Outline

• Technique
• Clinical Applications
  – Stroke
  – Brain Tumors
  – Head & Neck
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CT Perfusion Protocol
CT Perfusion

- Define ROIs for:
  - Vein
  - Artery
- Software has automated vessel selection capability
Time enhancement duration of contrast input transit time in tissue.
CT Perfusion – What is behind it?

\[ Q(t) = CBF \cdot C_a(t) * R(t) \]

Deconvolution

- Technique described by Leon Axel, M.D., Ph.D. in 1983
- Measure Time-concentration in an input artery.
- Use mathematical process called “deconvolution” to separate effect of input from observed contrast time in tissue.
Computation

- Calculations are made based on the “central volume principle” which relates blood flow, blood volume and mean transit time.

\[ BF = \frac{BV}{MTT} \]
Technique

- Non-enhanced Brain
- CT Perfusion acquisition acquired at level of the basal ganglia
  - 8cm total coverage
  - 50cc of 370 contrast
  - 4cc/sec for 12.5 sec
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CT Perfusion

Qualitative Assessment

Salvageable tissue: $\downarrow CBF, \leftrightarrow CBV \uparrow MTT$

Infarct: $\downarrow CBF, \downarrow CBV$ and $\uparrow MTT$

Hunter et al. Radiology 2003;227:725-730
CBF, CBV and MTT in left ACA and most of left MCA territories compatible with infarction
Findings compatible with right PCA infarct

- CBF
- CBV
- MTT
Perfusion CT changes compatible with ischemia

- CBF
- CBV
- MTT

No cortical infarct on 8 mo. follow up CT
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### Perfusion CT Imaging: Glioma Grading

<table>
<thead>
<tr>
<th></th>
<th>nCBV Mean (SD)</th>
<th>nCBF Mean (SD)</th>
<th>nMTT Mean (SD)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong># patients</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Low Grade (5)</td>
<td>1.44 (0.42)</td>
<td>1.16 (0.36)</td>
<td>1.69 (1.12)</td>
</tr>
<tr>
<td>High Grade (14)</td>
<td>3.06 (1.35)</td>
<td>3.03 (2.16)</td>
<td>1.29 (0.55)</td>
</tr>
<tr>
<td><strong>p-value</strong></td>
<td>0.005</td>
<td>0.045</td>
<td>0.559</td>
</tr>
</tbody>
</table>

Perfusion CT Imaging: Glioma Grading

WHO Grade II (Low Grade Glioma)

34 yo man with WHO grade II glioma. CBV map shows low blood volume (nCBV=0.94).

WHO Grade III (Anaplastic Astrocytoma)

WHO grade III glioma in a 39 yo woman who presented with seizure. CBV map shows higher CBV (nCBV=2.61).

### Perfusion CT: Recurrent Tumor vs. Radiation Necrosis

<table>
<thead>
<tr>
<th></th>
<th>nCBV Mean (SD)</th>
<th>nCBF Mean (SD)</th>
<th>nMTT Mean (SD)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Recurrent Tumor (RT)</td>
<td>2.54 (0.22)</td>
<td>2.63 (0.34)</td>
<td>1.02 (0.09)</td>
</tr>
<tr>
<td>Cerebral Radiation Necrosis (CRN)</td>
<td>1.17 (0.15)</td>
<td>0.97 (0.08)</td>
<td>1.41 (0.09)</td>
</tr>
<tr>
<td>p-values RT vs. CRN</td>
<td>&lt;0.0001</td>
<td>&lt;0.0001</td>
<td>&lt;0.0042</td>
</tr>
</tbody>
</table>

Perfusion CT Imaging: Recurrent Tumor vs. Radiation Necrosis

Cerebral Radiation Necrosis

49 yo male with left temporal lobe anaplastic astrocytoma presented with a recurrent enhancing lesion 13 months after radiation therapy.

Low CBV, low CBF and high MTT consistent with cerebral radiation necrosis.
Recurrent Tumor

21 yo male with a left posterior temporal lobe astrocytoma 24 months after radiation therapy presenting with a recurrent enhancing lesion.

