# Age-Related Normal Variants of Sternal Uptake on Bone Scintigraphy

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**Purpose:** The purpose of this study was to describe the variable age-related normal appearance of the sternal area on bone scintigraphy.

**Methods:** We studied 334 patients (158 males and 176 females) aged 15 days to 85 years, mean age  $32.5 \pm 19.9$  years, who did not have symptoms associated with the sternum and chest wall or a history of malignancy. All patients underwent whole-body bone scan 3 hours after intravenous injection of Tc-99m MDP.

Results: In patients younger than 10 years, sternal uptake was equal to nearby ribs with homogeneous uptake and poorly defined outlines. In older patients, the sternum showed markedly greater uptake than nearby ribs and the borders became well defined. Different patterns of sternal uptake were noted: 1) increased uptake in the manubrium; 2) hot spots in the angle of Louis, body and xiphoid; 3) a photopenic area just above the xiphoid process; 4) heterogeneous sternal body uptake; and 5) hyperactivity along the sternal body borders. Of these variants, the angle of Louis hot spot was the most common finding (63.5%). A linear pattern of hot spots in the sternal body was seen most frequently between 10 and 30 years old and corresponded to 3 transverse ridges of bone, representing the sites of union. Increased tracer uptake only at the medial end of the clavicle in the SC joints was seen in 42.13% of patients younger than 30 years. Conclusion: This study showed age-related normal variants of sternal uptake on bone scanning in asymptomatic patients. Understanding these

variants may be helpful in differentiating normal and abnormal patterns of uptake in the sternum on radionuclide bone imaging.

Key Words: bone scintigraphy, sternum, angle of Louis, normal variants, aging

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**B**one scintigraphy is frequently performed to investigate many skeletal abnormalities in daily nuclear medicine practice. Interpretation of a skeletal scintigraphic study requires not only images of high quality, but careful scrutiny, bearing in mind the normal variants and evaluation in light of

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the particular clinical problem.<sup>1</sup> The normal appearance of the sternal area is highly variable on planar bone imaging<sup>2</sup> and changes dramatically between infancy, childhood, adolescence, and mature adulthood.<sup>3</sup> The sternum consists of 3 portions: manubrium, body, and xiphoid process. Two symphysis articulations exist between the segments of the sternum: the manubriosternal joint and the xiphosternal joint. The sternoclavicular joint is a synovial articulation.<sup>4</sup> The pattern of ossification during the development of the sternum is variable.<sup>5,6</sup> Previous studies have reported increased uptake at the angle of Louis<sup>7,8</sup> and a photopenic defect in the lower sternum.<sup>2</sup> After an extensive search on Medline, only one study was found about age-related patterns of sternal uptake on bone scintigraphy.9 This current study attempts to describe normal variants of sternal uptake and related joints as well as their relationship with age.

# PATIENTS AND METHODS

We investigated all patients referred for whole-body bone scanning from January 2002 to January 2004. Patients with complaints of pain, a history of known pathology, trauma, surgery, or radiation in the sternum or chest wall as well as a history of any malignancy were excluded (Table 1). Overall, 334 patients (158 males and 176 females), ranging in age between 15 days and 85 years (mean age,  $32.5 \pm 19.9$ years) were studied. All patients underwent whole-body bone scan with acquisition of multiple anterior and posterior spot views 3 hours after intravenous injection of Tc-99m methylene diphosphonate (MDP) using a single-head gamma camera (model DSX; Summit Medical Vision, France) fitted with a low-energy, high-resolution collimator. Anterior images of the chest were obtained with 750 kcounts and were stored in a 256  $\times$  256 matrix. The adult dose was 740 to 900 MBg (20-25 mCi), whereas in children, the dose was adjusted for body weight. Appropriate zoom imaging was applied in children. The Tc-99m MDP uptake within the sternum and sternoclavicular joints (SC joints) was evaluated on the anterior view of the chest. Special attention was paid to the sternal borders, body, manubrium, angle of Louis, xiphoid process, and SC joints. The uptake in these areas was compared with nearby ribs and the patterns of uptake and the presence of areas of increased or decreased activity with respect to anatomic position were obtained.

