Normal and Abnormal Single Photon Emission Computed Tomography of the Skull: Comparison with Planar Scintigraphy

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Using a rotating gamma camera the normal single photon emission computed tomography (SPECT) anatomy of the skull was defined in eight subjects. The value of SPECT as compared with planar scintigraphy was assessed in 34 patients with known or suspected disease of the skull. Seven patients had normal planar scintigraphy and SPECT. In 12 of 27 patients with bone involvement SPECT and planar scintigraphy showed essentially the same findings. In 15 patients SPECT was superior to planar scintigraphy. In three of these patients SPECT detected lesions while planar scan was normal. In the other 12 patients SPECT showed better anatomic localization and defined the full extent of the lesion. This was most obvious in patients with involvement of sphenoid, petrous, clivus, maxilla, and zygomatic bones. Our findings confirm the potential of SPECT to detect lesions in deep bones that are overlapped by superficial bony structures that cannot be visualized clearly with planar scintigraphy.

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The complex structure of the skull that is made of 22 bones may cause difficulties in detection and localization of lesions on planar bone scintigraphy. Single photon emission computed tomography (SPECT) has the potential to obtain improved images of the bony structures. SPECT has been reported to be useful in some patients with facial bone lesions or malignant otitis externa (*1–4*). In the present study we define the normal anatomy of the skull as it appears on images obtained from a gamma camera with a rotating gantry and compare the value of SPECT with routine planar scintigraphy for the detection of skull lesions.

MATERIALS AND METHODS

Eight patients examined for stress fractures were studied as controls to define the normal SPECT anatomy of the skull. There was no indication of generalized bone involvement, disease of the head and neck, or skull involvement in any of these patients. During a period of 18 mo 34 patients had SPECT of the skull in addition to planar scintigraphy. Table 1 lists the number of patients and their diagnosis. Twenty-seven patients had involvement of the skull that was diagnosed by a combination of clinical findings, radiologic evaluation, planar scintigraphy and follow-up of 6 mo or more. Planar bone scintigraphy of the skull was performed 2 to 3 hr after 25 mCi (925 MBq) of technetium-99m methylene diphosphonate was injected i.v. A large field-of-view, digital camera (Elscint, Apex 415) was used to obtain 600,000 counts on a 256 × 256 byte matrix for each view of the skull in the anterior, posterior, right, and left lateral projections. SPECT examinations were performed with the same camera using a rotating gantry and a high resolution collimator. Our technique and equipment for SPECT have been described previously (*5,6*) and only the alterations done for skull investigation will be described here. Data were acquired during 20 min over 360° of rotation. One hundred and twenty projections were obtained in a 64 × 64 byte matrix using an angle step of 3°. The acquisition time was 10 sec and count density 70,000 for each projection. Reconstruction was accomplished by back-projection using a Wiener filter (*7,8*). The filtered backprojection data was used to reconstruct 32 seven-mm-thick (1 pixel) transaxial, coronal, and sagittal tomograms. The reconstructed sections of the normal skull were compared with the cross-sectional anatomy of cadavers to define the normal bone anatomy on SPECT (*9,10*).

RESULTS

The normal SPECT anatomy of the skull in the transaxial, sagittal and coronal sections is shown in

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TABLE 1
Correlation of Abnormal Findings in Planar Scintigraphy and SPECT of the Skull in 27 Patients

Diagnosis	No. of patients	Similar planar and SPECT (No. pts)	Advantage of SPECT over planar (No. pts)	Bones - No.
Carcinoma of nasopharynx	6	1	5	Sphenoid - 5 Petrous - 2 Clivus - 2 Maxilla - 2 Zygoma - 1
Carcinoma of ear	4	—	4	Petrous - 4 Sphenoid - 1
Malignant otitis externa	2	—	2	Petrous - 2
Carcinoma of mandible	2	2	—	
Carcinoma of maxilla	2	1	1	Sphenoid - 1
Osteomyelitis of skull vault	2	2	—	
Other malignant tumors*	6	4	2	Sphenoid - 2
Histiocytoses†	2	1	1	Petrous - 1 Sphenoid - 1
Fibrous displasia of vault	1	1	—	

*This group included one carcinoma of the orbit, carcinoma of the larynx, carcinoma of the lower lip, carcinoma of the palate, malignant melanoma of the eye, metastatic breast carcinoma.
†This group included the patients with Histiocytosis X and eosinophilic granuloma.

