Technetium-99m-Sulfur Colloid SPECT Imaging in Infants with Suspected Heterotaxy Syndrome

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For the evaluation of a variety of hepatosplenic disorders, SPECT complements planar ^{99m}Tc-sulfur colloid liver/spleen imaging. By isolating small, ectopic or poorly functioning spleen(s) from overlying or adjacent liver, SPECT imaging should facilitate identification of splenic tissue in infants with suspected heterotaxy syndrome. **Methods:** During a 10-yr period, 10 planar-only and 9 planar-plus-SPECT liver/spleen scans were obtained from 15 infants, 13 of whom were less than 1 mo of age at first examination. Four of the planar-only group had follow-up planar-plus-SPECT imaging. Scintigraphic diagnosis regarding presence of splenic tissue was correlated with clinical diagnosis. **Results:** Thirteen infants had splenic tissue; two were asplenic. Planar-only imaging provided correct diagnoses in six [four with, two without spleen(s)] but was negative or equivocal in four infants. Planar-plus-SPECT imaging was positive in all in whom it was performed; moreover, in 4/13 infants (31%), splenic tissue was documented only by SPECT imaging. **Conclusion:** Particularly when planar views are inconclusive, SPECT imaging is invaluable for identification and localization of functioning splenic tissue in infants with suspected heterotaxy syndrome.

Key Words: technetium-99m-sulfur colloid; infantile polysplenia/asplenia syndromes; single-photon emission computed tomography; heterotaxy syndrome

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Infants with cardiac malformation and malposition may rarely have one of the polysplenia/asplenia syndromes (*1,2*). Polysplenia is associated with less severe heart disease and more favorable prognosis. Asplenic infants have more severe cardiac anomalies and greater mortality; lacking a spleen, they are prone to infection and must receive immunizations and prophylactic antibiotics (*3,4*). Traditionally, the presence of functioning splenic tissue may be determined by examination of peripheral blood for Howell-Jolly bodies (red blood cell inclusions normally cleared by the spleen) and planar liver/spleen scintigraphy (*3*). For a variety of hepatosplenic conditions, SPECT has proven superior to planar imaging alone (*5*).

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We retrospectively reviewed 19 ^{99m}Tc-sulfur colloid liver/spleen scans on 15 infants and children to investigate the diagnostic value of adjunctive SPECT imaging in suspected polysplenia/asplenia syndrome.

MATERIALS AND METHODS

Patients

Between November 1984 and June 1994, 15 infants (9 girls, 6 boys) with suspected heterotaxy syndrome were evaluated with ^{99m}Tc-sulfur colloid liver/spleen scintigraphy. Twelve patients had complex congenital heart disease and three had abdominal anomalies only. At first examination, their ages ranged from 3 days to 11 mo; 13 infants were less than 1 mo old. Follow-up studies were performed on four children at 1 mo, 14 mo, 4 yr and 6 yr of age. In all, 10 planar-only and 9 planar-plus-SPECT studies were performed.

Liver/spleen scintigraphy was performed 20 min after intravenous injection of 3.2 MBq/kg (0.086 mCi/kg) (range 37.0–81.4; MBq 1.0–2.2 mCi) ^{99m}Tc-sulfur colloid. No infant required sedation. Standard planar imaging protocol consisted of 5-min views in eight projections: anterior, right anterior oblique, right lateral, right posterior oblique, posterior, left posterior oblique, left lateral and left anterior oblique. The images were acquired on a standard or large field of view gamma camera equipped with a low-energy, all-purpose or high-resolution, parallel-hole collimator and peaked at 140 keV with a symmetric 20% window. A single-head rotating gamma camera was used to obtain SPECT images immediately after planar imaging, beginning approximately 60 min after injection. Sixty projections, 25 sec each, over a 360° circular orbit were obtained; each view contained an average of 50–75 kcts. Standard filtered backprojection processing with uniformity and center of rotation corrections, but without attenuation correction were used to create 1-pixel (6.2 mm) sections in the transaxial plane followed by reconstruction in the coronal and sagittal planes. The reconstruction algorithm used a Butterworth filter with a cutoff frequency of 0.5 and an order of 8.0. SPECT images were reviewed interactively on a Microdelta (Siemens, Hoffman Estates, IL) computer terminal and were photographed in single-pixel slices.

