CT Perfusion in Acute Stroke

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Stroke

- Infarct: Ischemic=80%; Hemorrhagic=20%
- Affects 700,000 people in US per year
- 3rd leading cause of death (after heart disease and cancer)
- $60 billion per year in costs
CT perfusion in ischemic stroke
WHY?

Salvage the “penumbra”!
CT Perfusion Terminology

• Cerebral Blood Flow (CBF)
  • Flow rate of volume of blood through cerebral vasculature. (ml/100gm/min)

• Cerebral Blood Volume (CBV)
  • Volume of flowing blood. (ml/100gm)

• Mean Transit Time (MTT)
  • Time required for blood to pass through tissue. (sec)
CT Perfusion

CBV, MTT

CBF = \frac{CBV}{MTT}
CT Perfusion

- Cerebral Blood Flow (CBF) ml/100gm/min

Normal  55 - 110
Oligemia  23 - 44
Ischemia  10 - 22
Infarction  <10

Modified from W.T.Yuh and others
CT Perfusion

- CBV - Used to identify “Core” of infarcted tissue

- ↓CBF or ↑MTT - Used to identify “Penumbra” or potentially salvageable tissue at risk
Our Equipment:
GE 64-detector VCT
Multi-Detector CT

64 slices x 0.625mm = 40mm / revolution
Anatomy-CTA

Volume rendered images
Physiology of Plaque
Perfusion Imaging

Brain Anatomy

• Large Vessels
  Anterior Circulation - ICAs, MCAs, ACAs
  Posterior Circulation - Vertebrals, Basilar, PCAs

• Small Vessels
  Arterioles, Capillaries, Venules
Perfusion Imaging
Brain Imaging/Physiology

Large Vessels - Angiography

- DSA - Digital subtraction
- MRA - Magnetic resonance
- CTA - Computed tomography

Small Vessels - Perfusion Methods - Tracers

- Diffusion - PET (FDG, O$_2$, rubidium)
  SPECT (99mTc-HMPAO)
  CT (xenon)

- Kinetics - MR (gadolinium)
  CT (iodine)
Perfusion Imaging
CT Angiography

Can diagnose occlusion of large intracranial vessels with high sensitivity and specificity

Perfusion Imaging
CT Angiography

Can diagnose occlusion of large intracranial vessels with high sensitivity and specificity\(^1\)

99% agreement with digital subtraction angiography\(^2\)

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Diagnoses 100% of proximal occlusions (ICA, MCA, BA)\(^3\)

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CT Angiography

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Diagnoses 100\% of proximal occlusions (ICA, MCA, BA)\(^3\)

Acute MCA occlusion is most common cause of cerebral infarction.\(^4\)

PROACT trial: 38\% MCA occlusion
19\% No occlusion

Perfusion Imaging
CT Perfusion

First demonstrated in the lab in 1980

Perfusion Imaging
CT Perfusion

First demonstrated in the lab in 1980\(^5\)

First pass technique measures change in density over time

Deconvolution method requires accurate arterial input function\(^6\)

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Perfusion Imaging

CT Perfusion

First demonstrated in the lab in 1980\(^5\)

First pass technique measures change in density over time

Deconvolution method requires accurate arterial input function\(^6\)

CT Perfusion equivalent to diffusion-weighted MRI/PWI\(^7\)

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CT Perfusion Imaging
Clinical Case

43 year-old female from Martha’s Vineyard
CT Perfusion Imaging Clinical Case

43 year-old female from Martha’s Vineyard

7:00am: Child noted slurred speech
7:30am: Fell out of bed; child called ambulance
8:54am: Head CT at MV Hospital “negative”

120 km to BMC
10:00am: Repeat head CT at BMC
CT Perfusion Imaging
Role of CT/CTA

• CT
  – Exclude hemorrhage
  – Subjective measurement of infarct edema
    • If >1/3 vascular territory, then not good candidate for intervention

• CTA/CTP
  – Look for occlusion
  – Evaluate size of core (infarct)
  – Evaluate penumbra (tissue at risk)
Acute Stroke - Perfusion Protocol

