Pitfalls and Artifacts in Nuclear Imaging Studies

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In interpreting scintillation images, one often is confronted with a variety of deviations from the typically normal study that need not represent definite pathology. Apart from normal anatomic variants in the position, shape, or configuration of an organ, one must also be prepared to appreciate alterations due to the radiodiagnostic agent employed and aberrations caused by faulty or improperly used instruments. Additionally, physiologic and/or functional changes associated with specific organ studies have provided a major source of error in routine image interpretation. It is the purpose of this article to acquaint (or reacquaint, as the case may be) the reader with many of these problems so that they may easily recognize them and, one hopes, improve their overall interpretive abilities.

The discussion will follow the lines of general considerations relating to instrumentation and radiopharmaceuticals followed by specific organ considerations. In this type of review, some intentional as well as some unintentional omissions may appear. The author hopes that most of the common sources of error have been included. Undoubtedly, some readers may think of other problems that they may personally have been confronted with.

I. Instrumentation. Problems related to instrumentation may be related to malfunction of the equipment or faulty technique.

A. Malfunction:

1. Lack of field uniformity. In using scintillation cameras, one must have a relatively homogeneous response to gamma photons over the entire crystal surface. A uniform crystal with properly balanced, normally functioning phototubes is a prime requisite to proper image interpretation. The response from different portions of the same crystal may vary from one another by as much as 20% to 30%. Computer programs have been written to correct this problem. Since most individuals do not have this facility, a simple field flood each morning using a sheet source or separate Cobalt-57 sources, with the collimator off, should, at least, help one appreciate what portions of the camera crystal are giving an inhomogeneous response. If the picture is particularly poor, the instrument should not be used and the manufacturer's service department should be consulted.

2. Faulty spectrometer. An inability to properly peak over the appropriate gamma photons of a radionuclide is a flaw that obviously would prevent one from obtaining a good image. Using the spectral bands available on the Anger scintillation camera, one should be able to appropriately "peak in" on the desired energy range. Using rectilinear scanners, one should be able to obtain maximal count response if the pulse height analyzer window is properly positioned around the peak gamma photon energy.

3. Defects in the electronic circuitry (preamplifier, and other equipment) or display system (cathode ray tube, and other equipment).

B. Technique:

Certain human errors also must be considered in operating any electronic instrument.

1. Improper calibration. Even though an instrument may be functionally sound, electronic "drifts" due to fluctuations in input voltage and other similar factors may cause changes in the settings required to obtain optimal response at a particular energy

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range. Frequent calibration checks by the technologist are needed to correct this difficulty.

2. Faulty settings for contrast enhancement, density, or time contrast. These are problems more often associated with rectilinear scanners than stationary cameras primarily related to the fact that there are many more dials for the technologist to manipulate on the former. Contrast enhancement settings deal with the range of gray scale over which the counts from the area being studied are spread. Too narrow a range will create a very contrasted image which may give a false impression of an abnormal area. The experienced interpreter should recognize this immediately. On the other hand, too little contrast enhancement may, in some instances, mask abnormalities. Similar situations may exist for density settings which deal with duration of light flash and time constant settings which deal with length of sampling time for a particular event or position of the detector.

3. Information (count) density. This refers to the amount of information one obtains in a unit area to create an interpretable rectilinear scan image. Nowadays, we strive for count densities of 600 to 2000 counts per square centimeter. A simple formula used to achieve this factor is as follows:

$$\text{Count Density} = \frac{\text{Maximal Count Rate}}{\text{Scan speed} \times \text{Line spacing}}$$

If one keeps the line spacing constant at 0.3 to 0.4 cm, a simple direct relationship between count rate and usable speed is obtained. A simple technique chart can be developed for the instrument operator relating these factors to obtain a desired count density.

4. Improper collimator. The use of an improper collimator can destroy an otherwise good study; for example, a low energy 140 kev collimator cannot be used for an ^{131}I-Hippuran renal study since the 364 kev gamma photon of ^{131}I will penetrate the collimator's lead septa causing considerable scatter radiation resulting in loss of resolution and image degradation.

Most of these aforementioned problems as well as several others are discussed at some length in a recent article by Harris (1).

II. Radiopharmaceuticals. Potential problems with radiodiagnostic agents are encountered in each individual organ-imaging area, and specific situations will be primarily considered as each organ system is discussed. These difficulties relate to both the preparation of these different materials as well as certain technical factors. Some general problems such as low specific activity or concentration, poor compound labeling, presence of radionuclide impurities, infiltration of the injected dose, and miscalculation of the dose are applicable to all of the subsequently discussed clinical areas.

III. Brain Imaging. In brain scintigraphy, difficulties with both the radionuclide angiogram (dynamic study) and blood-brain barrier study (static study) may be encountered.

A. Radionuclide angiogram.

1. Jugular-venous reflux. A sudden Valsalva maneuver by the patient during a rapid intravenous bolus injection of a radiopharmaceutical can cause the tracer to reflux up the jugular vein instead of proceeding on its normal pathway to the heart (2). This is recognizable as a band of activity entering the head (sometimes into the transverse sinuses) well before normal circulation time would fill the carotid arterial tree (Fig 1). It should not be misinterpreted as asymmetric arterial flow. A second factor that may cause such venous reflux is venous obstruction in the upper thorax, for example, superior vena caval obstruction, in which case reflux up the jugular represents the path of least resistance.