By conventional criteria, focal radiocolloid uptake separate and distinct from liver represented splenic tissue. In this series, three scan patterns were encountered: definite spleen, equivocal spleen and no spleen.

Final diagnosis regarding presence or absence of splenic tissue was based on history, clinical course and, when available, hematology, ultrasonography, computed tomography, surgery and/or autopsy.

TABLE 1
Clinical and Scintigraphic Features of Ten Patients: Planar-Only Liver/Spleen Imaging

Patient no.	Gender	Age	Clinical features	Blood smear	Scintigraphy		US/CT	(C)linical/ (S)urgery/ (A)utopsy
					Planar	SPECT		
1	M	4 d	CHD/Hydrocephalus	N/A	+S	N/A	N/A	+S (C)
2	F	9 d	CHD/DC	N/A	+S	N/A	N/A	+S (A)
3	F	18 d	CHD	−HJ	+S	N/A	N/A	+S (C)
4	F	3 mo	Microgastria	N/A	?S*	N/A	N/A	+S (C)
5	M	4 d	CHD/DC/SI/MR	+HJ	−S*	N/A	−S (CT)	−S (A)
6	M	7 d	CHD/DC/SI	+HJ	−S	N/A	−S (US)	−S (C)
7	F	1 mo	CHD/DC	N/A	+S	N/A	N/A	+S (C)
8	F	3 d	CHD/MR	N/A	−S	N/A	−S (US)	+S (S)
9	F	9 d	CHD/DC/SI	N/A	?S	N/A	N/A	?S (C)†
10	M	22 d	SI/MR	−HJ	−S	N/A	−S (US)	+S (S)

*With hepatobiliary "subtraction" imaging.
†+S (C) at follow-up planar-plus-SPECT imaging (Table 2).
CHD = congenital heart disease; DC = dextrocardia; SI = situs inversus/indeterminate (abdominal viscera); MR = malrotation (gut); HJ = Howell-Jolly bodies; +S = spleen(s) present; ?S = equivocal spleen(s); −S = spleen(s) absent; N/A = not applicable.

RESULTS

Thirteen children had splenic tissue and two were asplenic (Tables 1 and 2). Planar-only imaging (Table 1) provided the correct diagnosis in six children (four with, two without spleen). The diagnosis was negative or equivocal in four infants (Patients 4, 8, 9, and 10); Patients 8, 9, and 10 had positive follow-up planar-plus-SPECT imaging (Table 2; Fig. 1). Of nine planar-plus-SPECT studies (Table 2), the planar views were negative or equivocal in four children (Patients 9, 10, 14 and 15), while SPECT imaging demonstrated splenic tissue in these patients (Fig. 2).

As presented in Table 3, 8/19 (42%) planar studies were negative or equivocal. SPECT imaging provided a true-positive diagnosis in all in whom it was performed; moreover, in 4/13 (31%) children, splenic tissue was documented only by concurrent SPECT imaging.

DISCUSSION

Associated with abnormal position of the abdominal viscera (heterotaxy), the polysplenia/asplenia syndromes are characterized by bilateral left-sidedness or bilateral right-sidedness, respectively (*1,2*). Polysplenia syndrome occurs more often in females; there is slight male predominance in asplenia.

Occasionally discovered in adulthood, polysplenia syndrome is associated with less severe congenital heart disease (absent in 5%–10%), an interrupted inferior vena cava with azygous or hemiazygous continuation, bilateral

TABLE 2
Clinical and Scintigraphic Features of Nine Patients: Planar-Plus-SPECT Liver/Spleen Imaging

Patient no.	Gender	Age	Clinical features	Blood smear	Scintigraphy		US/CT	(C)linical/ (S)urgery/ (A)utopsy
					Planar	SPECT		
7	F	4 yr	CHD/DC	N/A	+S	+S	N/A	+S (C)*
8	F	14 mo	CHD/MR	N/A	+S	+S	N/A	+S (C)*
9	F	1 mo	CHD/DC/SI	N/A	?S	+S	N/A	+S (C)
10	M	6 yr	SI/MR	+HJ	−S	+S	+S (CT)	?S (C)*
11	F	3 d	CHD/DC	N/A	+S	+S	N/A	+S (C)
12	F	6 d	CHD/DC/MR/ multiple anomalies	N/A	+S	+S	+S (US)	+S (C)
13	M	9 d	CHD	−HJ	+S	+S	N/A	+S (C)
14	F	14 d	CHD	N/A	?S	+S	N/A	+S (C)
15	F	11 mo	SI/MR	−HJ	−S	+S	N/A	+S (C)†

