation.

CTA Spot Sign Performance

- **N=39; <6 hrs**
 - **33% Spot positive**
 - **Sens 91%, Spec 89%; PPV 77%, NPV 96%**
 - **Predictor hematoma expansion**
- **N=104; <48 hrs ; retrospective**
 - **56% Extravasation positive**
 - **Sens 93%, Spec 50%; PPV 24%, NPV 98%**
 - **Predictor hematoma expansion**
- **N=56; median 13 hrs; retrospective**
 - **18-23% Extravasation positive**
 - **Predictor hematoma expansion and mortality**
- **N=573; retrospective**
 - **Sens 88%, Spec 93%; PPV 69%, NPV 98%**
 - **Predictor of hematoma expansion and poor outcome**

Sens 99-93%, Spec 89-93%, NPV 96-98%, PPV 69-77%

CTA Spot Sign Definition

Spot Sign Characteristic*	Points
No. of spot signs	
1-2	1
≥ 3	2
Maximum axial dimension	
1-4 mm	0
≥ 5 mm	1
Maximum attenuation	
120-179 HU	0
≥ 180 HU	1

- Where multiple Spots are present choose highest attenuation and largest dimension

CTA Spot Sign Definition

Spot Sign Characteristic*	Points	Risk of Hematoma Expansion, † %		In-Hospital Mortality Poor Outcome*		
		Spot Sign Score		Accuracy Parameter	(95% CI)	(95% CI)
No. of spot signs						
1–2	1	0 (n=296)	2	Sensitivity	41 (34–49)	23 (17–32)
≥3	2	1 (n=18)	33	Specificity	85 (81–88)	89 (85–92)
Maximum axial dimension		2 (n=18)	50	PPV	56 (47–64)	51 (38–64)
1–4 mm	0	3 (n=18)	94	NPV	76 (72–80)	70 (65–75)
≥5 mm	1	4 (n=17)	100	Positive LR	2.7 (2.0–3.7)	2.2 (1.4–3.4)
Maximum attenuation		AUC (95% CI)	0.93 (0.89–0.95)	Negative LR	0.69 (0.61–0.78)	0.86 (0.78–0.95)
120–179 HU	0	<i>P</i>	<0.0001	Accuracy	71	67
≥180 HU	1			Prevalence	31	33

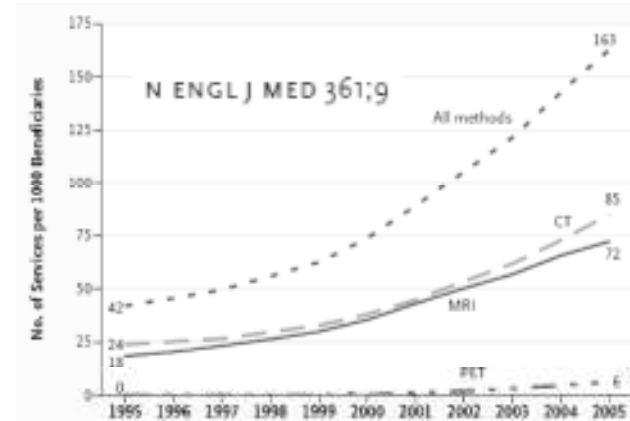
- Where multiple Spots are present choose highest attenuation and largest dimension
- Score requires refinement/ validation prospectively

www.spotlightstudy.com

Elements of Danger — The Case of Medical Imaging

Michael S. Lauer, M.D.

Related article, p. 849



Is Computed Tomography Safe?

Rebecca Smith-Bindman, M.D.

10.1056/NEJMp1002530 NEJM.ORG

July 31, 2010

After Stroke Scans, Patients Face Serious Health Risks

By WALT BOGDANICH

The New York Times



CT dose reduction

- Filtered back projection
 - Low dose, increased noise
- Adaptive statistical iterative reconstruction (ASIR-GE)
 - Iteratively compares obtained to ideal value, transforming obtained value each time
 - May be combined other techniques such as principle component analysis (PCA)
 - Allows identification & subtraction of noise
 - Applications
 - Obese patients
 - Low dose studies: Renal calculus, CT colonography, CTA incl coronary

