Non-neoplastic variants of the sternum detected on bone scintigraphy using a hybrid SPECT/CT machine

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Abstract Purpose: To identify the non-neoplastic variants of the sternal uptake in patients known to have a primary tumor, referred for detection of metastases elsewhere.

Materials and methods: This retrospective study was approved by the Institutional Review Board. Fifty eligible patients (17 males & 33 females) known to have a primary tumor underwent 99mTc-MDP-bone scan for detection of metastases. All patients underwent SPECT/CT of the chest region. For each patient, 10 subsites were evaluated (right & left sternoclavicular joints, right and left first costo-sternal articulation, manubrium sterni, manubriosternal junction, body of the sternum, xiphisternal junction, xiphoid process and other sub-sites (e.g. chondro-sternal articulations)). The uptake was described as normal or abnormal. CT findings were categorized as normal/abnormal (arthritis, degenerative, developmental & congenital). Any patient with suspicious metastatic sternal lesion based on CT findings or abnormal tracer uptake was excluded.

Results: A total of 500 sub-sites were analyzed. Increased uptake was seen in 189 sub-sites. Of them, 133 showed abnormal CT findings (95 arthritis, 33 degenerative, 3 developmental & 2 congenital) and 56 sites were unremarkable. Of the 311 with normal uptake, only 18 showed abnormal CT findings (8 arthritis & 10 degenerative). The association was statistically significant (P < 0.001).

Conclusion: Increased sternal uptake is significantly associated with CT structural abnormalities and knowledge of these non-neoplastic variants is essential for correct interpretation of SPECT/CT bone scans especially in patients with known cancers.

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Bone scintigraphy using technetium based phosphonate compounds is the standard method for detection of skeletal metastases from many cancers (1). Sternum is relatively a frequent site for skeletal metastasis especially in patients with breast cancer (2). The different age-related patterns of normal sternal uptake have been previously described in patients with no malignancy (3,4). Hybrid imaging using SPECT/CT was shown to increase the accuracy of bone scanning and significantly affects the clinical management decisions of cancer patients (5,6).

It is therefore fundamental to recognize the non-neoplastic variants of the sternal uptake and their corresponding CT changes using SPECT/CT.

2. Materials and methods

2.1. Patients

This retrospective study was approved by the Institutional Review Board. An informed consent was not required. We included patients known to have primary tumor referred for diagnosis/follow-up of bone metastases, in whom SPECT/CT of the chest region was performed with complete inclusion of the sternum and sternoclavicular articulations. Patients with known sternal pathology (pain, trauma, fracture, surgery), or patients with any lesion that is considered suspicious for being metastasis based on bone scan or low-dose CT findings were excluded.

During the period from February 2013 to May 2014, a total of 50 patients were deemed eligible for this study.

2.2. Imaging protocol

At first, whole body scans were obtained in the anterior and posterior projections 2 h after the IV injection of about 650–850 MBq of 99mTc-MDP. A dual-head γ-camera (Symbia T, Siemens Medical Solutions, USA) equipped with parallel-hole high resolution low-energy collimators using a 20% energy window set at 140 keV was used. The table speed was 12 cm/min, matrix size 256 × 1024.

SPECT/CT images of the chest region were obtained with the sternum and sternoclavicular joints fully included in the scanned field. SPECT procedure was acquired employing a step-and-shoot protocol, 25s/view for a total of 32 views using a noncircular orbit over 360° of rotation (180° per head) and a matrix size of 128 × 128.

Immediately after completing SPECT acquisition, low-dose CT study was acquired using the following parameters: tube current 70 mA s, tube voltage 130 kV, employing a dose-reduction algorithm (CAREDose 4D, Siemens Medical Solutions, USA). The CT dose index per volume (CTDIvol) was on average 7.6 mGy. CT images were reconstructed in 2-mm slices using bone and soft tissue kernels.

After completion of acquisition, the images were reconstructed with attenuation and scatter correction using 3D iterative algorithm (OSEM 3D Flash, Siemens Medical Solutions, USA).

The reconstructed attenuation-corrected SPECT images and CT images were transferred to the viewing stations for reviewing in axial, coronal, and sagittal planes.