1. Requires 18g antecubital IV (right arm preferred)
2. Tilt head forward (no gantry tilt)
3. Perform routine non-contrast head CT (5mm thick)
4a. Perform timing bolus at aortic arch (10cc contrast)
4b. CTA Neck and Brain
   (60cc O-350; 4cc/sec; optimized delay; 20cc NaCl)
5. Select 40mm thick volume for CT Perfusion (8 x 5mm)
6. CT Perfusion - cine mode
   (50rev; 40cc O-350; 4cc/s; optimized delay; 20cc NaCl)
7. Network data to GE workstation
8. Create CTA MIP images at console while data transfers:
   Brain – axial / coronal
   Neck – sagittal / coronal
9. Create Brain perfusion maps on workstation
10. Network to PACS
Neck CTA (MIP)
Head CTA (Volume Rendering)
Head CTA (Source)
Deconvolution Analysis

Density is a function of concentration and flow.

Deconvolution Analysis

Indicate start and end of arterial phase
Perfusion Maps

Cerebral Blood Volume

Cerebral Blood Flow

Mean Transit Time
Penumbra - Perfusion Mismatch
Tissue at Risk

CBV
Cerebral Blood Volume

MTT
Mean Transit Time
Penumbra - Perfusion Mismatch Tissue at Risk

- Mismatch when CBF or MTT map abnormality greater than core.
- Mismatch = Penumbra
- Mismatch > 20% of core has been used for certain intervention trials.
One week later
No intervention
Hyperdense MCA sign
Another Acute Stroke

Basal ganglia hypodensity
Another Acute Stroke

Insular ribbon sign
Perfusion Match
No Tissue at Risk

CBV
Cerebral Blood Volume

MTT
Mean Transit Time
54 year-old male, right parietal hypodensity
Acute Infarct

Right ICA occlusion
Acute Infarct

RMCA attenuated – Circle of Willis intact
Perfusion Mismatch

CBF                     CBV                      MTT

Perfusion Mismatch

Small core infarct
MRI (DWI)
91M with acute RMCA stroke NIHSS 14 at 3:12 pm
CT Perfusion Mismatch

Cerebral blood flow  Cerebral blood volume  Mean transit time
Treatment Options

• IV tissue plasminogen activator (IVtPA)
  – Only FDA approved drug for treatment of acute stroke.
  – 0-3hrs, IV-tPA; 3-6hrs, IA-tPA.
  – Hemorrhage: 6.4% IV-tPA; 0.6% placebo
• MERCI (Mechanical Embolus Retrieval in Cerebral Ischemia)- Concentric™ clot retrieval device.
• Penumbra™ catheter-FDA approved in 1/08.
Treatment Options
MERCI Catheter
Treatment Options
Penumbra Catheter
Treatment Options
Penumbra Catheter
Desmoteplase (DIAS-2)

- Plasminogen activator derived from vampire bat saliva.
- Potential advantage: Can be used IV for 3-9hrs following stroke symptoms.
DIAS-2
Desmoteplase in Acute Ischemic Stroke Phase II Clinical Trial

- Design: Randomized, double-blind, placebo-controlled, dose-ranging trial.

- Goal: To determine the safety and efficacy of recombinant desmoteplase in acute ischemic stroke.

- Inclusion: NIHSS score between 4 and 20, and ability to treat within 3-9 hours of stroke onset. Perfusion mismatch of ~20%.

- Exclusion: Stroke >1/3 MCA territory; ICA occlusion.

- Safety endpoint: Frequency of symptomatic intracranial hemorrhage.

- Efficacy endpoint: Infarct volume at 90 days
DIAS-2
Desmoteplase in Acute Ischemic Stroke Phase III Clinical Trial

• Results equivocal- No statistically significant difference between drug and placebo.
• Study will continue with DIAS-3 trials.
• Stay tuned!!!!
WITH A STROKE, TIME LOST IS BRAIN LOST.

Learn more at StrokeAssociation.org or 1-888-4-STROKE.
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