Sodium Fluoride PET/CT Bone Imaging: Theory and Practice

George Segall, M.D.
Why F-18 Fluoride?

• Faster
• Higher Resolution
• Anatomic Correlation
Chemiadsorption

Hydroxyapatite $\text{Ca}_{10}(\text{PO}_4)_6(\text{OH})_2$

Hydroxyfluorapatite $\text{Ca}_{10}(\text{PO}_4)_6(\text{OH})\text{F}$

Fluorapatite $\text{Ca}_{10}(\text{PO}_4)_6\text{F}_2$
## Tc99m MDP vs F-18 Fluoride

<table>
<thead>
<tr>
<th>Parameter</th>
<th>MDP</th>
<th>NaF</th>
</tr>
</thead>
<tbody>
<tr>
<td>RBC uptake</td>
<td>negligible</td>
<td>30 - 40%</td>
</tr>
<tr>
<td>Protein binding</td>
<td>25 – 70%</td>
<td>negligible</td>
</tr>
<tr>
<td>First pass extract.</td>
<td>40 – 60%</td>
<td>70 – 100%</td>
</tr>
<tr>
<td>Renal excretion</td>
<td>GFR</td>
<td>GFR – tub reabsorption</td>
</tr>
</tbody>
</table>
FDA Status

Na F-18 fluoride is FDA approved

“Sodium fluoride F18 injection is indicated for PET as a bone imaging agent to define areas of osteogenic activity”
THE SNM PRACTICE GUIDELINE FOR Sodium 18F-Fluoride PET/CT Bone Scans

Version 1.0    June 4, 2010

• Hydration
• Dose

Adult: 5 - 10 mCi
Ped: 1 - 5 mCi

(.07 mCi/kg)
• Start imaging

  Trunk: 30 - 45 min
  Extrem: 90 - 120 min

• Arm position

  Trunk: raised
  W Body: sides

• Emission acquisition time

  2 - 5 min / stop
• CT protocol

No CT vs

AC and registration vs

Optimized for diagnosis

ALARA
72 yr old man with prostate CA and PSA 131
59 yr old man with lung CA

No AC  AC  CT  PET-CT
Indications

• Detection of metastatic disease

• All other standard indications?

Back pain
Metastatic Disease


- 52 patients with lung cancer
- 13 (23%) had bone mets

<table>
<thead>
<tr>
<th>Test</th>
<th>sens</th>
<th>spec</th>
</tr>
</thead>
<tbody>
<tr>
<td>Planar bone scan</td>
<td>54%</td>
<td>88%</td>
</tr>
<tr>
<td>Planar + SPECT</td>
<td>92%</td>
<td>100%</td>
</tr>
<tr>
<td>F18 fluoride PET</td>
<td>100%</td>
<td>100%</td>
</tr>
</tbody>
</table>
## Metastatic Disease


- 44 patients with high risk prostate cancer
- 23 (52%) had bone mets

<table>
<thead>
<tr>
<th>Imaging Modality</th>
<th>sens</th>
<th>spec</th>
</tr>
</thead>
<tbody>
<tr>
<td>Planar bone scan</td>
<td>70%</td>
<td>57%</td>
</tr>
<tr>
<td>Multi FOV SPECT</td>
<td>92%</td>
<td>82%</td>
</tr>
<tr>
<td>F18 PET/CT</td>
<td>100%</td>
<td>100%</td>
</tr>
</tbody>
</table>
63 year old man with new prostate cancer
63 year old man with new prostate cancer
Metastatic Disease

Yen et al. Nucl Med Commun 2010;31:637-645

- Prospective study comparing NaF PET/CT vs MDP planar BS in 34 pts with HCC

Indications
- bone pain 56%
- tumor extent 21%
- path fx 12%
- other 11%

34 patients
- 24 bone mets
- 10 No bone mets
- 13 bone only
- 11 bone + other
Metastatic Disease

Yen et al. Nucl Med Commun 2010;31:637-645

Prospective study comparing NaF PET/CT vs MDP planar BS in 34 pts with HCC

<table>
<thead>
<tr>
<th></th>
<th>Lesion</th>
<th>Patient</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>sens (n=90)</td>
<td>spec (n=48)</td>
</tr>
<tr>
<td>MDP planar BS</td>
<td>73%</td>
<td>79%</td>
</tr>
<tr>
<td>NaF PET/CT</td>
<td>93%</td>
<td>100%</td>
</tr>
</tbody>
</table>
47 yr old woman with thigh pain
False - MDP planar bone scan, True + NaF PET/CT
Yen et al. Nucl Med Commun 2010;31:637-645

78 yr old man with back pain

False + MDP planar bone scan, True - NaF PET/CT
**Table 2** Independent estimates of analyses on patient basis and lesion basis

