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Radionuclide Imaging, Computed Tomography, and Gray-Scale Ultrasonography of the Liver: A Comparative Study

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Transmission computed tomography (CT), gray-scale ultrasonography, and scintillation-camera imaging were compared for detection of intrahepatic space-occupying processes. Fifty patients with suspected liver disease were studied by the three modalities. In the 35 cases with confirmed abnormalities, the modalities were rated on a scale of 0 to 5 in terms of their detection value. Each modality was found to have definite advantages and disadvantages. The mean score of ultrasound was highest (3.61), followed by nuclear medicine (3.11) and then CT (2.77). The combination of ultrasound and nuclear medicine identified all lesions, whereas CT alone or in combination with another technique occasionally failed to detect abnormal foci. In the future, the relative efficacy of these procedures may change with improved imaging technology and increased interpreter experience.

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Computed tomography (CT) of the liver is becoming common practice (*1–3*). No studies have yet compared CT with both gray-scale hepatic ultrasonography and radionuclide imaging with ^{99m}Tc-sulfur colloid (*4–8*). We examined 50 patients with suspected liver disease to explore the relative value of these three techniques for detection of intrahepatic space-occupying processes and to determine which modality or combination of modalities would provide maximal information without the need for invasive procedures.

METHODS

Patients studied initially by one of the three methods were also examined within 10 days by the other two methods. Gamma images were obtained with 5 mCi of ^{99m}Tc-sulfur colloid, high-resolution parallel-hole collimation, and a scintillation camera.* Ultrasonography† and CT‡ were performed with standard commercial instruments. In the first 25 cases, CT was repeated after a 100-cc intravenous injection of Renografin-76 only if the noncontrast study was suspicious. The remaining cases were routinely studied with and without contrast enhancement. Relatively wide "window" settings (400–600) were utilized for the CT images.

Of 50 patients in the series, 46 had all three examinations and four had CT and radionuclide imaging but not ultrasonography. When an abnormality was detected, the liver images produced by each method were numerically rated according to the scale defined in Table 1. The ratings for CT in this study included information gained from both plain and contrast-enhanced examinations. When images from all techniques were normal, ratings were not assigned.

Gamma images were interpreted without prior knowledge of either CT or ultrasound results. On the other hand, CT and ultrasound examinations

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TABLE 1. EXPLANATION OF NUMERICAL SCORES ASSIGNED TO EACH MODALITY

Rating	Diagnostic information provided
0	Failure to show any hepatic abnormality when another modality is definitely positive, or finding thought to represent a real lesion is proven to be a normal variant.
1	Suspicious, very subtle area or areas in or immediately adjacent to the liver that require clarification by further studies.
2	Definite abnormality or abnormalities poorly revealed; or multiple lesions, some reasonably well visualized and others not revealed.
3	Definite abnormality or abnormalities reasonably well seen.
4	Abnormality or abnormalities very well seen, or area considered abnormal by another modality is shown to represent a normal variant.
5	Excellent visualization and/or unique diagnostic information provided.

were usually performed with prior knowledge of the radionuclide findings and, in approximately half the cases, with prior knowledge of each other's results. Final ratings were assigned following side-by-side comparison of images from each technique by a group of six physicians representing CT, ultrasonography, and nuclear medicine.

For rating purposes, functional information such as "increased splenic or marrow radiocolloid uptake" was excluded. Visualization of lesions in other organs, including spleen, pancreas, stomach, bones, and retroperitoneal space, did not affect the ratings unless such lesions deformed the hepatic contour. Each technique was rated for its ability to detect intrahepatic processes (including veins and bile ducts) and extrahepatic lesions sufficiently close to deform the liver.

The patients' clinical diagnoses included distant primary tumor (18), lymphoma (5), unexplained hepatosplenomegaly (3), abnormal liver-function tests (3), alcoholic cirrhosis (3), pancreatic mass (3), leukemia (2), suspected biliary-tract obstruction (2), amebic abscess (1), peliosis hepatis (1), abdominal pain (1), primary hepatoma (1), splenomegaly (1), probable viral hepatitis (1), and pyrexia of unknown origin (1).