2. Expected asymmetries in elderly patients. Fif-

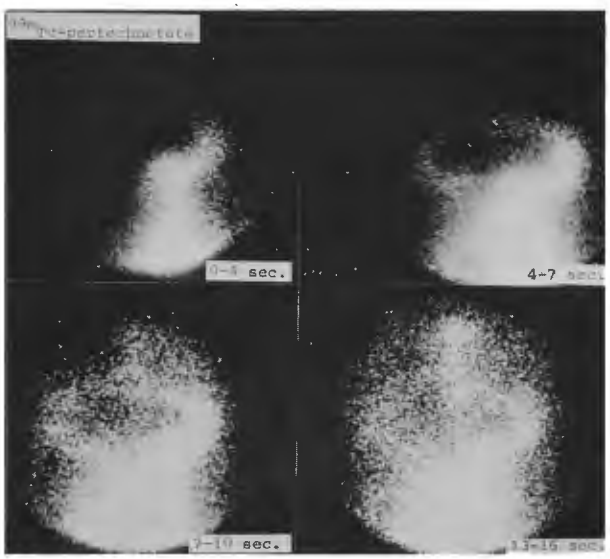

Fig 1—Jugulo-venous reflux. A bolus of ^{99m}Tc-pertechnetate administered through a left antecubital vein is seen to reflux up left jugular vein on 0-4-second scintiphoto. At 4-7 seconds, it has refluxed back into transverse sinus and down right jugular vein. At 7-10 seconds, normal arterial flow to head is visualized. Diminished right cerebral perfusion signifies presence of a right cerebrovascular accident.

teen to 20% of patients over the age of sixty can be expected to have asymmetric arterial flow solely on the basis of normal arteriosclerotic change (3). No focal neurologic findings are demonstrable in this group of patients.

3. Bilateral carotid stenosis. The author has encountered two situations where bilateral carotid artery stenosis has caused long delays in the cerebral appearance of an antecubital intravenous injection of ^{99m}Tc-pertechnetate. Since an infiltrated injection could cause the same finding, one should be aware of this particular disease entity when encountering such a study.

4. Luxury perfusion in cerebrovascular accidents. On occasion, increased rather than decreased flow may be observed in a patient with an acute cerebrovascular accident (3). This is believed due to regional hyperemia and vasodilatation around the infarcted area. This phenomenon generally subsides over a two- to four-week period. Such increased perfusion should not be misinterpreted as a vascular malformation or neoplasm.

B. Static brain studies:

1. Choroid plexus activity. The normal biologic localization of radiopertechnetate in the choroid plexus has been greatly emphasized (4, 5). Prior competitive blocking with potassium perchlorate has greatly minimized this problem. If continuing difficulty exists, even after perchlorate block, a repeat study with a different tracer such as ^{99m}Tc-DTPA may be obtained. The question of whether or not perchlorate premedication will prevent pertechnetate uptake in an abnormal choroid plexus, for example, papilloma or meningioma, has aroused some interest. In general, most reports indicate that it will not interfere with uptake in choroid plexus lesions. This was also the case in this author's large series of one case (Fig 2).

2. Saliva artifacts. Since pertechnetate is actively picked up by the salivary glands and excreted into the mouth, saliva artifacts must be watched for. This is generally encountered in comatose or semicomatose patients and children where drooling may allow saliva to collect on different parts of the head and neck (Fig 2). Repeat studies after cleansing of the area should resolve the problem.

3. Prosthesis—metal plate, glass eye, and other artificial parts. The relatively low gamma photon of ^{99m}Tc is easily attenuated by such foreign objects. The old standbys of physical examination and plain skull radiographs should clarify any suspicions in this area.

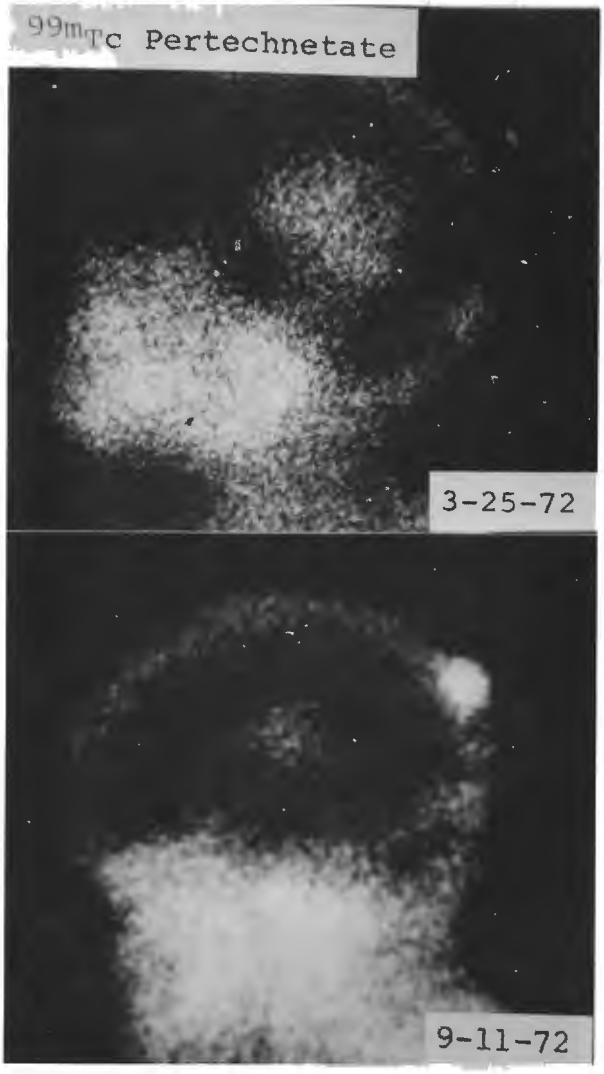

Fig 2—Uptake in choroid plexus papilloma in a child unaffected by potassium perchlorate premedication. Right lateral scintiphoto at top shows intense uptake in a choroid plexus papilloma. Pretreatment with perchlorate failed to block uptake in this abnormality. A follow-up study several months after radiotherapy is shown at bottom. The lesion has decreased in size. The "hot" spot on the back of the head is a salivary artifact caused by drooling.

