Diffusion and Perfusion Imaging in the Head and Neck

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Learning objectives

- Review technical aspects and challenges of diffusion and perfusion imaging
- Discuss clinical applications in the head and neck

43 y/o M status post parotidectomy

Diffusion Weighted Imaging

- Imaging of diffusion of water molecules
- Strong gradients in 3 orthogonal directions
- ADC (Apparent diffusion coefficient)
- Expressed in mm$^2$/s
- Higher the ADC, more is the degree of motion (and vice versa)
**DWI neck - technique**

**ECHO-PLANAR IMAGING**
- Single shot: Limited spatial resolution, greater geometric distortion, shorter acquisition
- Multi shot: Higher resolution, reduced geometric distortion, longer acquisition

**NON ECHO-PLANAR**
- HASTE
- PROPELLER
- BLADE
  - Less susceptibility artifact
  - Thinner sections, higher imaging matrices
  - Longer acquisition
  - Lower signal to noise ratio

**Diffusion Weighted Imaging**

- **?Surrogate marker for cellularity**
- Less cellularity (Benign) → **HIGHER ADC**
- More cellularity (Malignant) → **LOWER ADC**

**CLINICAL APPLICATIONS**

- Benign vs. malignant lesions

**Challenges with DWI neck**

- Susceptibility artifacts
- Parallel imaging
- Minimize echo train length (duration of recording)
- Geometric distortions (especially at root of neck)
- Read out segmented EPI, Reduced FOV DWI
Pleomorphic adenoma

ADC = 1.5 x 10^{-3} \text{ mm}^2/\text{s}

Adenocarcinoma

ADC = 0.7 x 10^{-3} \text{ mm}^2/\text{s}

Basal cell adenocarcinoma

19 y/o female with LE tingling and numbness

Venous vascular malformation

High grade acinic cell CA parotid with left level II metastatic node
Benign vs. malignant lesions

ADC

ADC value of $1.3 \times 10^{-3} \text{ mm}^2/\text{s}$ at 3T – threshold value for differentiation

65 y/o M with stridor and laryngeal mass

Mucoepidermoid carcinoma

Chondrosarcoma

Paraganglioma
CLINICAL APPLICATIONS

Benign vs. malignant lesions
Post-therapy changes vs. recurrence

POST-THERAPY

Patient 1

Patient 2

POST-THERAPY

Patient 1

Patient 2

POST-THERAPY

ADC can be helpful in differentiating residual or recurrent tumor from post therapy changes

Residual or recurrent tumor ↓ ADC
Post-therapy changes ↑ ADC

ADC of $1.30 \times 10^{-3}$ mm$^2$/s as a threshold

82 y/o F –
H/o Large cell Lymphoma and neutropenia

POST-THERAPY

ADC = $0.8 \times 10^{-3}$ mm$^2$/s
Biopsy proven recurrence

ADC = $1.8 \times 10^{-3}$ mm$^2$/s
Biopsy: Benign granulation

ADC map

b1000 diffusion ADC map
Two patients—both with new mass in the surgical bed post parotidectomy

- Restricted diffusion (low ADC—Path proven recurrence)

43 y/o M status post parotidectomy

- High ADC—No malignant cells on path

**CLINICAL APPLICATIONS**

- Benign vs. malignant lesions
- Post-therapy changes vs. recurrence
- Prediction of therapy
- Monitoring of response

**PREDICTION OF RESPONSE**

**PRE-TREATMENT ADC**

- COMPLETE responders
- PARTIAL responders

1.04 x 10^{-3} mm^2/s

1.35 x 10^{-3} mm^2/s

- Significant ↑ in ADC in complete responders within 1 week of treatment

- Prediction of response
  - Pre-Rx ADC and change in ADC

**INTRA-THERAPY**

- ADC - Monitoring early therapeutic response

  - Increase in ADC during early phase of therapy relative to baseline value suggesting conversion of solid tumor to necrotic tissue
Intra therapy tumor response assessment

Rx
b1000 diffusion
ADC map

CLINICAL APPLICATIONS
Benign vs. malignant lesions
Post-therapy changes vs. recurrence
Prediction of therapy
Monitoring of response
Recurrent cholesteatoma