### RESULTS

We considered the uptake in the sternum to be uniform if there was no area of focal increased or decreased uptake in

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#### TABLE 1. Exclusion Criteria

Pain in the sternum or chest wall
Known pathology of the sternum or chest wall
History of trauma to the sternum or chest wall
History of surgery of the chest or sternotomy
History of radiation to the chest
Referred for bone scan to exclude bony pathology related to sternum or chest wall
Bone scan showing pathology involving the ribs
History of any malignancy

the sternum as well as no increased uptake in the borders of the sternum (Fig 1). Any other pattern was considered as nonuniform uptake and grouped according to patterns of nonuniformity (Fig 2). Overall, 92 (27.5%) patients had uniform uptake in the sternum. Although this pattern was the only pattern of sternal uptake in children age  $\leq 10$  years, it was seen less frequently in older patients (Fig. 3).

Different uptake patterns in the sternum and SC joints are summarized in Table 2, Table 3, Figure 3, and Figure 4.

Overall, a hot spot at the angle of Louis or xiphoid were seen in 212 (63.5%) and 21 (6.3%) patients, respectively. However, an angle of Louis hot spot was not seen in patients younger than 10 years (Table 2). Increased tracer uptake in the manubrium or xiphoid was never seen in all 58 patients less than 15 years of age. Hyperactivity in the manubrium was seen in 15.9% of patients, increasing from 5.7% (3 of 53) in the age range of 15 to 20 years to 26.3% (41 of 156) in patients older than 30 years (P = 0.001). Hot spots in the body of the sternum were seen in 62 (18.6%) patients, starting from age 10, peaking in 15 to 20 years old and decreasing thereafter to reach 5.3% in patients older than 30 years. The pattern of hot spots in the body of the sternum was transverse lines in all patients with the exception of 3 people in whom focal round hot spots were seen. Of 62 patients with sternal



**FIGURE 2.** Different patterns of nonuniform sternal uptake: (A) heterogeneous uptake in the body; (B) increased uptake in the manubrium; (C) photon-deficient area in the lower sternum just above the xiphoid process; (D) angle of Louis hot spot; (E) hot spots in the body (linear); (F and G) increased activity in the body borders; (H) xiphoid hot spot.

body hot spots, 42 (67.7%) had one, 17 (27.4%) had 2, and 3 (4.84%) had 3 hot spots.

Twenty-four (7.1%) patients had heterogeneous tracer uptake throughout the body of the sternum of whom the majority (62.5%) were older than 40 years and others (9 patients, 37.5%) were between 15 and 40 years (Table 2).

Patients were put into 2 groups according to the level of tracer activity in the sternum in comparison with uptake in the anterior arcs of the upper 4 ribs; the first group had sternal uptake almost equal to nearby ribs and the second group had significantly more activity in the sternum than the ribs. The proportion of patients with increased sternal uptake compared with nearby ribs as well as patients with ill-defined borders of the sternum were depicted in Figure 4. The borders of the sternum were poorly defined in all patients under 5 years old and became more well defined with increasing age (Fig. 4).

On the other hand, bone scans in 47 (14.7%) patients showed greater activity in the borders of the sternal body as compared with the body (Table 2). Hyperactivity of the



FIGURE 1. Uniform radiotracer uptake in the sternum.

64



**FIGURE 3.** Percent of nonuniform uptake throughout the sternum in each age group.

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Age (years)	Heterogeneous Uptake in the Body	Increased Uptake in the Manubrium	Hyperactivity of the Sternal Body Borders	Hot Spot in the Angle of Louis	Xiphoid Hot Spot	Hot Spot in the Body	Total Number of Patients
Age $\leq 10$	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	29
$10 < age \le 15$	0 (0%)	0 (0%)	1 (3.4%)	7 (24.1%)	0 (0%)	8 (27.6%)	29
$15 < age \le 20$	2 (3.8%)	3 (5.7%)	0 (0%)	42 (79.2%)	5 (9.4%)	29 (54.7%)	53
$20 < \text{age} \le 25$	0 (0%)	5 (11.6%)	3 (7%)	35 (81.4%)	5 (11.6%)	10 (23.3%)	43
$25 < \text{age} \le 30$	2 (8.3%)	4 (16.7%)	6 (25%)	17 (70.8%)	1 (4.2%)	6 (25%)	24
Age >30	20 (12.8%)	41 (26.3%)	37 (23.7%)	111 (71.1%)	10 (6.4%)	9 (5.8%)	156
Total	24 (7.1%)	53 (15.9%)	47 (14.1%)	212 (63.5%)	21 (6.3%)	62 (18.6%)	334

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sternal body borders was seen more frequently in those subjects older than 25 years.