4. Superficial pathology. The nonspecific uptake of radiopertechnetate includes lesions of the skull and scalp. Multiple views usually will clarify the problem since intracerebral abnormalities must be demonstrable on at least two images obtained at 90° angles. Extracerebral but intracranial abnormalities such as subdural hematomas, however, do not exhibit the finding and may be difficult to differentiate from more superficial pathology. Palpation of the scalp

and skull radiographs should be used. Bony lesions can be elucidated with ^{99m}Tc-labeled phosphate studies. In addition, serial studies with ^{99m}Tc-pertechnetate over a several-hour period may be useful, since most intracranial abnormalities show increased uptake with time, while most bone and soft tissue lesions seem to lose activity with time (6).

5. Previous surgery. Surgical flaps and other defects may concentrate a tracer and show activity for several years after an operation. It is useful to obtain a baseline study shortly after surgery. This makes judgments on subsequent studies concerning residual or recurrent abnormalities more lucid.

6. Vertex view artifacts. Mouth activity from the tongue and oral mucous membranes may mask a frontal lesion. Prior administration of atropine helps diminish this. Obvious attention to this use of atropine in problems of the elderly, for example, glaucoma and urinary retention, should be given. Visualization of the stomach on the vertex view in a child has been reported to cause some difficulty as well, since the appearance on that one view simulated a neoplasm.

7. Need for serial studies after injection. Considerable emphasis has been placed on the need to obtain delayed scintigrams in many intracranial problems, such as avascular primary neoplasms, metastatic lesions, and extracerebral hematomas. By confining the static brain scan to 45- or 60-minute studies, one may miss or have to equivocate on some lesions that often are well demonstrated on two- to four-hour studies (7,8).

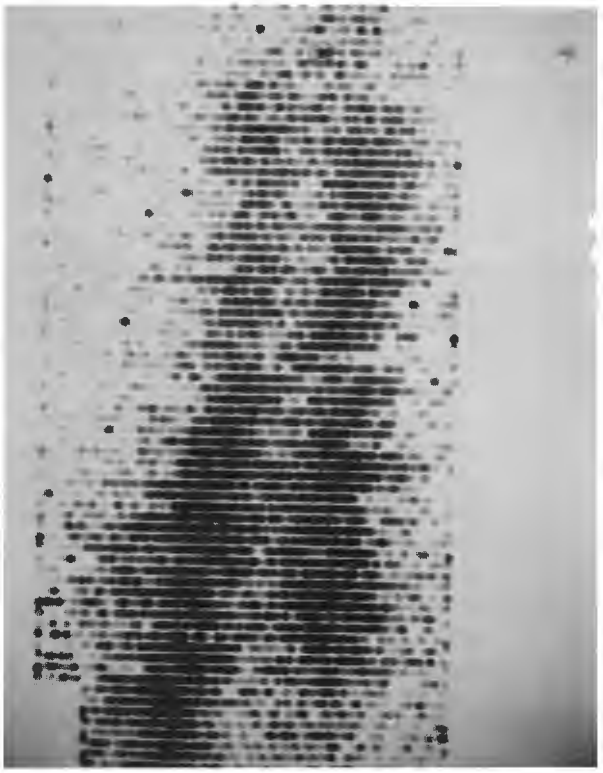

Fig 4—Misinjection in cisternography. Six hours after lumbar intrathecal administration of ^{131}I-Human Serum Albumin, no intracranial activity was detectable. This scan of the back shows the column of tracer split instead of as a solitary column. This is the appearance of subdural instead of subarachnoid injection.

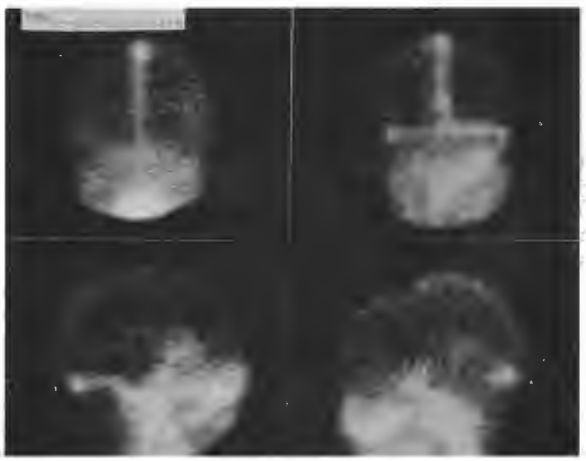

Fig 3—Abnormal ^{99m}Tc-pertechnetate brain image following a stannous pyrophosphate bone image. This 4-view static study 2 days after a pyrophosphate bone scan demonstrates increased activity in all vascular structures (sagittal sinus, transverse sinus, neck vessels, carotid siphon). The choroid plexus is particularly well seen on left lateral view despite perchlorate premedication (see text for explanation).