One of several criteria was mandatory for inclusion in the comparative series: (A) a lesion or lesions were unequivocally shown by at least one method; (B) a suspicious area on one method was proved to represent a normal variant by another procedure; or (C) a suspicious area on one method, while not detected by other procedures, was angiographically or histologically confirmed. The classification "unequivocal" indicated that none of the six observers experienced any doubt whatsoever regarding a finding's presence or absence.

In this study, detection of a lesion and determination of its nature by analysis of echo pattern and determination of attenuation characteristics ("Delta number") were the end points. Many unequivocal abnormalities did not necessitate biopsy or angiography, since combined CT and ultrasound are frequently able to exclude ominous processes without an invasive diagnostic procedure. Therefore, beyond this characterization, many lesions were not histologically proven.

RESULTS

Ten patients were normal by all three techniques and therefore were not rated, and five patients were not rated, despite suspicious findings on one or more modalities, due to a lack of histologic or angiographic proof needed to establish with certainty the presence or absence of a lesion. Thus, of 50 patients, the images of 35 were rated. In 31 cases studied by all three modalities, each modality was rated of greatest value in approximately the same number (Table 2). However, whereas the gamma images were considered least useful in ten of 31 cases and the CT study was considered least informative in eight, ultrasonography was never the least-effective procedure. In the remaining 13, no single modality was clearly least effective. The mean score of ultrasonography was highest (3.61), followed by the radionuclide study (3.11) and then CT (2.77). In three out of four patients studied only by radionuclide scanning and CT, the ^{99m}Tc-sulfur colloid images were rated superior.

TABLE 2. RESULTS OF RATING 31 ABNORMAL CASES STUDIED BY THREE MODALITIES AND FOUR ABNORMAL CASES STUDIED BY TWO MODALITIES

	Radionuclide liver scan	Computed tomography	Gray-scale ultrasonography
Total score	109	97	112
No. cases rated	35	35	31
Mean score	3.11	2.77	3.61
Judged most useful in 31 cases studied by all three modalities	7	6	6
Judged least useful in 31 abnormal cases studied by all three modalities	10	8	0
Judged most useful in four abnormal cases studied by radionuclide scanning and CT only	3	0	—

TABLE 3. ADVANTAGES AND DISADVANTAGES OF EACH MODALITY: NUMBER OF CASES IN WHICH EACH ADVANTAGE OR DISADVANTAGE WAS JUDGED SIGNIFICANT

Disadvantages	No. of cases	Advantages	No. of cases
	Radionuclide imaging		
Limited resolution	6	Liver region inaccessible to ultrasound is clarified	2
Prominent portal area or gallbladder region requiring clarification	6		
Peripheral or 'edge' defect—extrinsic or intrinsic?	2		
	Ultrasound		
Inaccessible right lobe under ribs	2	Clarification of portal region, biliary anatomy or 'edge' defect	6
Total or near-total parenchymal replacement	2		
Bowel gas or rib artifact	4	Superior resolution	1
	Computed tomography		
Motion artifact, or clip artifact, or isodensity problem	13	Clarification of portal region, biliary anatomy or 'edge' defect	4
Reader inexperience	1	Change in delta number with contrast is helpful	3
		Low delta number excludes solid tissue density	3

DISCUSSION

Each modality has advantages and disadvantages for the detection or characterization of certain types of hepatic lesions (Table 3).

The generation of CT scanners utilized in this study is severely hampered by artifacts due to motion or to abrupt discontinuities in density (Fig. 1). These difficulties are much less troublesome with the newer and faster scanners (*2,3*). However, the "isodensity" problem (failure to detect a lesion because its linear attenuation coefficient is similar to that of normal liver) will not disappear with rapid scanning. An additional problem for all modalities, including CT, is the wide variation in normal hepatobiliary anatomy. Further experience with CT, the newest modality, will improve recognition of anatomic variants. While these problems may result in failure to visualize lesions in the liver, CT is capable of providing unique diagnostic information (Figs. 2 and 3) by determining absorption coefficients and changes in density following contrast enhancement of the vascular space. Intravenous injection of 100 cc of Renografin-76 may increase the radiographic density of hepatic veins and vascular lesions, differentiating them from dilated bile ducts or avascular abnormalities. Moreover, even "isodense" masses may be detectable following intravenous contrast material if they are more vascular, or less so, than liver parenchyma.