A photon-deficient area just above the xiphoid process in the lower sternum was seen in 22 (6.6%) patients. They all were older than 33 years.

Two patterns of increased tracer activity were seen in the sternoclavicular joints; 146 (43.7%) of 334 patients had increased tracer activity in the SC joints (in both the clavicular and sternal sides of the joint) and 75 (22.46%) patients had increased tracer uptake in only the medial end of the clavicles. There was asymmetric uptake between the 2 SC joints in 15 (4.5%) patients (Fig. 5). Age-related SC joints variants are seen in Table 3.

### DISCUSSION

A great variety of skeletal pathologic entities may involve the sternum. However, as a result of normal variations in anatomy and centers of ossification, as well as age-related changes, the appearance of the normal sternum on a bone scan may somewhat mimic the findings of significant sternal pathology. Therefore, any nuclear medicine physician who interprets bone scans should be familiar with the normal variants in sternal uptake.<sup>9</sup>

Variations related to anatomy and ossification in the sternum have been evaluated using computed tomography<sup>7,10</sup> and studies on cadavers.<sup>11</sup> Postnatal development and maturation of the human sternum are highly variable and is not completed until the 35th postnatal year.<sup>11</sup> At birth, the sternum usually consists of the manubrium, mesosternum (body),

and xiphoid process.4,11 Individual segments of the mesosternum are referred to as sternebrae. There are 4 intercostal ossification centers: one in the manubrium and 3 within the mesosternum, which appear before birth but are not present in the xiphoid process until 6 years.<sup>11,12</sup> Each ossification center is surrounded by a spherical physis that contributes to the 3-dimensional expansion of individual sternebra. Each sternebra is histologically analogous to an epiphyseal center of ossification. Synostosis begins with the formation of a midline osseous bridge between 2 mesosternebrae and subsequently leads to closure of the synchondrosis.<sup>11</sup> (Synchondroses are temporary joints that exist during the growing phase of the skeleton. A typical synchondrosis is the cartilaginous growth plate between the epiphysis and metaphysis of a tubular bone.<sup>13</sup>) Ossification between segments in the sternal body occurs between puberty and the 25th year of life.<sup>4</sup> Ossification of the xiphoid process is usually complete by the 35th year. Manubriosternal fusion is rare as a result of the presence of a fibrocartilaginous joint-restricting ossification.4,11

In previous studies, 2 normal sternal variants on bone scintigraphy have been described: a photon-deficient area above the xiphoid in 30% of patients older than 30 years old using SPECT<sup>2</sup> and an angle of Louis hot spot in 36% of adults.<sup>8</sup> Syed et al have recently described age-related normal variants of sternal uptake in 152 patients. However, patients with a history of malignancy were not excluded in that study.<sup>9</sup>

We investigated normal uptake patterns within the sternum and SC joints in patients with no history of sternal or chest wall pathology as well as no history of malignancy. Our

TABLE 3. P on Age	Patterns of Tracer Uptake in the Sternoclavicular Joints in Different Subgroups Based							
Age (years)	Increased Activity in the SC Joints (both side of articulation)	Increased Activity Only in the Clavicle End	Asymmetric Uptake Between 2 SC Joints	Total				
Age $\leq 5$	0 (0%)	2 (15.4%)	0 (0%)	13				
$5 < age \le 10$	0 (0%)	11 (68.8%)	0 (0%)	16				
$10 < \text{age} \le 15$	0 (0%)	27 (93.1%)	0 (0%)	29				
$15 < age \le 20$	19 (35.8%)	25 (47.2%)	2 (3.8%)	53				
$20 < \text{age} \le 25$	23 (53.5%)	7 (16.3%)	1 (2.3%)	43				
$25 < \text{age} \le 30$	10 (41.7%)	3 (12.5%)	0 (0%)	24				
Age >30	94 (60.3%)	0 (0%)	12 (7.7%)	156				
Total	146 (43.7%)	75 (22.5%)	15 (4.5%)	334				