8. Abnormal pertechnetate brain scans following bone scans. Several investigators have reported an altered appearance of radiopertechnetate brain scans performed one or two days following pyrophosphate or polyphosphate bone studies (9, 10, 11). This consisted of abnormally increased activity in the area of the sagittal sinus, transverse sinus, and choroid plexus (Fig 3). It has been postulated that tin attaches to red blood cells following bone imaging and subsequently administered pertechnetate undergoes intracellular reduction with labeling of the erythrocytes during the brain scan (10). It is suggested that brain scans should precede pyrophosphate bone scans or, alternately, the brain scan, as the second procedure, should be performed with ^{99m}Tc-DTPA.

9. Problems with cisternography. Only a couple of problems will be discussed here. The first relates to

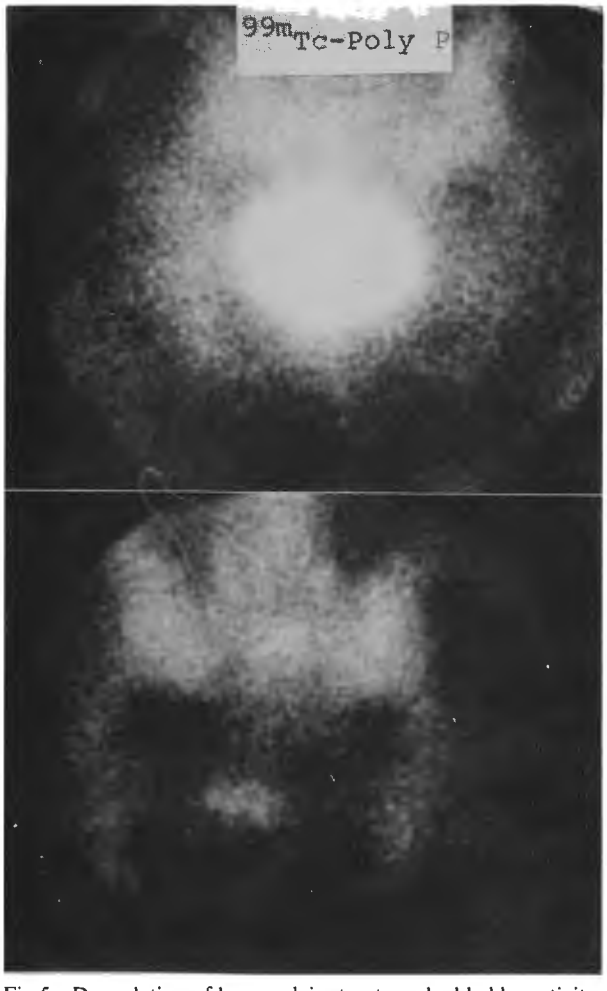

Fig 5—Degradation of bony pelvic structures by bladder activity. Upper posterior scintiphoto of pelvis was obtained 2 hours after administration of ^{99m}Tc-polyphosphate. Scatter from intense bladder activity severely degrades resolution of surrounding bony structures. Marked improvement in image quality is seen after patient voided and study was repeated (*lower scintiphoto*).

injection technique. If the intrathecally administered material (nowadays, primarily ^{111}In-DTPA) is placed outside the subarachnoid space, for example, sub- or epidural, no activity will reach the head. A scan of the back showing a split, rather than solitary, column of activity will confirm the suspicion of a faulty injection (Fig 4).

In studying cerebrospinal fluid leaks, it often is helpful to examine the patient in the same position in which the leak is occurring. A recent report showed an interesting artifact caused by residual ^{99m}Tc-pertechnetate activity from the previous day's brain scan (12). It was in the region of the nasopharynx or mouth, creating the illusion of a CSF leak. Peaking solely on the higher gamma photon (247 kev) of ^{111}In would guard against this.

IV. Bone Imaging. Within the past three years, bone imaging has changed considerably primarily because of the introduction of ^{99m}Tc-labeled phosphate compounds. Prior to the "phosphate" era, Strontium-85 and subsequently ^{87m}Sr and ^{18}F were the radionuclides used.

1. Visualization of interfering colon activity with ^{85}Sr. This is the one difficulty associated with this older radiopharmaceutical that will be discussed. Because of a persistently high soft tissue and blood background, ^{85}Sr studies generally were performed at 2 to 3 days following injection. At this delayed time, the gastrointestinal tract represents the prime mode of excretion. Laxatives should be administered prior to performance of the study. On occasion, persistent colon activity might mimic osseous uptake if it is superimposed on a bony region such as the iliac wing.

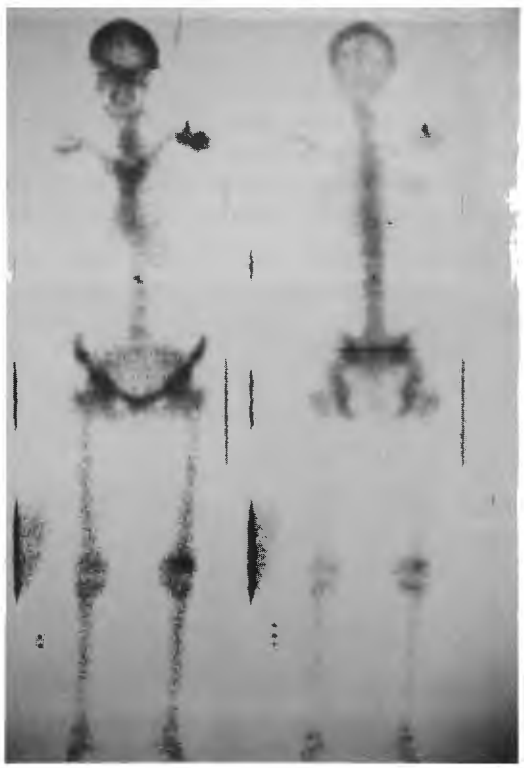

Fig 6—Diffuse bony metastases with relatively normal-appearing scan showing "missing kidney" sign. Patient with radiographically demonstrated diffuse bony metastases from breast carcinoma. Bony structures (except possibly the skull) appear normal on scan. The absence of kidney visualization is the prime clue that an abnormality is present (see text for further explanation).