Conventional
dose
190 mA; 4.9mSv

Low dose
50 mA; 0.5mSv
No ASIR

Low Dose
50 mA; 0.5mSv
ASIR

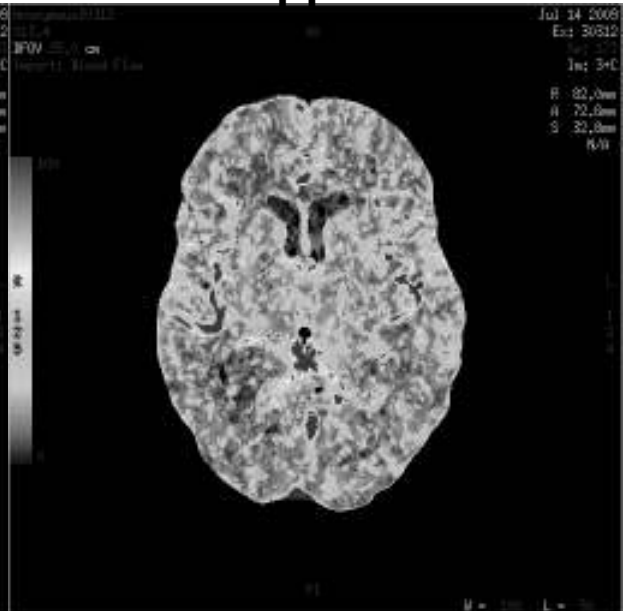
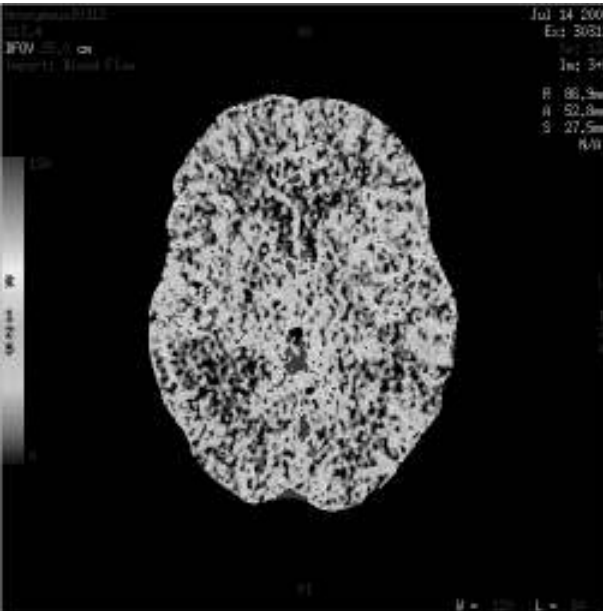
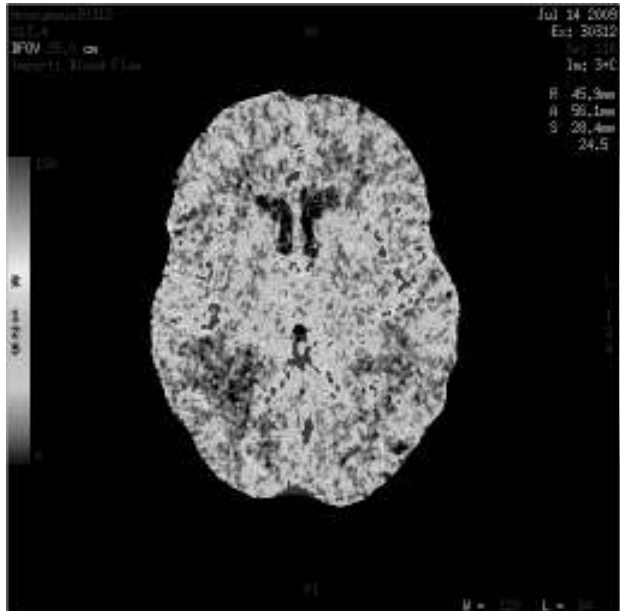