Radionuclide hepatic imaging is frequently unable to distinguish extrinsic processes that deform the liver from peripheral intrinsic lesions. This difficulty

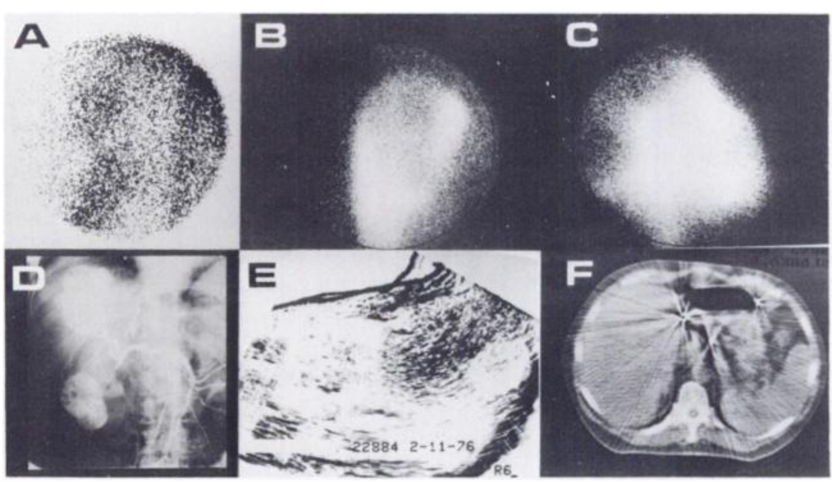

FIG. 1. (A) Posterior radionuclide angiogram; early vascularity in two large lesions in the right upper quadrant. (B) Posterior gamma image: irregular large posterior lesion. (C) Right lateral gamma image: large lobulated posterior lesion. (D) Selective angiogram: large vascular lesions corresponding to those of radionuclide flow study. (E) Longitudinal sonogram (head to viewer's right): large lesions both anteriorly and posteriorly. (F) CT at the level of superior posterior lesion: radiating surgical-clip artifacts. No abnormality noted. Metal-induced and motion artifacts may contribute to CT failure in detecting this surgically proven hepatoma.

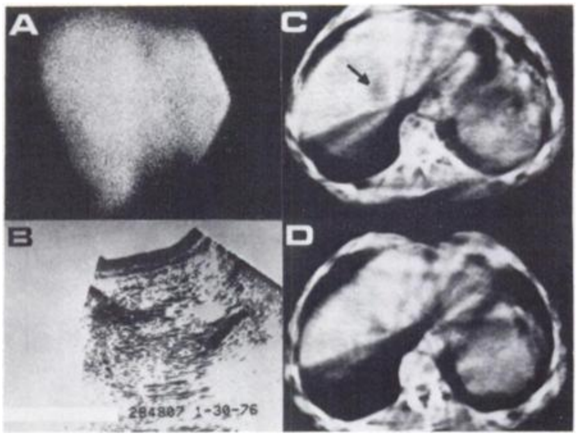

FIG. 2. (A) Anterior gamma image: focus of decreased activity in superomedial portion of right lobe. Lesion or hepatic vein? (B) Longitudinal sonogram (head to viewer's right): focus seen in (A) is sonolucent. (C, D) CT without and with contrast material: clearly identified lucency (arrow) fails to opacify. Hepatic vein and other vascular structures are excluded. Diagnosis of simple hepatic cyst was made.

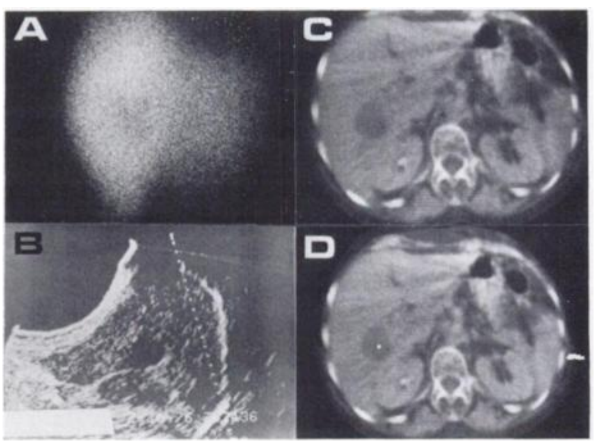

FIG. 3. (A, B) Anterior gamma image and longitudinal sonogram: solitary large lesion on ^{99m}Tc study is sonolucent. (C, D) CT images without and with cursor: lesion is identified (C) and its attenuation coefficient determined (D). Blood, pus, and solid or necrotic tumor are excluded by determination of extremely low attenuation coefficient (Delta number = 4). Again, simple hepatic cyst was diagnosed, obviating need for invasive diagnostic procedures.

