Imaging of Acute Ischemic and Hemorrhagic Stroke

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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
  – ↑ Size of final infarct
  – ↓ Final clinical outcome

CT Stroke Protocol

CT Scan time: 3-5 minutes
Contrast: 100-140 ml (iodinated)
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

Strategies to improve CT detection

- Stroke window sensitivity 20%\(^6\)
  - WW 35 WL 35
- CTA-SI sensitivity 20%\(^7\)
- CTP maps sensitivity 20%\(^8\)
• 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

<table>
<thead>
<tr>
<th>Level of confidence ≥4</th>
<th>Sensitivity %</th>
<th>Specificity %</th>
</tr>
</thead>
<tbody>
<tr>
<td>NC-CT</td>
<td>40.8</td>
<td>86.6</td>
</tr>
<tr>
<td>NC-CT+CTA-SI</td>
<td>50.8</td>
<td>86.2</td>
</tr>
<tr>
<td>NC-CT+ CTA-SI +CTP</td>
<td>70.6</td>
<td>86.8</td>
</tr>
</tbody>
</table>

AUC
NCCT 0.67
CTA 0.72
CTP 0.81

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

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

1) AJNR 2010;31:1669 2) Neurology 2010;75:1678
MRI Stroke Protocol

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 hrs\(^1\)
      - 10* more likely posterior fossa
      - Small subcortical infarcts\(^2\)
  - False positives
    - Abscess, cellular tumor, encephalitis, CJD, seizure

False positive Diffusion

Glioma/ cellular tumor

Abscess

Encephalitis/ CJD

Seizure/ Venous thrombosis

T2    DWI    ADC    T1+c
Brain swelling

- Increased CBV
- Unstable state
- 60% infarct

Hyperdense/ hypointense MCA sign

- 35-50% MCA strokes
- Predicts
  - >100ml at risk
  - Poorer response to tPA
  - Mortality 5-45%
- Survivors poor outcome
- 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 outcome\(^2\)
  - Mortality 44\% vs 12\% if absent

CT Fogging

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

9 July

14 July
CT limitations-1

Small Lesion Profile

Microangiopathic change

Radiation dose - cancer risk

Head CT 1/3 of all CT exams

1) NEJM 2007:357:2277
• Renal impairment CIN (25% $\uparrow$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 group$^3$
  • 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 factors$^5$
  • N=640 ER presentation 35 (5.5%) sCR
    – 75% risk factors for renal insufficiency- 8 (1.3%) no risk factors$^6$
  • 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% control$^7$

• 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 toggle

320 slice scanner- whole brain coverage

MRI limitations

Scan Environment

Contraindications 10%

Access/ Speed

Nephrogenic Systemic fibrosis

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

• AHA guidelines limitations

• Risk of structural lesion in ICH is between 2-3% Basal Ganglia and up to 11% in all locations

Dural fistula  Vascular malformation  Sinus thrombosis

NCCT  CTA
CTA detection of secondary ICH

- Retrospective series
- N=623; ≤24hrs;
  - 91/623 (15%)
  - CTA Sens 96%; Spec 99; Accuracy 98%
- N=78; 49±14yrs;
  - 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 <40yrs;
  - 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 ~2* greater than hematoma

Wada Stroke 2007;38:1257
CTA Spot Sign Definition

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

Appearance of contrast extravasation differs according to scan orientation.

Wada Stroke 2007;38:1257
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CTA Spot Sign Definition

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

Axial CTA
Appearance of contrast extravasation differs according to scan orientation.

Coronal CTA Reformat
Wada Stroke 2007;38:1257
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**

<table>
<thead>
<tr>
<th>Spot Sign Characteristic*</th>
<th>Points</th>
</tr>
</thead>
<tbody>
<tr>
<td>No. of spot signs</td>
<td></td>
</tr>
<tr>
<td>1–2</td>
<td>1</td>
</tr>
<tr>
<td>≥3</td>
<td>2</td>
</tr>
<tr>
<td>Maximum axial dimension</td>
<td></td>
</tr>
<tr>
<td>1–4 mm</td>
<td>0</td>
</tr>
<tr>
<td>≥5 mm</td>
<td>1</td>
</tr>
<tr>
<td>Maximum attenuation</td>
<td></td>
</tr>
<tr>
<td>120–179 HU</td>
<td>0</td>
</tr>
<tr>
<td>≥180 HU</td>
<td>1</td>
</tr>
</tbody>
</table>

*Where multiple Spots are present choose highest attenuation and largest dimension*
CTA Spot Sign Definition

- 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.

Is Computed Tomography Safe?
Rebecca Smith-Bindman, M.D.

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

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  – Neurology and Neuroradiology groups Sunnybrook Hospital
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  – Research team

Thank you. Any Questions?