Repeat study after enema or a couple of days later should help differentiate colon from true osseous activity.

2. Diminished resolution of normal pelvic structures due to bladder activity. This represents a basic problem in all imaging procedures. It is particularly well demonstrated in this area (Fig 5). The patient should be asked to void immediately prior to starting the scan. If bladder activity first presents as a problem after a study is performed, a repeat examination of the area after voiding should be obtained.

3. Marginally active lesions missed due to excessive contrast enhancement. In bone imaging we generally are searching for "hot" rather than "cold" areas. In setting up a study, the technologist may, inadvertently, use an extremely active region, such as the epiphysis in a child. This might prevent detection of an abnormal, but not intensely active, focus in another bony area in the same imaging field of view. Coned-down camera views of a suspicious area often are helpful.

4. Occasional false-negative studies in purely lytic or diffuse blastic lesions. The exact mechanism of uptake of ^{99m}Tc-phosphates is unknown. Several theories have been advanced which include ion exchange, chemisorption, and collagen uptake. In addition, blood flow and/or concentration appears to play a key role in delivering the radionuclide to the abnormal area. Most radiographically lytic lesions will have a significant reparative (blastic) component on histologic examination which would ensure their detection by radionuclide study. On occasion, a purely lytic lesion, for example, round cell sarcoma, may be relatively quiescent histologically and might, therefore, escape scintigraphic detection.

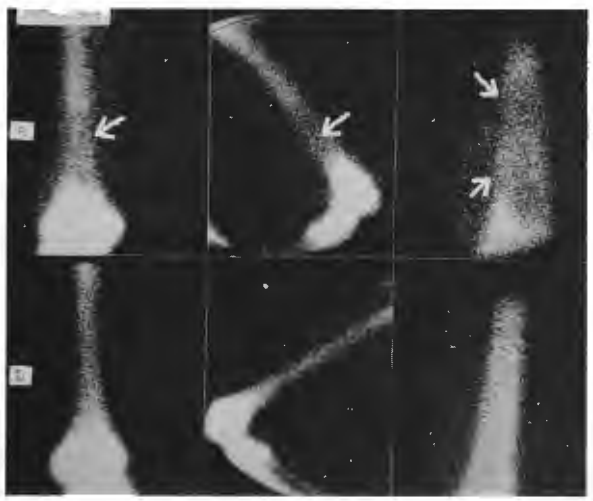

Fig 7—"Photon Deficient" bone lesion. The patient was a young girl with sickle cell disease and focal pain in distal right femur. Anterior, lateral, and anterior pinhole magnification views are shown for each distal femur. The area of mottled decreased activity ("cold" lesion) seen best on right lateral and right anterior pinhole collimator views (*arrows*) is characteristic of bone infarction.

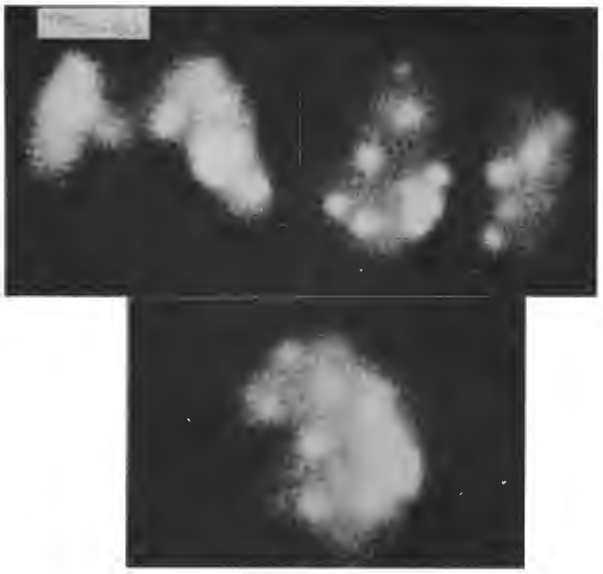

Fig 8—Radioactive pulmonary emboli. Anterior, posterior, and left lateral lung fields. (See text for explanation).

On the other hand, lesions that tend to have diffuse osseous involvement, for example, prostate or breast carcinomas, also might give false-negative studies (13). In bone scintigraphy, we depend upon a gradient between normal and abnormal uptake to detect a lesion. In diffuse, uniform involvement, all bones may be "hot" and such a gradient may not exist. One potential clue to the existence of such diffuse involvement is a diminution or absence of renal activity (Fig 6) (14). Approximately 30% to 50% of the administered dose of ^{99m}Tc-labeled phosphate should reach the skeleton with enough of the remaining activity going through the kidneys so that renal activity on a two-hour study should be fairly intense. Conceivably, lesions having hypermetabolic activity might utilize more than their usual share of tracer, thereby leaving only small amounts for the kidney. This finding has been useful to the author and should be looked for.