Figure 1. There was no area of increased activity in the skull in any of the eight control patients. Seven patients with disease of the head and neck had normal planar and SPECT scintigraphy. The results of the comparison of planar scintigraphy and SPECT in 27 patients are summarized in Table 1. In 12 patients with lesions in the bony structures, SPECT and planar scintigraphy showed essentially the same findings. SPECT was superior to planar scintigraphy in providing better anatomic localization and in detecting the whole extent of the lesion in 15 patients. In three of these patients SPECT detected lesions which were not visible on planar scintigraphy. When involvement of individual bones was analyzed in the 15 cases with superior SPECT it was found that it included ten cases of involvement of the sphenoid, nine of the petrous, two of the clivus, two of the maxilla and one of the zygomatic bone (Table 1, Figs. 2–5).

Knowledge of skull anatomy in the transaxial, sagittal and coronal sections is important for defining the extent of spread of lesions in patients with tumors or bone infections (Figs. 2–5). The improved contrast of SPECT enhances the high sensitivity of planar bone scintigraphy. Lesions in three patients that were not evident on planar scintigraphy were detected by SPECT. The main advantage of SPECT was in better visualization of lesions in the sphenoid and petrous bone that are deeply situated in the skull and superimposed by other structures. SPECT did not show any advantage in the superficial bones, vault of the skull or the mandible.

DISCUSSION

Bone scintigraphy is an extremely sensitive method for detection of bone pathology and is considered the in vivo gold standard to which other methods are compared. SPECT adds an improved contrast and better defines the anatomic localization and extent of bone