High Dose 190 mA

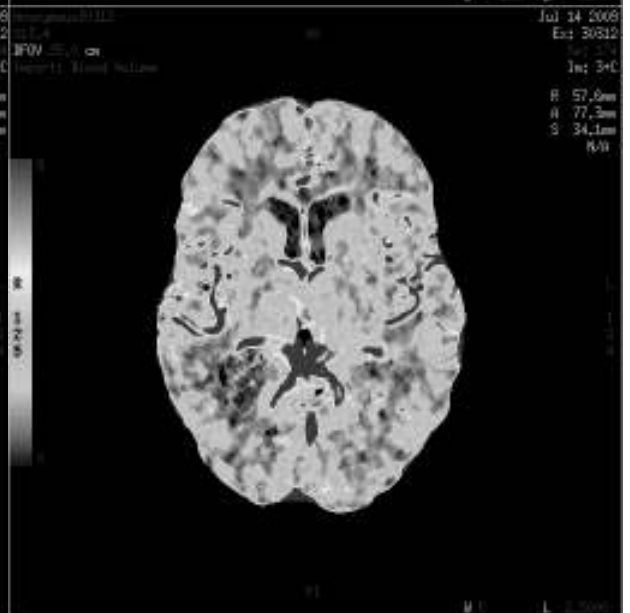
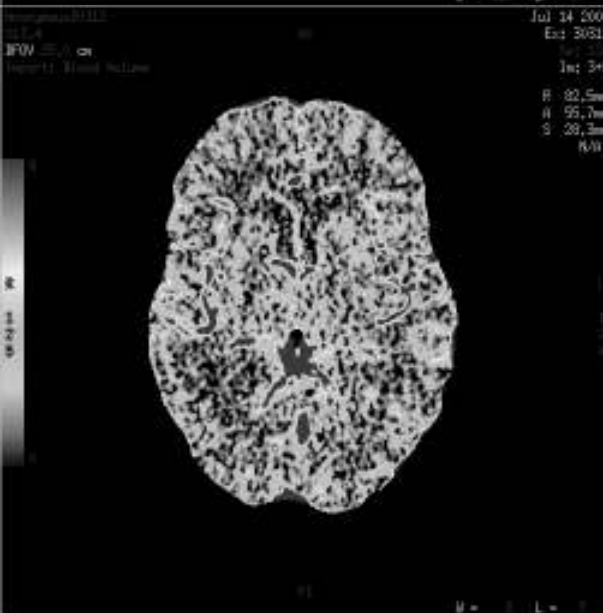
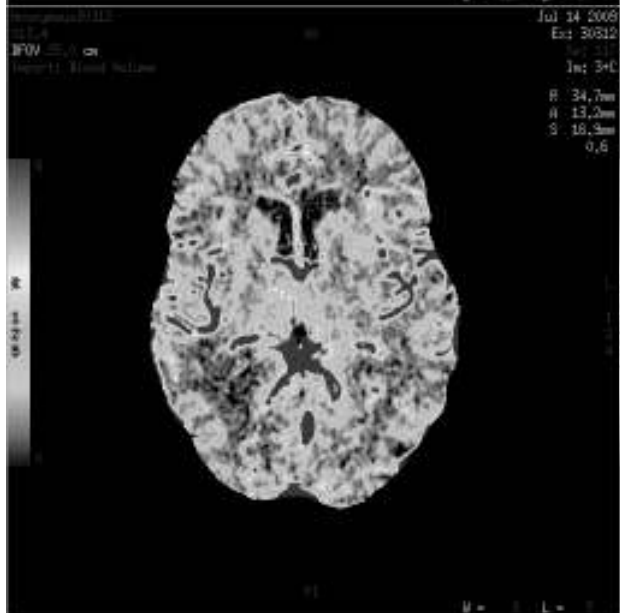
Low Dose 50 mA

Low Dose with Noise
Suppression

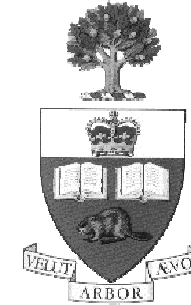
Blood Flow



Blood Volume



Conclusion



- Stroke detection
- Typical scan protocols
- Methods of stroke detection
 - Limitations
 - Renal impairment
- Developments in imaging of Intracranial Hemorrhage
 - CTA detection of causes of secondary ICH detection
 - Spot Sign
- CT dose and dose reduction strategies

Acknowledgements

- Collaborators
 - Neurology and Neuroradiology groups Sunnybrook Hospital
 - Professor Ting Lee; Lawson Research Institute
 - Research team

Thank you. Any Questions?