5. Photon deficient ("cold") lesions. On occasion, abnormalities on bone scan may present as "cold" rather than "hot" lesions (16). Complete interruption

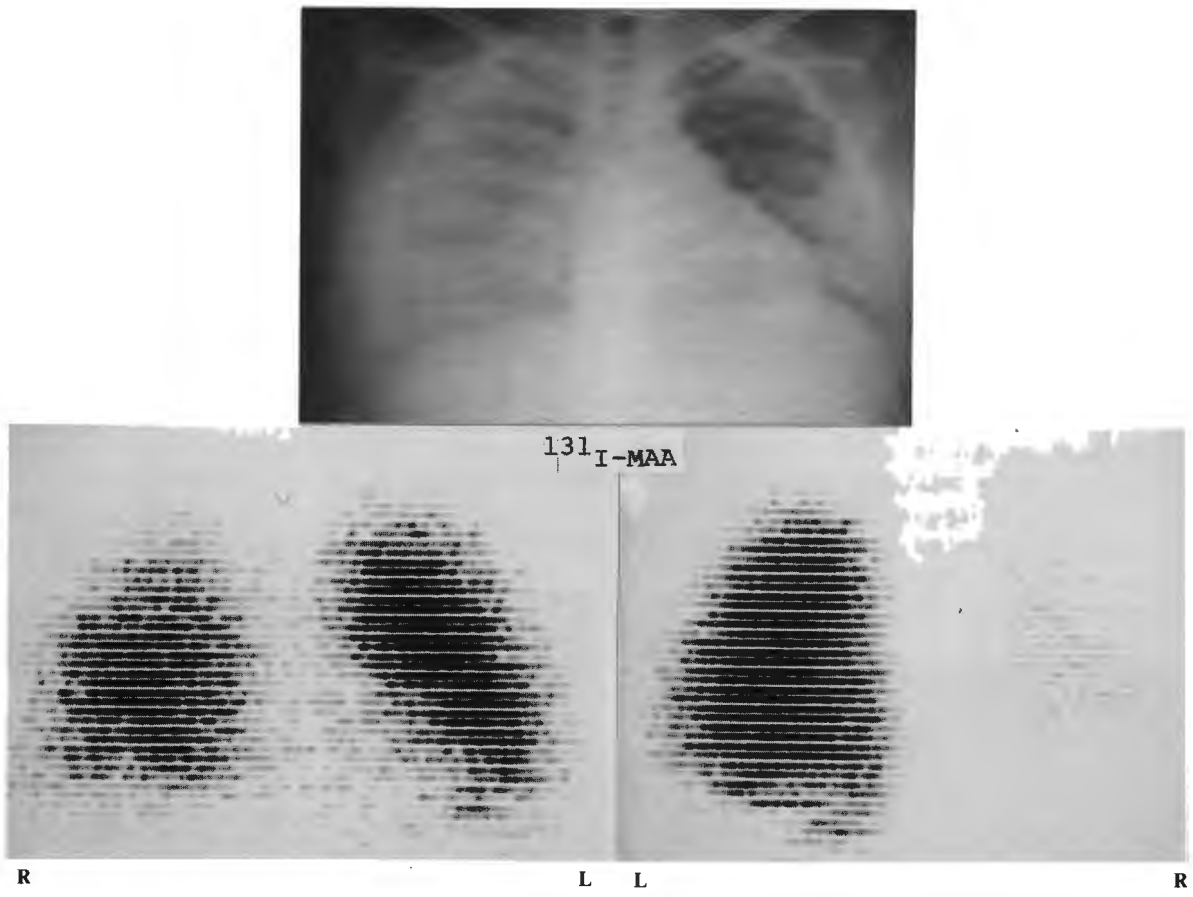

Fig 9—Interference of pleural fluid on dual-headed scanner study. Anterior scan (*lower left*) shows minimal diminution in right lung perfusion. Posterior scan (*lower right*) demonstrates much more severe apparent diminution in right lung activity due to interposed pleural fluid shown on chest x-ray (see text for explanation).

of blood supply, as in bone infarction, is a major cause of this finding (Fig 7). Other lesions such as occasional metastases and Legg-Calvé-Perthes' disease in children (17) also have shown this finding. In examining a bone scan, one, therefore, should be aware of this alternate evidence of an abnormal lesion.

6. Asymmetries in chest activity due to radical mastectomy. With reduced muscle mass following mastectomy, the osseous structures on the involved side appear more intense on the anterior scan (15). If the asymmetry appears on both anterior and posterior studies, a different explanation, such as pleural fluid, should be sought. Once again, a history, physical, and chest x-ray should solve any problems in this regard.

7. Prosthesis, for example, pacemakers. As in brain studies, overlying metallic or bulk objects such as pacemakers will attenuate radiation and create a void on scan. The characteristic rounded shape of a pacemaker should help differentiate it from a possible "photon deficient" lesion (see section 5 above).

8. Femoral vessel activity. Some patients, particularly in older age groups, will show linear bands of increased activity medial to the femoral shafts. It is felt that, in some cases, this may represent actual changes in the femoral vessel wall. It may or may not be associated with radiographic evidence of calcification.

V. Lung Imaging.

1. Radioactive "pulmonary emboli." On occasion, large "hot" spots are seen on a lung scan (Fig 8) (18). This finding is most often encountered in situations where difficult venipunctures have allowed excessive red cell and macroaggregate mixture time in the syringe. Larger than usual aggregates (100μ to 1000μ) are formed which lodge in more proximal

arterial beds causing these radioactive pulmonary emboli. They are not of any clinical consequence, but do interfere with interpretation. Their typical appearance should easily be recognized.

2. Macroaggregated hold-up on damaged endothelium. Visualization of axillary vessels on the side of injection is sometimes noted; particularly in patients who have had indwelling venous catheters for a few days. The MAA or microspheres adhere to the irritated endothelium of these vessels. Thrombosed vessels behave in the same fashion. This cannot be used as a reliable indicator of lower extremity venous thrombosis after foot injection because venous stasis or insufficiency from other causes will behave similarly (19).