High nCBV, high nCBF and lower nMTT suggestive of recurrent tumor.
Cerebral Radiation Necrosis

50 yo male post radiation therapy for lung carcinoma metastases. Lesion has low CBV suggesting cerebral radiation necrosis.
Patient was treated supportively with Vitamin E and Treental, and no anti-neoplastic treatment. 8 month follow-up MR shows resolution of the lesion confirming radiation necrosis.
38 yo female with dizziness and headache

Low CBV suggested tumefactive MS rather than a glioma. Biopsy revealed this to be a demyelinating lesion.
63 yo female with history of multiple sclerosis and a lung mass

High CBV and low PS suggested neoplasm rather than TDL. Biopsy showed metastatic adenocarcinoma.
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CT Perfusion

HNSCCA vs Normal Muscle

↑ CP  
↑ BF  
↑ BV  
↓ MTT
CTP Perfusion vs Microvascular Density

• Intratumoral microvessel density (MVD)
  – Marker of tumor angiogenesis
  – Prognostic indicator in head and neck squamous cell carcinoma (HNSCCA)

• Increased MVD
  – Advanced tumor stage
  – Locoregional and distant metastases
  – Reduced disease-free survival
  – Higher tumor oxygenation

• Requires endoscopic biopsy/tissue specimen
45 yo male with stage IV Tongue Base SCCA
• Increased BF = 190.15 ml/100g/min
• Increased MVD = 47.2 vessels/mm²

57 yo female with stage III Tongue Base SCCA
• Decreased BF = 39.13 ml/100g/min
• Decreased MVD = 19.2 vessels/mm²

Ash et al. Radiology 2009;251:422-428
CT Perfusion

**Microvascular Density**

- Positive correlation
  - MVD & BF
  - MVD & BV
- No correlation
  - MVD & MTT
  - MVD & CP
Clinical Applications

Neoadjuvant Protocol

Pre-Tx Assessment → 1 cycle CHTX → Post-Tx Endoscopic Assessment

- >50% Response → CHTX/RT
- <50% Response → SX
CT Perfusion

Pre-treatment Parameters

Blood Flow

Blood Volume
CT Perfusion

Pre-treatment Parameters: Blood Volume

![Graph showing tumor response vs. blood volume](image-url)
CT Perfusion

Pre-treatment Parameters

<table>
<thead>
<tr>
<th>p-value</th>
<th>BF</th>
<th>BV</th>
<th>MTT</th>
<th>CP</th>
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<tbody>
<tr>
<td>0.03</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0.004</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0.29</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0.07</td>
<td></td>
<td></td>
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</tr>
</tbody>
</table>

- Pretreatment values of BV & BF were significantly correlated to >50% reduction in tumor size following induction therapy.
- All patients with blood volume greater than 6 mg/dl successfully responded to induction therapy.

Zima et al. AJNR 2007;28:328-334
Bisdas et al. AJNR 2009;30:793-799
Proposed Organ Preservation Therapy
Treatment Plan

CT Neck Perfusion

BV > 6.0 → NSOPT

BV < 6.0 → Induction Chemotherapy

>50% Response → NSOPT

<50% Response → Surgery

Zima et al. AJNR 2007;28:328-334
Pre-Tx

1 cycle
Pre-Tx

1 cycle
CTP vs Clinical Response

Neoadjuvant Therapy

<table>
<thead>
<tr>
<th>CTP Parameter</th>
<th>Kappa Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Blood Volume</td>
<td>0.73</td>
</tr>
<tr>
<td>Blood Flow</td>
<td>0.37</td>
</tr>
<tr>
<td>Capillary Perm</td>
<td>0.37</td>
</tr>
<tr>
<td>MTT</td>
<td>0.37</td>
</tr>
</tbody>
</table>

Gandhi et al.  *AJNR* 2006;27:101-106
CTP vs Clinical Response

Concommitant Therapy Monitoring

40y & 70gy

- Decreased BV suggests responders (40Gy)
- No change or increase BV indicates non-responders

Surlan-Popovic et al. AJNR 2010;31:570-575
Correlation with EGFR Biomarker
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• Radiation Dose Update
At least 206 patients in an 18-month period received extremely high radiation doses during perfusion CT imaging. Patients were expected to receive a dose of 0.5 Gy (max) to their head but instead received 3-4 Gy.

Resulted in hair loss and skin erythema. Possibility of long term effects

CT unit had been set at incorrect levels for 18 months, after the hospital made an error while reconfiguring the scanner.
FDA Alert: 12/8/09

• FDA has identified at least 50 additional patients who were exposed to excess radiation during CT perfusion scans

• Cases involved more than one CT vendor

• If patient doses are higher than the expected level, but not high enough to produce obvious signs of radiation injury, the problem may go undetected and unreported, putting patients at increased risk for long-term radiation effects including cataracts.
1. Assess whether patients who underwent CT perfusion scans received excess radiation

2. Review radiation dosing protocols for all CT perfusion studies to ensure that the correct dosing is planned for each study

3. Implement quality control procedures to ensure that dosing protocols are followed every time and the planned amount of radiation is administered.

4. Technologists check the CT scanner display panel before performing a study to make sure that amount of radiation to be delivered is at the appropriate level for the individual patient.