2.3. Data interpretation

A combined reading of the SPECT/CT data was performed by one nuclear medicine physician (11 years experience) and one radiologist (15 years experience). Both physicians have prior knowledge of the aim of the study and clinical data of the patient (age, gender, primary tumor site and received treatments).

For each patient, 10 sites were evaluated: right and left sternoclavicular joints (SCJs), right and left first costo-sternal junctions, manubrium, manubrosternal junction (MSJ), body of the sternum, xiphisternal junction, xiphoid process and other sub-sites (e.g. lateral borders of the sternum at the sites of cartilaginous rib attachment).

For each site, the intensity of tracer uptake was described as normal or increased. The CT findings were also described as either normal or abnormal. The abnormalities were categorized as follows: arthritic (e.g. joint line irregularity, sclerosis, osteophytes, sub-chondral cystis), degenerative (e.g. calcification, ossification, vacuum phenomenon), developmental (e.g. growth centers), or congenital (e.g. sternal cleft, bony islands). Any other changes (e.g. trauma and bone cysts) were also noted.

2.4. Statistical analysis

Qualitative data were expressed as frequencies and percentages. Associations were performed using chi-square. The analyses were carried out using the SPSS 21.0 (SPSS Inc., Chicago, Illinois, USA), (MedCalc, Ostend, Belgium), and Microsoft Excel (Microsoft, USA) softwares.

3. Results

A total of 50 patients (17 males & 33 females) with median age 55.5 years (range: 6–86) were eligible for inclusion in that study.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>N</th>
<th>Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cancer site</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Right breast</td>
<td>14</td>
<td>28%</td>
</tr>
<tr>
<td>Left breast</td>
<td>12</td>
<td>24%</td>
</tr>
<tr>
<td>Bilateral breast</td>
<td>2</td>
<td>4%</td>
</tr>
<tr>
<td>Prostate</td>
<td>4</td>
<td>8%</td>
</tr>
<tr>
<td>Kidney</td>
<td>2</td>
<td>4%</td>
</tr>
<tr>
<td>Other</td>
<td>16</td>
<td>32%</td>
</tr>
</tbody>
</table>

The numbers in parentheses indicate the range of the data.
Twenty-eight patients (56%) had breast cancer of them 18/28 (64%) had history of post-operative irradiation (Table 1).

### 3.1. Patient-based analysis

Patients were categorized according to their ages into young age (<35 years; n = 6), middle age (35-60 years; n = 26) and old age (>60 years; n = 18).

Thirty-three patients showed CT changes in their SCJs (22 bilateral, 3 left, 8 right; total 55 positive subsites). SCJ arthritis was the most frequent finding seen in 28 patients (19 bilateral, 2 left & 7 right), 14 of them were in the old age group (78% among group) and 13 were middle-aged (50%). The association of SCJ arthritis and age was statistically significant (Fig. 1) (P = 0.02).

CT abnormalities of the first costo-sternal articulations were documented in thirty patients (22 bilateral, 4 left & 4 right; total 52 positive subsites). Of these patients, 11 were old-aged (61%) and 19 were middle-aged (73%). No CT changes were detected in the young age group. The age-related CT changes were statistically significant (P = 0.004). The pattern of detected CT changes was either degeneration (n = 33) or arthritis (n = 19).

The MSJ showed CT changes in 30 patients (29 arthritis & 1 degeneration). Of them, 12 patients were in the old age group (67%), 17 were middle aged (65%) and only one patient was less than 35 years. The association did not reach statistical significance (P = 0.07).

Partial sternal cleft with pes cavus was seen in one patient. Growth centers were detected in two young patients (15 & 20 years; respectively) in the body of the sternum and medial ends of both clavicles.

### 3.2. Relation to different cancers

In this study, 28 patients had breast cancer. Fifteen of them showed CT findings of SCJ arthritis (54%) compared to 13 of the remaining 22 patients with non-breast cancer (59%). Likewise, 23 patients showed increased tracer uptake at SCJs (82%) compared to 17 patients with cancers other than the breast cancer. No statistically significant association noted between the presence of breast cancer and SPECT/CT changes in the SCJs.

Of the same 28 patients, 14 patients had right-sided and 12 had left-sided breast cancer. The remaining 2 showed bilateral breast cancers. There was no significant association between the laterality of breast cancer and the presence/absence of abnormal uptake or CT findings.