3. Position during injection. Macroaggregated albumin distributes along gravitational pathways in normal lungs. Therefore, an injection performed in an oblique, lateral, or upright position will result in a different scan than one performed in a supine or prone position.

4. Perfusion changes due to pulmonary venous hypertension. In patients with left ventricular failure and mitral heart disease, an anti-gravitational phenomenon results in redistribution of perfusion. The anterior and upper portions of the lung field will exhibit greater activity than the posterior and lower portions after a supine injection of MAA or microspheres. The degree of change generally is related to the severity of the pulmonary venous hypertension associated with the disease process.

5. Free fluid distribution with dual-headed detectors. Free pleural fluid usually gravitates to the dependent portion of a hemothorax which is that portion away from the detector head of an Anger camera or single-head rectilinear scanner. It will, therefore, have a minimal effect on the observed perfusion pattern. However, when a dual-headed detector is used, the fluid will be interposed between the lung and the lower detector. It often may cause a "dampening" effect and an impression of generalized decreased perfusion on the posterior scan only (Fig 9). Adherence to the cardinal rule of not interpreting a lung scan without a concurrently obtained chest radiograph should help avoid any problems.

6. Size discrepancies with dual-headed detectors. In interpreting lateral lung scans performed with dual-headed detectors, one should be aware of a "shrunken" appearance occasionally encountered in the "down" side of normal lungs. This is actually caused by the fact that the "up" side is hyperexpanded. The "down" side is actually expanding and deflating more than the "up" side.

7. Loss of activity due to right-to-left shunt. The presence of right-to-left cardiac shunts will cause a loss of pulmonary activity. The finding of kidney activity should arouse some suspicion. In children with known large, right-to-left shunts, careful consideration should be given to the advisability of performing the lung scan. The prime reason for this is possible complications from the shunting of the macroaggregates to the brain.

In patients who have had surgically created shunts, details of the shunt anatomy will help the interpreter of the study determine if the particles are distributing the way they should.

VI. Liver Imaging.

1. Altered distribution due to colloid particle size. Technetium-99m-sulfur colloid particles (~ 100-400

Fig 10—Subphrenic abscess simulating intrahepatic lesion. On this combined anterior liver-lung study, a massive concave defect is seen on right lateral border of hepatic activity. It appears as if some liver parenchyma is superior to the defect. The initial impression in this postoperative febrile patient was that of an intrahepatic abscess. At repeat laparotomy, the collection was completely extrahepatic and had displaced the liver medially.

mμ) are 10 to 20 times larger than gold-198 colloid particles (10-20 mμ). Although the vast majority of these larger particles still localize in the liver, a significantly greater proportion also will be phagocytized by the spleen's reticulo-endothelial system (20). In other words, we routinely image the spleen on ^{99m}Tc-sulfur colloid studies, whereas this was not the case on ^{198}Au scans. Increased splenic visualization was a significant indicator of diminished hepatic perfusion on ^{198}Au studies. Because of the normally different distribution, this finding is not as sensitive an indicator of decreased liver blood flow on ^{99m}Tc-colloid studies.

2. Considerable anatomic variation in normal liver. The liver scan is regarded by most nuclear medicine physicians as one of the most difficult to interpret. The tremendous variation that one encounters in the normal liver is a major contributing factor to this problem (21). Such variants as Riedel's lobe, left lobe thinning, high hemidiaphragms, interposed colon, and gallbladder fossa must be fully appreciated by the nuclear medicine physician before he can interpret hepatic scintigrams intelligently.

3. Extrinsic pressure deformities from neighboring organs and structures. Because of its great pliability, the liver's shape and configuration may be easily altered by normal variants or disease processes in neighboring organs and structures (22). Any process in the retroperitoneal area, for example, kidney or pancreas masses; intraperitoneal area, for example, high hepatic flexure of colon or subphrenic abscess; or intrahepatic area, for example, dilated gallbladder or bile ducts, can cause apparent hepatic defects that are often indistinguishable from true intrahepatic space-occupying lesions (Fig 10). An appreciation of this possibility and correlation with physical findings and other radiographic examinations are helpful in elucidating such problems.

4. Apparent defects due to attenuation of the gamma photons. As in other organ areas, overlying objects such as pacemakers, breast prostheses, and other objects may cause defects in the image. Physical examination at the time of study will assist the interpreter.

5. "Pseudomasses" in cirrhosis and hepatitis. Focal defects simulating space-occupying lesions may be encountered in patients with diffuse parenchymal problems such as cirrhosis or hepatitis. In cirrhosis, such defects have been attributed to fibrosis, atrophy, shunting, and nonfunctioning areas of regenerative nodulation (23). The potential existence of a hepatoma in such a "cold" area presents a problem that generally may be solved by performing a radionuclide angiogram with pertechnetate and/or ^{75}Se-selenomethionine or ^{67}Ga-citrate metabolic studies. Hepatomas usually will be active with each of these tracers while almost all cirrhotic pseudomasses will not.

Less well appreciated is the pseudomass of hepatitis which appears to be due to nonuniform involvement of the disease process. Focal, severe swelling of the polygonal cells somehow appears to compromise function of much less prevalent R-E cells (24) (Fig 11).