<table>
<thead>
<tr>
<th>Diagnostic methods</th>
<th>No. of studies</th>
<th>Sensitivity (95% CI)</th>
<th>Specificity (95% CI)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Analysis on a patient basis</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>BS planar</td>
<td>5</td>
<td>0.468 (0.398–0.537)</td>
<td>0.883 (0.829–0.936)</td>
</tr>
<tr>
<td>BS planar and SPECT</td>
<td>3</td>
<td>0.815 (0.706–0.923)</td>
<td>0.990 (0.973–1.000)</td>
</tr>
<tr>
<td>¹⁸F-Fluoride PET</td>
<td>7</td>
<td>0.949 (0.912–0.986)</td>
<td>0.987 (0.972–1.000)</td>
</tr>
<tr>
<td>¹⁸F-Fluoride PET/CT</td>
<td>3</td>
<td>0.977 (0.938–1.000)</td>
<td>0.959 (0.905–1.000)</td>
</tr>
<tr>
<td>BS planar or BS planar and SPECT</td>
<td>8</td>
<td>0.569 (0.510–0.627)</td>
<td>0.980 (0.964–0.996)</td>
</tr>
<tr>
<td>¹⁸F-Fluoride PET or PET/CT</td>
<td>10</td>
<td>0.962 (0.935–0.989)</td>
<td>0.985 (0.970–1.000)</td>
</tr>
<tr>
<td>Analysis on a lesion basis</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>BS planar</td>
<td>4</td>
<td>0.579 (0.526–0.632)</td>
<td>0.954 (0.924–0.984)</td>
</tr>
<tr>
<td>BS planar and SPECT</td>
<td>1</td>
<td>0.357 (0.198–0.516)</td>
<td>0.961 (0.921–1.000)</td>
</tr>
<tr>
<td>¹⁸F-Fluoride PET</td>
<td>7</td>
<td>0.958 (0.942–0.974)</td>
<td>0.983 (0.969–0.996)</td>
</tr>
<tr>
<td>¹⁸F-Fluoride PET/CT</td>
<td>4</td>
<td>0.978 (0.964–0.991)</td>
<td>0.978 (0.966–0.990)</td>
</tr>
<tr>
<td>BS planar or BS planar and SPECT</td>
<td>5</td>
<td>0.557 (0.507–0.607)</td>
<td>0.956 (0.932–0.981)</td>
</tr>
<tr>
<td>¹⁸F-Fluoride PET or PET/CT</td>
<td>11</td>
<td>0.969 (0.959–0.980)</td>
<td>0.980 (0.971–0.989)</td>
</tr>
</tbody>
</table>
77 year old man with new prostate cancer. PSA 168

99mTc-MDP

18F-fluoride
99mTc-MDP

18F-fluoride
F-18 Fluoride vs FDG

Bone Metastases

Lytic

FDG >90%

Blastic

F18 >90%
F-18 Fluoride vs FDG

F-18 Fluoride vs FDG


20 patients with different cancers

150 Metastatic Lesions

• 72 FDG and F18 +
• 44 FDG + but F18 -
• 34 FDG - but F18 +
F-18 Fluoride + FDG


75 yr old man with prostate cancer
Assessment of Back Pain


- 15 patients (9-19 yrs) with severe pain
- PET/CT diagnostic in 10 patients

- spondylolysis 3
- osteoid osteoma 2
- fracture 3
- osteitis pubis 1
- sacroilitis 3
- herniated disk 2
Assessment of Back Pain


- 94 patients (4-26 yrs) with back pain
- PET/CT diagnostic in 52/94 (54%) patients

<table>
<thead>
<tr>
<th>Injury Type</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>pars/pedicle stress</td>
<td>34%</td>
</tr>
<tr>
<td>spinous process injury</td>
<td>16%</td>
</tr>
<tr>
<td>vertebral body ring</td>
<td>14%</td>
</tr>
<tr>
<td>transitional L5/S1</td>
<td>7%</td>
</tr>
<tr>
<td>SI joint stress/inflammation</td>
<td>3%</td>
</tr>
</tbody>
</table>
Assessment of Back Pain

- Facet Arthropathy

56 year old man with low back pain
Assessment of Back Pain

67 year old man with chronic low back pain
Assessment of Back Pain

67 year old man with chronic low back pain
Problems and Limitations

• Availability and Accessibility
• Radiation Exposure
• Cost and Reimbursement
<table>
<thead>
<tr>
<th>Radiation Exposure</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Bone</strong></td>
</tr>
<tr>
<td>Tc99m MDP 25 mCi</td>
</tr>
<tr>
<td>F18 Fluoride 10 mCi</td>
</tr>
<tr>
<td>CT trunk 100 mAs pitch 1.2</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td>-------------</td>
</tr>
<tr>
<td>Tc99m MDP</td>
</tr>
<tr>
<td>F18 Fluoride</td>
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</tbody>
</table>

Pediatric radiation dose is 3.5 - 4.5 x adult dose
F-18 Fluoride PET Bone Scan registry opened in January 2011

Exams are covered by CMS under “coverage with evidence development”

• Initial treatment strategy
• Subsequent treatment strategy
Summary

• F-18 fluoride shows promise as an imaging agent with PET/CT
• Accuracy is higher than MDP BS
• Faster and more convenient for patients
• Radiation exposure is higher than MDP BS
• Cost effectiveness is unknown
Has The Future Arrived?


“…we can expect that F18-fluoride will replace bone scintigraphy completely within several years.”
Sodium F18-fluoride PET/CT bone scans have become a routine clinical procedure in patients with known or suspected skeletal metastases, and is being used for other indications in selected patients.