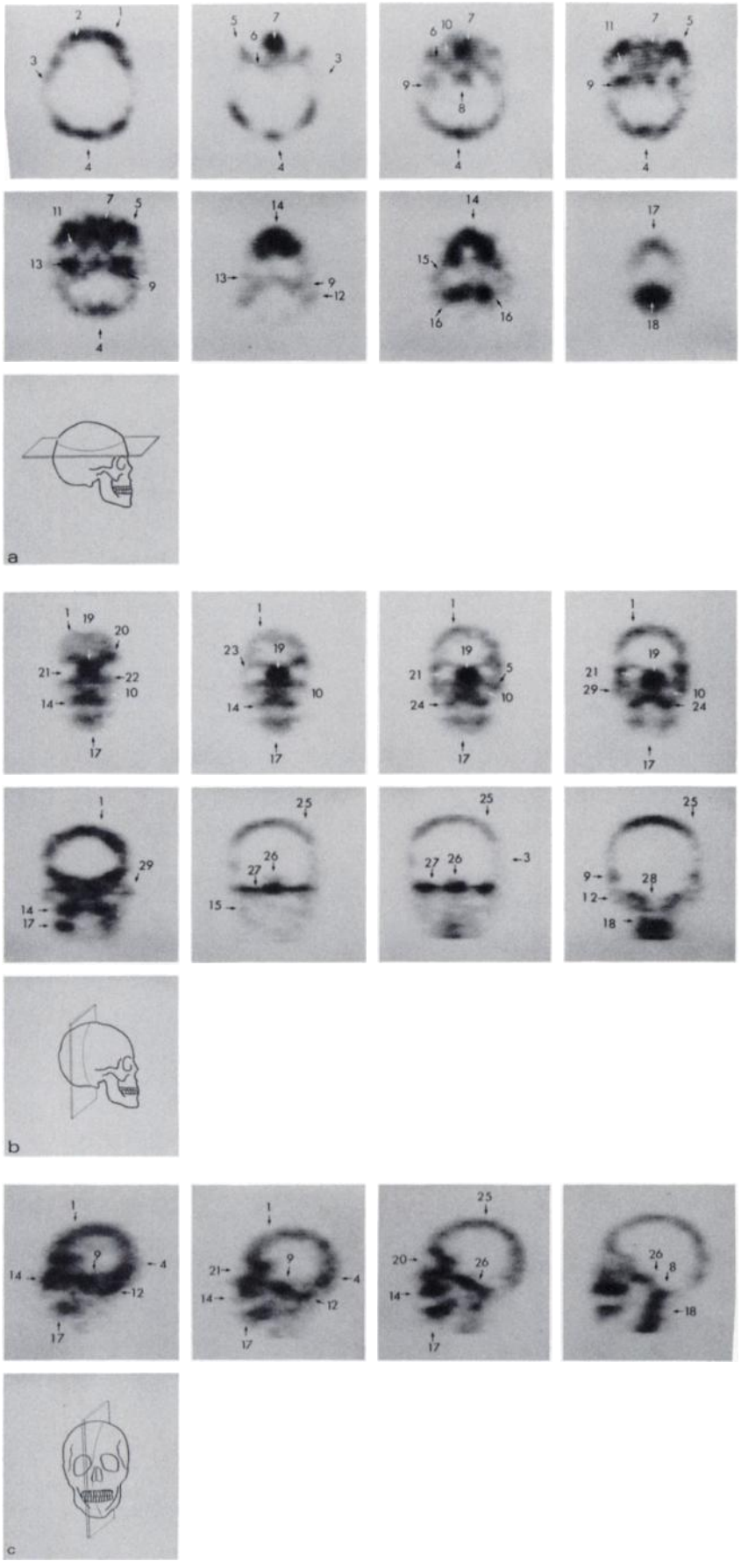

FIGURE 1
Normal SPECT anatomy of the skull. 1. Frontal bone. 2. Frontal bone and sinus. 3. Temporal bone. 4. Occipital bone. 5. Zygomatic bone. 6. Sphenoidal bone. 7. Ethmoidal cells. 8. Clivus. 9. Petrous bone. 10. Maxillary sinus. 11. Infratemporal fossa. 12. Mastoid process. 13. Temporo-mandibular joint with mandibular condyle. 14. Maxillary bone. 15. Ramus of mandibula. 16. Occipital condyle. 17. Mandibula. 18. First and second cervical vertebrae. 19. Ethmoidal bone and nasal concheae. 20. Orbital roof. 21. Orbita. 22. Orbital floor. 23. Fronto-zygomatic process. 24. Hard palate. 25. Parietal bone. 26. Sphenoid sinus. 27. Greater wing of sphenoid. 28. Occipital bone (foramen magnum). 29. Zygomatic arch. a. Transaxial slices. b. Coronal slices. c. Sagittal slices.