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**FIGURE 4.** Percent of patients with increased sternal uptake compared with nearby ribs (white hatched bars) and with ill-defined borders of the sternum (black dotted bars) in each age group.

findings suggest that evolutionary changes of the sternum appear to exist throughout life, which is comparable with previous radiologic, histologic, and scintigraphic studies.<sup>9–11</sup>

In the early years of life (before 10–15 years old), the sternum appears on bone scanning as a homogeneous structure with poorly defined borders and uptake equal to nearby ribs. No focal variant in uptake in the sternum was noted in this group. However, as patients become older, the sternum shows markedly greater activity than nearby ribs and the borders become well defined. In older patients, some variety in sternal uptake may be seen, including increased uptake in the manubrium, angle of Louis, body and xiphoid hot spots, a photon-deficient area just above the xiphoid process in the lower sternum, heterogeneous body uptake and hyperactivity along the sternal body borders.



**FIGURE 5.** Patterns of sternoclavicular joint uptake: (A and B) symmetric increased tracer uptake in the SC joints; (C) asymmetric increased tracer uptake in the SC joints; (D) increased tracer uptake in the medial end of the clavicle.

Of the focal variants, the angle of Louis hot spot was the most common finding (63.5%). The incidence of increased tracer uptake in the manubrium is increasing by age.

It is very interesting that a linear pattern of sternal body hot spots is most frequently seen between 10 and 30 years old (peak at 15–20 years). They are in a transverse linear pattern corresponding to the 3 transverse ridges of bone, representing the sites of union between osseous sternal segments<sup>4</sup> and correspond to ossification between segments in the sternal body that occurs around puberty.<sup>4,11</sup>

In 75 patients (42.13%) younger than 30 years (178 patients), the scan showed increased tracer uptake at the medial end of the clavicle in the SC joints. This pattern is seen in almost all patients at ages between 10 and 15 but is never seen after 30 years. Our study showed that increased uptake in both sides of the SC joint is seen in 43.7% of patients, mainly in patients older than 30 years. There was an asymmetric uptake between the 2 SC joints, most frequently after 30 years old (7.7%), which may be a result of aging and degenerative changes.

The age-related variants of the sternum are distinct in appearance from common sternal pathology. The normal variants show a regular outline, focal hot spots are central in location, and ridges are straight and transverse. It is important to note the location and nature of these variants as well as the age of the patient. Photopenic spots were seen in the lower segment only, hot spots were more common than photopenic spots and were usually seen in a linear pattern before 30 years old. Hence, a cold spot in any other location should be given due consideration. Children usually show uniform sternal uptake with no cold or hot spots. Thus, any heterogeneity, hot or cold spot in any location in the sternum in children should be considered as abnormal and warrants further evaluation.<sup>9</sup>

Malignant lesions can be found anywhere in the sternum but are usually seen in the manubrium and angle of Louis.<sup>14,15</sup> Kwai et al reported that lesions in the sternum tend to occur on the same side as that of a primary breast tumor.<sup>14</sup> Another useful point to remember is the fact that an isolated sternal metastasis is rare and additional skeletal and visceral lesions are usually present.<sup>9</sup> Trauma resulting from direct force causes fracture of the body of the sternum and commonly involves the body of the sternum in the horizontal axis<sup>16,17</sup>; in contrast, indirect force characteristically produces injury at or adjacent to the manubrium and manubriosternal joint.<sup>18</sup>

We conclude that age-related normal variants of uptake in the sternum are present and should be considered in interpreting bone images. Any heterogeneous uptake in the sternum in patients less than 10 years should be considered abnormal unless proven otherwise. Any cold spot in the body or manubrium may be considered abnormal as well except in the lower portion.

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