*Re-evaluation for functioning splenic mass.
†−S (S) at 18 d of age.
CHD = congenital heart disease; DC = dextrocardia; SI = situs inversus/indeterminate (abdominal viscera); MR = malrotation (gut); HJ = Howell-Jolly bodies; +S = spleen(s) present, ?S = equivocal spleen(s), −S = spleen(s) absent; N/A = not applicable.

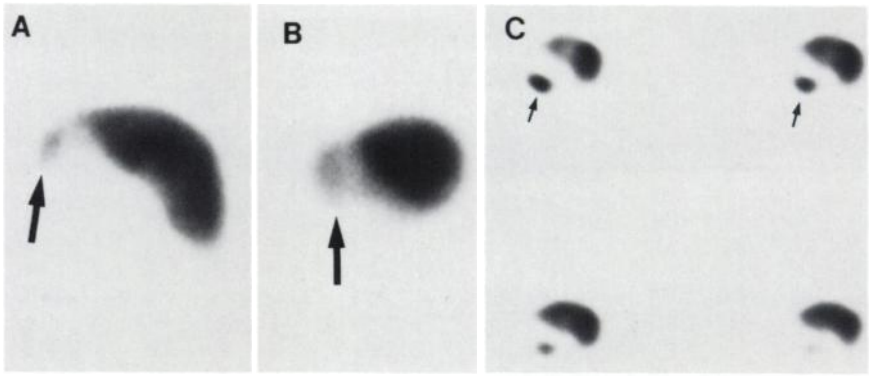

FIGURE 1. Patient 8. Ectopic spleen confirmed by follow-up SPECT imaging in situs inversus. (A) Right anterior oblique view shows possible right-sided spleen (arrow). (B) Right lateral planar view shows possible right-sided spleen (arrow). (C) Transverse SPECT images demonstrate discrete splenic tissue (arrow).

hyparterial bronchi and bilobed lungs, partial or complete malrotation of the gut and multiple spleens, often retrogastric in location. Conversely, asplenia is associated with complex cyanotic congenital heart disease, bilateral eparterial bronchi and trilobed lungs, malrotation of the gut and absent spleen. Asplenic children have greater morbidity and mortality due to more severe cardiac anomalies and a predisposition to sepsis.

In cases of suspected heterotaxy syndrome, the presence of splenic tissue traditionally has been established by two means: (a) inspection of peripheral blood for Howell-Jolly bodies and other hematologic markers of splenic dysfunction and (b) various imaging modalities, including liver/spleen scintigraphy, using either heat-damaged radiolabeled red blood cells or radiocolloid (*1–4,6,7*). The spleen normally clears damaged red blood cells; circulating debris-laden red blood cells (Howell-Jolly bodies) indicate absent or insufficient splenic function. Occasionally, despite splenic radiocolloid uptake, Howell-Jolly bodies may be found in, for example, cyanotic heart disease; this phenomenon has been termed "functional hyposplenia" (*8*). The diagnosis of adequate splenic function has a profound impact on clinical management because asplenic/hyposplenic patients must be immunized and receive prophylactic antibiotics to prevent overwhelming sepsis (*3,4,8*).

In young children, identification of functioning splenic tissue using planar ^{99m}Tc-sulfur colloid imaging may occasionally be difficult. In heterotaxy syndrome, a large, midline, or bilobed liver may obscure uptake in small or ectopic spleen(s) (*1–3,9*). Historically, one strategy to improve scintigraphic diagnosis involved visual comparison of complementary liver/spleen and hepatobiliary ("subtraction") scans for discordance or concordance. Discordance indicated presence of spleen; concordance suggested asplenia (*9*).

Although more "spleen-specific," heat-damaged ^{99m}Tc-labeled red blood cell scintigraphy is technically more demanding (*6,7*). Radiopharmaceutical preparation requires careful cell handling and proper heating to achieve optimal results. In infants, it may be difficult not only to obtain an adequate blood sample but also to reinfuse the labeled cells. By comparison, ^{99m}Tc-sulfur colloid is technically simpler and does not require handling of blood products.