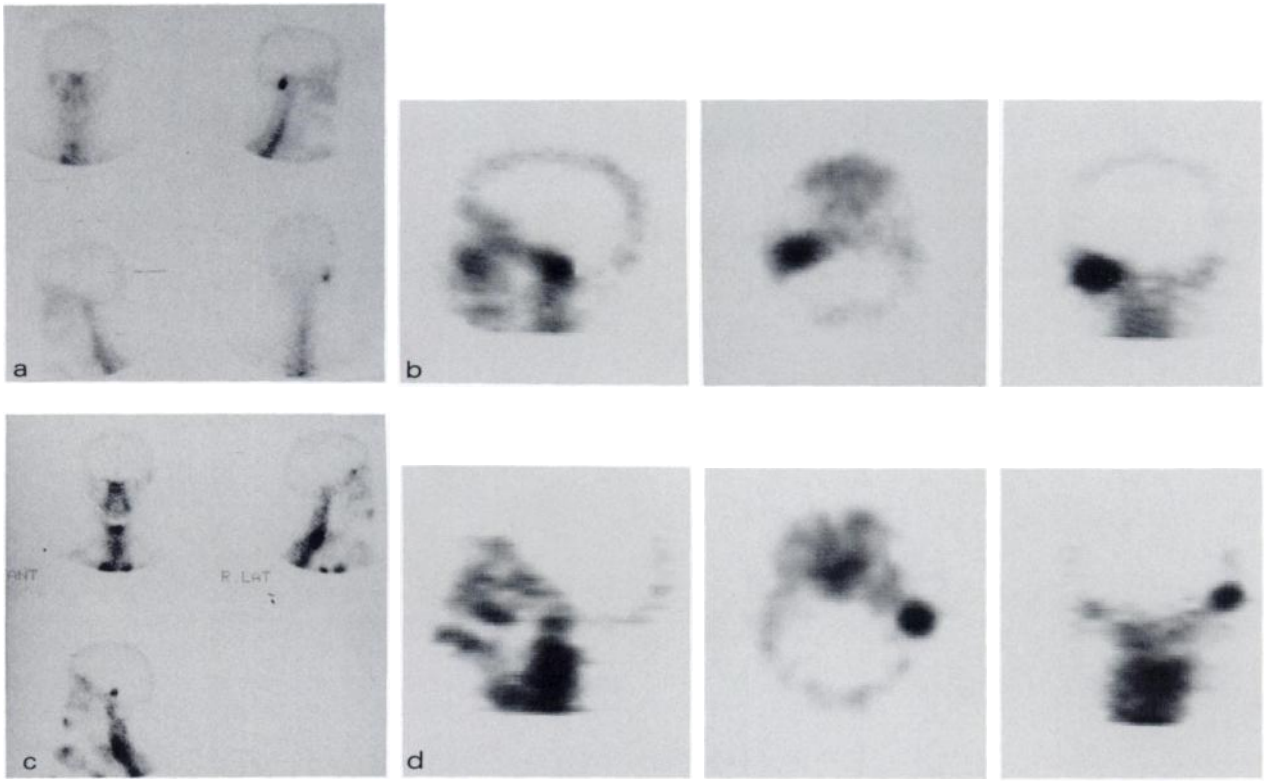

FIGURE 2
SPECT visualization of petrous bone involvement. a: Planar scintigraphy in a 64-yr-old male patient with malignant otitis externa shows only abnormal uptake in the right temporal region. b: SPECT shows a large lesion in the petrous part of the temporal bone. Involvement of the petrous part, evident only on SPECT, was proven by surgery. c: Planar scintigraphy in another patient shows essentially the same region of abnormal uptake as in a. SPECT (d), however, shows that the lesion in this patient is superficial. The normal petrous bone was detected only by SPECT.