5. If more than one study is performed on a patient during one imaging session, practitioners should adjust the dose of radiation so it is appropriate for each study.
level, causing a CT radiation overdose. Now, patients who were affected by the excess CT scan radiation have filed lawsuits against Cedars-Sinai and the makers of the CT machine, GE Healthcare Inc. and GE Healthcare Technologies.

FREE CASE EVALUATION
Send your CT Brain Scan Radiation claim to a Lawyer who will review your case at NO COST or obligation.

CLICK HERE

CT Brain Perfusion Scan Radiation Overdose

According to an FDA alert, at least 206 patients in an 18-month period received extremely high radiation doses when they were undergoing perfusion CT imaging. Specifically, the FDA says that the patients were expected to receive a dose of 0.5 Gy (maximum) to their head but instead received 3-4 Gy.

An article in The New York Times (October 15, 2009) notes that Cedars-Sinai Hospital disclosed that it had accidentally exposed patients to high doses of radiation. Meanwhile, in an incident unrelated to the FDA CT scan alert at Cedars-Sinai, at Mad River Community Hospital in Arcata, California, an x-ray technician has lost her state license for reportedly putting a 2½ year old through more than an hour of CT scans, according to the same article in The New York Times.

The FDA alert notes that some patients experienced hair loss and erythema (redness of the skin). However, also of concern is that overexposure to radiation that is not at doses high enough to produce obvious signs of radiation injury may put patients at risk for long-term radiation effects. Furthermore, there is a concern that the problem may be more widespread than just one facility.

*While this event involved a single kind of diagnostic test at one facility, the magnitude of these

CT Brain Scan Radiation Overdose Legal Help

If you or a loved one has suffered an adverse health event resulting from CT brain perfusion scanning, please click the link below and your complaint will be sent to a lawyer who may evaluate your claim at no cost or obligation.

Please click here for a free evaluation of your CT Brain Scan Radiation case
Attorneys in Huntsville, AL, have filed suit in federal court on behalf of a patient who allegedly received excessive radiation during a CT perfusion head scan for suspected stroke.

The lawsuit represents more than 300 patients, including many of the 260 patients who allegedly received CT overdoses at Cedars-Sinai Medical Center in Los Angeles.
<table>
<thead>
<tr>
<th>Scanner #</th>
<th>Measured head phantom (mGy)</th>
<th>Random patient head dose from scanner display (mGy)</th>
<th>Acceptable dose range for brain perfusion according to FDA (mGy)</th>
</tr>
</thead>
<tbody>
<tr>
<td>CT 2</td>
<td>387</td>
<td>309</td>
<td>&lt;500</td>
</tr>
<tr>
<td>CT 4</td>
<td>355</td>
<td>317</td>
<td>&lt;500</td>
</tr>
<tr>
<td>CT 6</td>
<td>389</td>
<td>311</td>
<td>&lt;500</td>
</tr>
</tbody>
</table>
**FDA requirement for perfusion study: less than 500 mGy**

<table>
<thead>
<tr>
<th>120 mm acute stroke volume shuttle</th>
<th>80 mm shuttle axial</th>
<th>40 mm cine</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.4 s rotation</td>
<td>0.4 s rotation</td>
<td>1.0 s rotation</td>
</tr>
<tr>
<td>40 mm detector coverage</td>
<td>40 mm detector coverage</td>
<td>40 mm detector coverage</td>
</tr>
<tr>
<td>5 mm thickness</td>
<td>5 mm, 8i</td>
<td>5 mm, 8i</td>
</tr>
<tr>
<td>pitch 0.984:1, 39.37 mm/rot</td>
<td>coverage time=46.6s</td>
<td>coverage time=50s</td>
</tr>
<tr>
<td>coverage time 45.7 s</td>
<td>17 passes</td>
<td>80 kV</td>
</tr>
<tr>
<td>27 shuttle passes</td>
<td>80 kV</td>
<td>200 mA</td>
</tr>
<tr>
<td>80 kV</td>
<td>500 mA</td>
<td>80 kV</td>
</tr>
<tr>
<td>490 mA</td>
<td></td>
<td>500 mA</td>
</tr>
</tbody>
</table>

**CTDI**
- 617.30 perfusion
- 45.92 non-contrast head
- **Total CTDI** 663.22 mGy

- 222.57 perfusion
- 45.92 non-contrast head
- **Total CTDI** 268.49 mGy

- 654.76 perfusion
- 45.92 non-contrast head
- **Total CTDI** 700.68 mGy

300 mA  
CTDI=378 perfusion  
**Total CTDI** 424 mGy

350 mA  
CTDI=441 perfusion  
**Total CTDI** 487 mGy
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