### 3.3. Site-based analysis

Of the 500 subsites assessed, increased tracer uptake in different patterns was noted in 181 sites of the sternum (36%) while the rest of the sites (n = 319; 64%) showed normal tracer uptake pattern (Table 2).

Overall 138/181 (76%) of the sternal sites with increased tracer uptake showed corresponding CT changes in the form of arthritic (53%), degenerative (19%) (Fig. 2), developmental (2%) or congenital changes (1%). No CT changes could be detected in 24% of these sites. On the other hand, among all the sites with normal tracer uptake (n = 319) CT showed arthritic changes in 9 sites (3%) and degeneration was detected in another 9 sites (3%). Unremarkable CT findings were seen in the remaining 301 sites (94%). The association between the tracer uptake and CT findings was highly significant (P < 0.001).

### 4. Discussion

The introduction of hybrid imaging modalities adds new challenges to the interpreting physician. A good example of these challenges is met with the introduction of SPECT/CT machines. It is well-known that SPECT/CT enhances the specificity of bone scans and improves the overall accuracy (7). It is therefore mandatory to identify different pathologic and non-pathologic patterns from both modalities.

The sternum is considered relatively a frequent site for skeletal metastasis. Previous studies have described the age-related variants of sternal uptake from planar imaging in non-cancer patients (3,4). Findings from hybrid SPEC/CT
machines in patients referred to exclude bone metastases were not reported. With this aim in mind, we included the patients with known primary tumor and referred to exclude bone metastases. Also, the clinical data of the patients were readily available.

The importance of identifying variable CT changes corresponding to increased/normal tracer uptake was emphasized in this work. In 76% of sternal sites, the increased tracer uptake would correspond to CT changes. Arthritic changes were dominating the positive CT abnormalities especially in middle and old age patients.

It was previously reported that first costo-chondral degeneration is more common in males (8). In this work, no gender differences could be detected although a trend to increased incidence in females is noted (females: 23/33 vs. males: 7/10; \( P = 0.05 \)). This could be explained by higher inclusion of post-menopausal female patients with breast cancer.

In 18 patients, degenerative and arthritic CT changes were not matched to increased tracer uptake. It has been shown that inactive osteoarthritis and mature ossification/osteophytes are metabolically inert and do not avidly accumulate the tracer (9,10).

Inevitable respiratory movement of the more mobile anterior part of the chest wall— including the sternum— can result in slight misregistration between the nuclear medicine and CT studies. However, it could be easily recognized and realigned.

Although breast cancer is frequently associated with upper extremity impairment (11), no statistically significant difference could be detected in this series between the breast/non-breast cancer patients regarding either the incidence or laterality of SCJ changes.

Though infrequent, abnormal tracer uptake within developmental and congenital changes has been encountered and should not be mistaken for neoplasm. Two patients showed increased tracer uptake within the growth centers, another one showed relatively decreased uptake at sternal cleft and one showed normal uptake within multiple small bone islands. Developmental sternal CT changes have been previously discussed (12).

The tracer uptake pattern was not the primary goal of this work being previously described in the literature (3,4,13). However, it is worth mentioning that we frequently faced the finding of relative central photopenia within the sternal body with increased tracer uptake toward the periphery. This finding has been previously shown as normal variant (13). In our series, that was correlated to partial sternal cleft in one patient. In most of the remaining patients it was “false” photopenia related to the relatively higher tracer uptake at the lateral margins of the sternal body at the site of attachment of costo-chondral cartilage to the sternum. It is worth noting that at these sites CT can be mistaken for lytic/soft tissue lesions due to soft tissue prominence and/or sternal body invaginations imposed by the rib attachments (8,14). Symmetry, laterality and CT revision in all planes are the keys to exclude true pathology in these sites.

In conclusion, non-neoplastic SPECT/CT findings in the sternum and sternoclavicular articulations are frequent and in most cases associated with structural CT findings. Knowledge of these variants is fundamental for the correct interpretation of bone scintigraphy especially in cancer patients in whom the sternum is a potential site for harboring metastases.

**Conflict of interest**

The authors state that there is no conflict of interest.
References