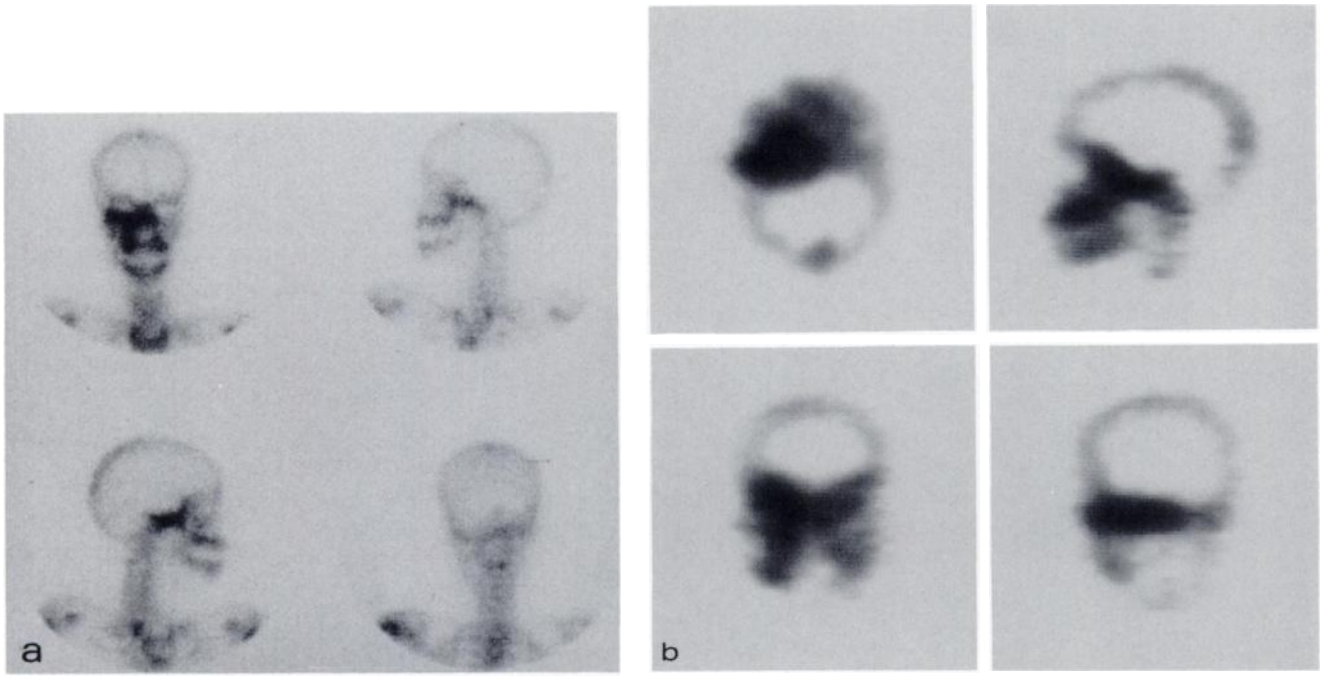

FIGURE 3
SPECT visualization of sphenoid bone involvement. Carcinoma of the nasopharynx with bone involvement in a 14-yr-old boy. a: Planar scintigraphy shows abnormal uptake in the right maxilla and zygomatic bone. b: SPECT shows involvement of the right maxilla and extended involvement of the sphenoid bone which cannot be detected on planar scintigraphy.

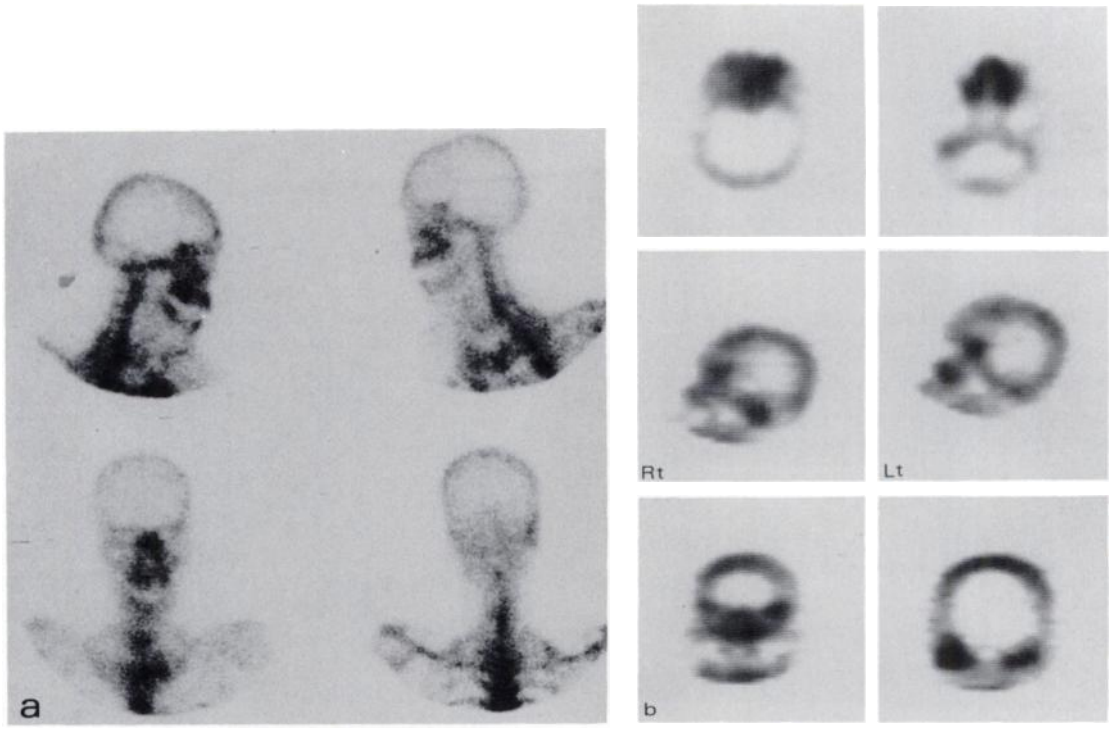

FIGURE 4
Carcinoma of the nasopharynx in a 65-yr-old female with involvement of the facial bones. a: Only poorly defined uptake is seen on planar scintigraphy. b: SPECT visualization of bone involvement of the maxilla, zygomatic and temporal bones.