Post mastoidectomy for cholesteatoma
Recurrent Cholesteatoma + Scar

CLINICAL APPLICATIONS
Benign vs. malignant lesions
Post-therapy changes vs. recurrence
Prediction of therapy
Monitoring of response
Recurrent cholesteatoma
Miscellaneous

Post-Op for petrous apex cholesteatoma
Recurrent Cholesteatoma + Scar

CLINICAL APPLICATIONS
Intraocular abscess
Melanoma, Evaluate brain metastases

Extracranial and brain metastases present

**MR Perfusion**

- With or without contrast administration

- **T2** - Dynamic susceptibility contrast or **T1** - Dynamic contrast enhanced

- Blood flow and blood volume, capillary permeability and transfer coefficients

**MR Perfusion - DCE Technique**

Axial plane
- 2D-multislice, T1-weighted fast-field echo
- 3D spoiled Gradient T1-weighted

- Slice thickness of 5-6 mm (3 mm overlap)

- Craniocaudal length of coverage - 5 to 6 cm

- 0.1 mmol/kg of Gadolinium at 5 mL/sec
  Then, 20 mL saline flush at 5 mL/sec
MR Perfusion - Challenges

- Patient motion
- Skull base susceptibility artifacts
- Good cardiovascular function
- Good renal function
- Values are relative, so semi-quantitative

DSC Perfusion - Benign vs Malignant

DSC % threshold value
Could be helpful for differentiating malignant from benign nodes and metastatic from lymphomatous nodes

Mean DSC% of malignant tumor >> Mean DSC% of benign lesions

MRI - Perfusion imaging

Benign vs. malignant

Prediction of outcome

Chondrosarcoma

MRI scans before therapy and 2 weeks into chemo-RT

- Blood volume in the primary tumor after 2 weeks of chemo-RT was increased significantly in the local control patients compared with the local failure patients (p < 0.03)

- Reduction in tumor volume after 2 weeks of chemo-RT did not predict local control

Prediction of outcome using DCE MRI

Recurrence tumor vs. Post-therapy benign changes

**DCE MR perfusion**

Post-therapy benign changes showed

\[ \uparrow \text{TTP} \land \downarrow \text{RWO} \text{ (relative washout ratio)} \]

than recurrent tumor

\[(\text{Courtesy: } \text{Furukawa et al. Head Neck 2013;35:923-929})\]
CT Perfusion

- Requires contrast administration and dynamic imaging
- Post-processing using deconvolution algorithm
- Blood volume, blood flow, mean transit time, time to peak, capillary permeability

CT Perfusion - Technique

Cine mode

- 40 mm detector coverage
- 5 mm slice thickness
- 50 cc Non-ionic contrast at 4 cc/s
- 20 cc saline flush at 4 cc/s
- 5 sec delay
- 50 sec scan duration

CT Perfusion - Challenges

- Patient motion
- Z axis coverage limited
- Streak from dental amalgam
- Good renal function

CT Perfusion

Pre-Rx

- Higher BF and BV correlate with better response
- BV correlates with microvascular density, an important prognostic indicator
- CP correlates with EGFR overexpression

Post Rx

- Responders show lower BV and BF

Surlan-Popovic K et al. AJNR 2010;31:570-575.

CT PERFUSION

Post treatment

Increased blood volume and blood flow – recurrent tumor

CT PERFUSION

Post treatment

Increased blood volume and permeability – residual tumor
<table>
<thead>
<tr>
<th>Summary</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Pre-Rx</strong></td>
</tr>
<tr>
<td>Low ADC: Malignant</td>
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<tr>
<td>Elev. blood volume/K: Trans</td>
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<tr>
<td>Good prognosis</td>
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<tr>
<td><strong>During Rx</strong></td>
</tr>
<tr>
<td>Increasing ADC</td>
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<tr>
<td>Transient increase in BV</td>
</tr>
<tr>
<td>Good response</td>
</tr>
<tr>
<td><strong>Post Rx</strong></td>
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Always interpret diffusion/perfusion imaging along with anatomic information.

ALLERGIC FUNGAL SINUSITIS

**THANK YOU**