Readily performed, SPECT imaging has been applied to a variety of splenic disorders, including accessory spleen, splenosis and intrasplenic masses (*5,10,11*). By resolving overlapping activity and enhancing visualization of deep structures, SPECT facilitates identification and localization of small, ectopic, or poorly functioning spleen(s). In the study presented here, SPECT imaging depicted splenic tissue clearly in all in whom it was performed (Tables 2 and 3). More importantly, it documented functioning splenic tissue in four children (Patients 9, 10, 14 and 15) in whom the planar diagnosis was incorrect or equivocal (Tables 1 and 2). Ectopic spleens were found in four children (Patients 7, 9, 10 and 15). Speculatively, initial "misdiagnosis" of asplenia in four infants (Patients 4, 8, 9 and 10) might have been obviated by concurrent SPECT imaging; Pa-

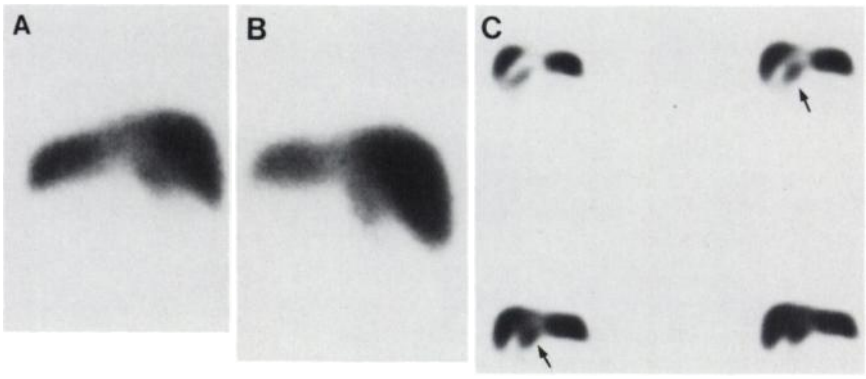

FIGURE 2. Patient 15. Ectopic spleen identified only on SPECT images. (A) Right posterior oblique and (B) posterior planar views do not clearly show spleen. (C) Coronal SPECT images define spleen (arrows) inferoposterior to the right hepatic lobe near the midline.

TABLE 3
Planar Versus SPECT Imaging for Detection of Splenic Tissue

Scintigraphic technique	True-positive	False-positive	Equivocal	True-negative	False-negative
Planar-only	4	0	2*	2	2*
Planar-plus-SPECT					
Planar	5	0	2†	0	2†
SPECT	9	0	0	0	0

*Follow-up positive planar-plus-SPECT imaging (3/3); 1 without follow-up study.
†Positive concurrent SPECT (4/4).

tients 8, 9, and 10 had positive follow-up planar-plus-SPECT imaging at an older age.

Ultrasonography (US), CT and MRI are noninvasive imaging modalities for evaluating structural cardiovascular and abdominal anomalies, including absent or multiple spleens, in heterotaxy syndrome (*2,7,12,13*). Ideal for pediatric imaging, US does not involve ionizing radiation, but is operator-dependent and requires patient cooperation, particularly for detailed abdominal examinations. Computed tomography and MRI often require sedation for young children, and MRI is too costly for routine use (*7*). Compared to scintigraphy, these anatomic techniques are limited in their ability to characterize masses.

In the small series presented here, only four infants underwent US and one, CT; none had MRI (Tables 1 and 2). Although true-positive in one and true-negative in another, US failed to identify multiple, small spleens found surgically in two infants. One infant had a true-negative CT scan. An older child (Patient 10) had a true-positive CT scan showing multiple spleens. Surgical exploration to correct malrotation in an 18-day-old infant (Patient 15) missed multiple, small, ectopic spleens later confirmed by liver/spleen SPECT imaging.

CONCLUSION

In infants and children with suspected heterotaxy syndrome, the diagnosis of functioning splenic tissue is critical, given the impact on clinical management decisions regarding need for prophylactic antibiotics and immunization. As an alternative to heat-damaged radiolabeled red blood cells, ^{99m}Tc-sulfur colloid is easy to prepare and does not require handling of blood products. Practical and readily performed without sedation, SPECT imaging is essential whenever standard planar views are negative or equivocal for spleen(s).

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