is most frequently seen in the left lobe of the liver (Fig. 4). Dilated bile ducts and variations in the porta hepatis create further difficulties. In each of these problem areas both ultrasound and CT are superior and often define the specific cause of the abnormality. The new ^{99m}Tc hepatobiliary agents (Fig. 5) will improve visualization of the gallbladder and biliary ducts (*9,10*). However, CT and ultrasound will probably continue to be more effective, since these modalities depend only upon bile-duct size, whereas radionuclide techniques depend upon both size and continued hepatic function.

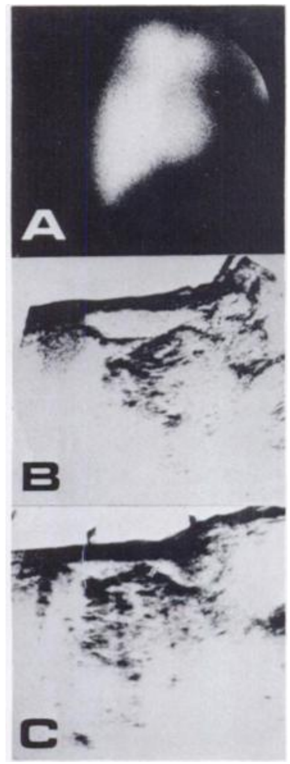

FIG. 4. (A) Anterior gamma image: apparent lesion occupying left hepatic lobe. (B, C) Longitudinal sonograms (head to viewer's right): extreme thinning of left hepatic lobe—a normal variant. No intrinsic hepatic or intrinsic retrohepatic lesions are present.

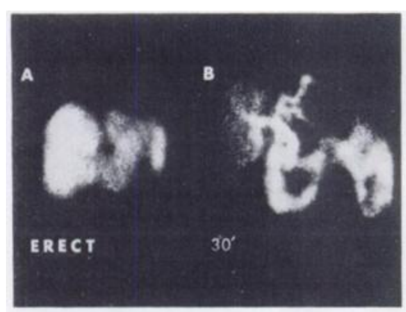

FIG. 5. (A) Anterior erect sulfur-colloid image: prominent defect in portal region—dilated ducts or intrahepatic mass? (B) Hepatobiliary image utilizing ^{99m}Tc-Nα-(2,6-diethylacetanilide) iminodiacetic acid: prominent but patent intra- and extrahepatic bile ducts explain "lesion" in (A). In the near future, such studies may eliminate need for ultrasound or CT clarification of suspiciously prominent portal defects.

In two cases the radionuclide images failed to detect intrahepatic lesions clearly shown by ultrasonography. In one of these, the gamma images demonstrated only the larger of two adjacent metastases. In this case, CT failed to detect either abnormal focus, and sonography detected only the smaller lesion (Fig. 6). In the second case, ultrasonography revealed three sonolucent intrahepatic lesions,