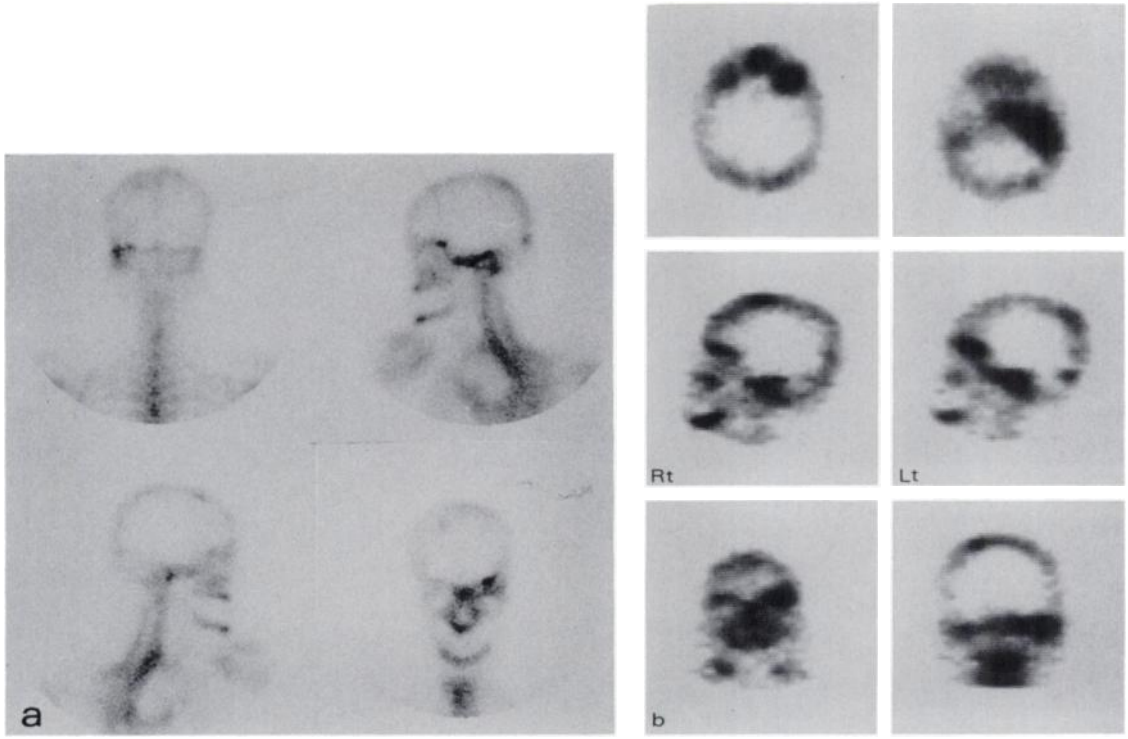

FIGURE 5
Histiocytosis X in a 35-yr-old male. a: Planar scintigraphy shows focal uptake in the frontal and temporal regions. The exact location of the bone lesion cannot be defined. b: SPECT shows the involvement of the deeply situated sphenoid and petrous bones.

lesions. Modern high resolution rotating cameras provide good definition of the normal anatomy by separation of the various bones and regions of the skull (Fig. 1). Proper positioning of the head is important for good visualization of bony structures and shifting of the patient's head can make interpretation difficult.

De Roo et al. (*11*), using transaxial slices only, were also able to detect lesions that were not evident on planar scintigraphy. However, as we have shown, (Figs. 2–5) the sagittal and coronal planes are necessary to define the complete extent of the lesion.

We believe that SPECT of the skull should be added to planar scintigraphy when: (a) a skull lesion is suspected but planar scintigraphy appears normal or equivocal; (b) and when information is necessary about the exact localization and extent of a lesion involving deeply located bones before surgery or radiotherapy.

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