What is BSI?
Its history and technique

Kenichi Nakajima, MD, PhD
Kanazawa University Hospital, Kanazawa, Japan

Disclosure Statement
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## Acquisition conditions for bone scan

<table>
<thead>
<tr>
<th></th>
<th>EU (EANM 2003)</th>
<th>USA (ACR-SNM 2014)</th>
<th>UK (BNMS 2014)</th>
<th>Japan (JSNMT2008)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Activity (^{99m}\text{Tc}) iv-injection</strong></td>
<td>300-740 MBq</td>
<td>555-1110 MBq (obese: 1480 MBq)</td>
<td>600 MBq</td>
<td>740 MBq</td>
</tr>
<tr>
<td><strong>Radiopharmaceutical</strong></td>
<td>MDP, HMDP or HEDP</td>
<td>MDP, HDP or comparable</td>
<td>MDP, HMDP</td>
<td>MDP, HMDP</td>
</tr>
<tr>
<td><strong>Labelling efficiency</strong></td>
<td>&gt;95%</td>
<td>.</td>
<td>.</td>
<td>.</td>
</tr>
<tr>
<td><strong>Time delay</strong></td>
<td>2 - 5 hrs</td>
<td>2 - 4 hrs</td>
<td>&gt;2.5 hrs</td>
<td>2 - 3 hrs</td>
</tr>
<tr>
<td><strong>Views</strong></td>
<td>Ant + Post</td>
<td>Ant + Post</td>
<td>Ant + Post</td>
<td>Ant + Post</td>
</tr>
<tr>
<td><strong>Collimator</strong></td>
<td>LEHR</td>
<td>LEHR/ultra-HR</td>
<td>LEHR/cardiac-HR</td>
<td>LEHR</td>
</tr>
<tr>
<td><strong>Energy window</strong></td>
<td>140 keV (±10%)</td>
<td>.</td>
<td>140 keV (±10%)</td>
<td>140 keV (±10%)</td>
</tr>
<tr>
<td><strong>Matrix</strong></td>
<td>256 x 1024</td>
<td>.</td>
<td>256 x 1024</td>
<td>256 x 1024</td>
</tr>
<tr>
<td><strong>Counts/view</strong></td>
<td>&gt;1.5 million (scan speed adjusted to)</td>
<td>&gt;1 million (scan speed 8-15 cm/min)</td>
<td>. (scan speed 10 cm/min)</td>
<td>. (scan speed &lt;15 cm/min)</td>
</tr>
</tbody>
</table>
Parameters from EXINI bone/BONENAVI

Three major indices of ANN, BSI and HSn

<table>
<thead>
<tr>
<th></th>
<th>ANN</th>
<th>BSI (%)</th>
<th>HSn</th>
</tr>
</thead>
<tbody>
<tr>
<td>ANN</td>
<td>0.99</td>
<td></td>
<td></td>
</tr>
<tr>
<td>BSI</td>
<td>0.59</td>
<td></td>
<td></td>
</tr>
<tr>
<td>HSn</td>
<td></td>
<td></td>
<td>9</td>
</tr>
</tbody>
</table>

Two colors of hot spots
- Low risk hot spot
- High risk hot spot
What is ANN (artificial neural network) value?

- ANN system was trained to mimic assessment of experienced readers
- ANN values indicate probability of abnormality
- ANN is calculated for each hot spot. Appropriate threshold of ANN depends on locations.
What is BSI?

• Amount of bone metastasis / whole body skeletal mass
• Summed only when ANN > 0.5

\[
\text{BSI} = \frac{\sum \text{Area of Metastases} \times C}{\text{Total Anatomical Area}}
\]

C = Anatomical Area Coefficient

Erdi et al, J Nucl Med 1997;38:1401
BSI from Memorial Sloan Kettering Cancer Center

Quantitative Bone Metastases Analysis Based on Image Segmentation

Yusuf E. Erdi, John L. Humm, Massimo Imbriaco, Henry Yeung and Steven M. Larson
Department of Medical Physics, Nuclear Medicine Service, Department of Radiology, Memorial Sloan–Kettering Cancer Center, New York, New York

A New Parameter for Measuring Metastatic Bone Involvement by Prostate Cancer: The Bone Scan Index

Massimo Imbriaco, Steven M. Larson, Henry W. Yeung, Osama R. Mawlawi, Yusuf Erdi, Ennpadam S. Venkatraman, and Howard I. Scher

- The fractional involvement of each bone by tumor was estimated visually from bone scan
A patient with prostate cancer
What is your interpretation?
A patient with prostate cancer
What is your interpretation?

2010

met+

2011

met+ improved

s/o met+

2012

no change

new met+
How does the computer think using ANN?

Regional ANN: probability of metastasis in each hot spot

2010

2011

2012
How does the computer estimate total amount of metastasis using BSI?

Total BSI and regional BSI (if required)

BSI = 1.6%
BSI = 0.19%
BSI = 0.71%
Follow-up summary using BSI and HSn using EXINI bone / BONENAVI

<table>
<thead>
<tr>
<th>Year</th>
<th>BSI</th>
<th>No. of HS</th>
</tr>
</thead>
<tbody>
<tr>
<td>2010</td>
<td>1.62%</td>
<td>11</td>
</tr>
<tr>
<td>2011</td>
<td>0.19%</td>
<td>2</td>
</tr>
<tr>
<td>2012</td>
<td>0.71%</td>
<td>4</td>
</tr>
</tbody>
</table>

- Instead of reporting “patly improved, partly worsened, essentially no change …”
Let’s understand severity using BSI

A: small
B: definite met+ localized
C: definite met+ many hot spots
D: multiple mets: super scan
Your impression is supported by BSI quantitatively.

- BSI 0.2: minimal
- BSI 0.9: some
- BSI 4.5: many
- BSI 9.6: severe-super
The purpose of BSI is:

- Not to decide specific hot spot is metastasis or not
- But to summarize the whole amount of metastasis

- Diagnostic guide
- Treatment effects
- Prognosis
Bone Scan Index: Prognostic use is one of the most important applications.

Events (death, skeletal related events, etc)

Survival

Years

Prognosis

BSI < 1
1-5
> 5

Good
Poor
Automatic processing

• What is time for processing?
  • <10 seconds for calculation
  • 1-2 min from retrieving data to output page

• High reproducibility
  • Minimal manual processing for accepting red/blue areas, excluding contamination, etc
  • AutoBSI (without manual adjustment) can be used for prognostic purpose
Japanese multi-center database project: Improved diagnostic accuracy for any cancer types

Trained by Japanese database with definitive diagnosis of metastasis (n=1532)

Nakajima, et al. EJNMMI Res 2013, 3:83
Why is quantification required?

Initial Dx
- Blue and red hot spots help nuclear medicine physicians to evaluate abnormality efficiently, and find total amount of metastasis.

Follow-up
- It is convenient as serial changes are sometimes associated with mixed improvement and worsening.

Therapy
- Treatment effects can be easily understood.

Prognosis
- Prognosis is poor in high-BSI patients, and it may change treatment strategy.

Multicenter clinical trial
- Convenient for inter-institutional comparison and multicenter study using uniform diagnostic criteria and quantification.