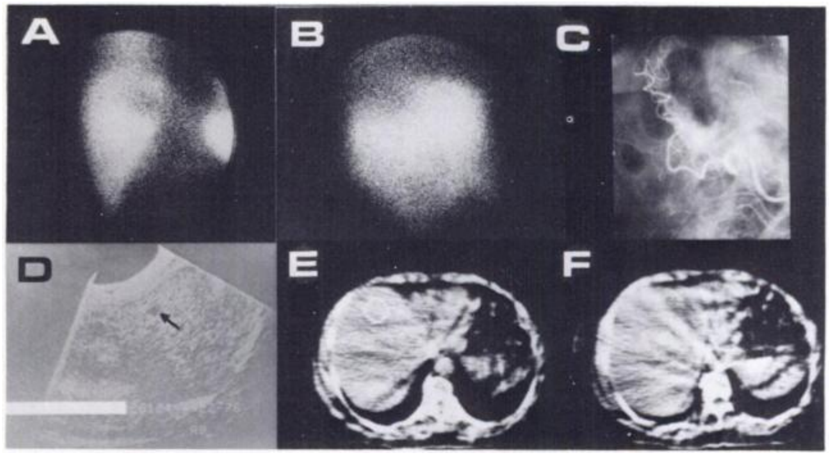

FIG. 6. (A, B) Posterior and right-lateral gamma images: solitary large lesion in supero-posterior portion of right hepatic lobe. (C) Angiogram: large right upper quadrant hepatic lesion surrounded by abnormal vessels. (D) Longitudinal sonogram (head to viewer's right): large lesion escapes detection because of its location under ribs, but small deep lesion (arrow) is clearly identified. (E, F) CT sections at levels of large and small lesions: no abnormal foci. Both lesions escape detection on CT, probably because of motion artifact. These represent surgically proven multiple hepatic abscesses.

gamma imaging identified one, and CT none. Better spatial resolution and motion correction of scintillation-camera images may improve the detection of small lesions. To date, however, small lesions missed by radionuclide imaging may be delineated by ultrasonography.

Ultrasound is limited by marked obesity, bowel gas, and difficulty in visualizing abdominal structures high under the rib cage, e.g., the posterosuperior portion of the right lobe of the liver. When a prominent lesion in this area is not detected by CT because of "isodensity" or motion artifact, only gamma imaging can provide a diagnosis (Fig. 6). Complete or almost complete replacement of the liver by neoplasm (to the extent that any single plane imaged by ultrasound contains little or no normal tissue) may occasionally result in diagnostic failure of this modality (Fig. 7). Gamma imaging, moreover, is less demanding than the other two in terms of operator skill and physician time.

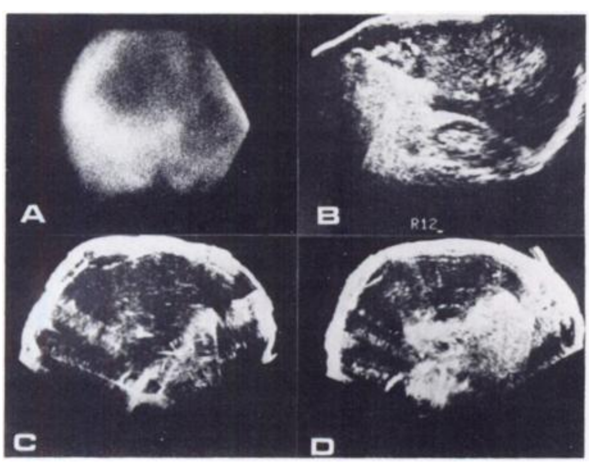

FIG. 7. (A) Anterior gamma image: extensive replacement of liver by metastatic neoplasm. (B) Longitudinal sonogram (head to viewer's right): hepatic echo pattern is coarse but fairly uniform. (C, D) Transverse sonograms (viewed from below): pattern similar to that seen in (B). Extensive metastatic replacement may rarely escape ultrasonic detection if no normal tissue is included in section, as in this metastatic pancreatic carcinoma.

The combination of ultrasound (with its superior resolution) and gamma imaging (with total liver visualization) identified all lesions in this study, whereas CT alone or in combination with either of the other techniques occasionally failed to reveal lesions.

In conclusion, this study suggests that radionuclide imaging should continue as the initial screening examination for suspected nonobstructive intrahepatic lesions, since the entire organ is easily imaged and false negatives are relatively uncommon. However, the left hepatic lobe, the porta hepatis, the bile ducts, and peripheral masses within or adjacent to the liver will often require clarification. Ultrasonography has proven effective for this purpose and may, in addition, reveal small deep lesions missed by radionuclide imaging. In selected cases, the unique information regarding radiographic density provided by computed tomography may then provide a more specific diagnosis. Additional experience with cross-sectional anatomy and with the effects of different "window widths" and "centers" may well increase the value of CT for liver study. Furthermore, comparative studies with faster CT scanners will be necessary to determine whether the relative ratings and recommended sequence for the three examinations should remain unchanged.

FOOTNOTES

* Ohio-Nuclear Series 100, Solon, Ohio; Searle Pho/Gamma III HP, Des Plaines, Ill.

† Unirad Sono II, Gray Zone Display, Denver, Col.

‡ Ohio-Nuclear Delta Scanner with 256 × 256 matrix and 2.7-min scan time, Solon, Ohio.

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