6. Hyperconcentration of colloid in occasional lesions. "Hot" spots in the liver have been reported by several investigators. Most of these cases have been instances of venous obstruction, for example, superior vena caval, where umbilical collaterals crossing over the anterior surface of the liver in the interlobar area locally deposit a large amount of col-

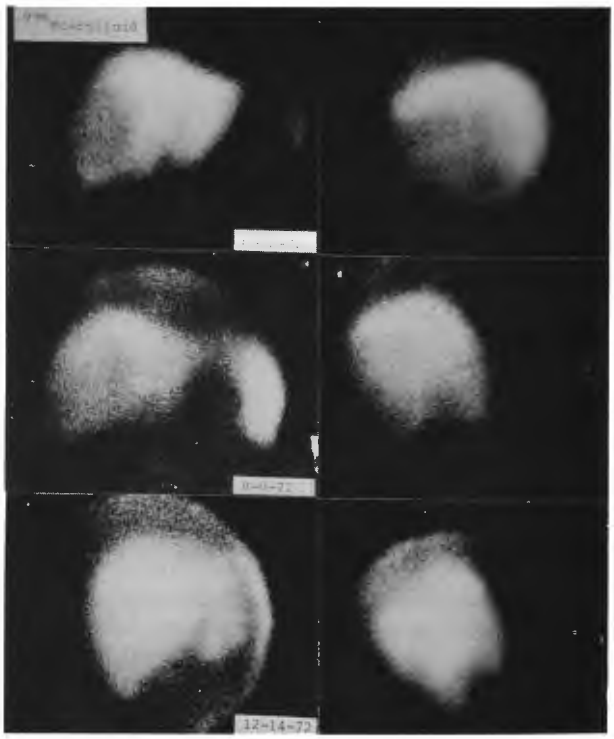

Fig. 11—Pseudomass in acute viral hepatitis. Upper row of ^{99m}Tc-sulfur colloid scintiphotos were performed in a 15-year-old, deeply jaundiced girl. An apparent space-occupying defect is seen in the right lobe. Liver biopsy of this area showed markedly swollen hepatocytes and a striking paucity of Kupffer's cells. The appearance was consistent with viral hepatitis. Middle and lower row of scintiphotos were obtained 6 weeks and 6 months later, respectively, and show a gradual return to normal.

loid (25). Two specific intrahepatic lesions that have shown "hot" rather than "cold" areas are abscess and hemangioma, the former because of R-E stimulation by the sepsis and the latter because of the markedly increased number of venous sinusoids with their associated R-E cells. Since we generally think of focal hepatic lesions as "cold" areas, one should remain attuned to this variant of the abnormal study. Recognition of its presence should make one feel a bit better after he or she has misinterpreted several hepatic masses.

7. Renal concentration in ^{131}I-rose bengal studies. Under normal circumstances, less than 5% of radioiodinated rose bengal is excreted by the kidneys. In patients with extrahepatic biliary obstruction or severe hepatic parenchymal disease, considerably more of the activity appears in the urine (26). This is particularly true in the former group of patients. Most likely it is free ^{131}I dissociated from the rose bengal that is appearing in the urine. With higher-than-normal levels of renal activity, the kidneys may be visualized on rose bengal abdominal scans (Fig 12). This finding must be differentiated from intestinal activity to avoid an erroneous interpretation of a patent biliary tract. This may be achieved by noting the following:

a. Bilaterality of renal activity

b. Same position, but more intense activity on follow-up studies

c. Posterior position on lateral study

d. Same position as kidneys on urogram or renal scintigram (if a, b, or c do not answer the question)

8. Altered ^{131}I-rose bengal excretion patterns due to fistulae and shunts. In naturally occurring, for example, cholecystocolonic, fistula or surgically produced shunts, for example, Longmeyer procedure, the rose bengal may escape the liver through an alternate pathway even though the biliary ducts may be obstructed. Careful observation of the time of transit as well as the pattern of extrahepatic activity are important considerations, as is the presence of a surgical history.

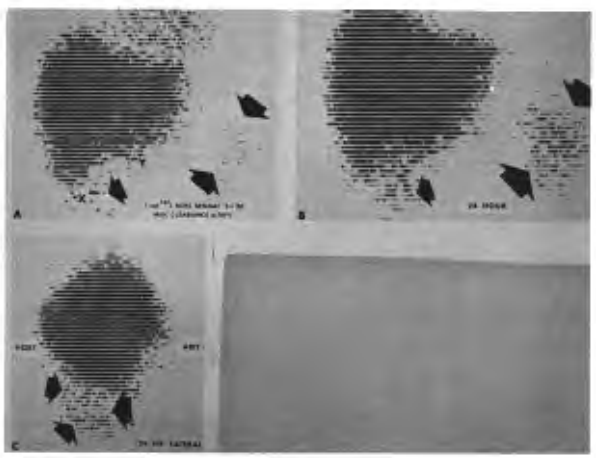

Fig 12—Renal concentration of radioiodinated rose bengal. Radioiodinated rose bengal scans on 68-year-old female with pancreatic carcinoma. *A*. 1-hr study demonstrates typical pattern of renal excretion (*arrows*). Because of its presence on this early scan, confusion with intestinal activity could easily lead to mistaken impression of patent biliary tract. 20/5 min clearance is 24% (normal = >35%). *B*. Serial scans, including this 24-hr study, reveal intensification, but no change in position of extrahepatic activity, confirming fact that activity represents kidneys (*arrows*). Upper half of right kidney is obscured by overlying hepatic activity. Failure of dye to leave liver supports impression of extrahepatic obstruction despite moderately impaired liver function (20/5-min blood clearance of 24%. *C*. 24-hr right lateral scan shows kidney in normal position posterior to liver.

VII. Spleen Imaging.

1. Bipartite spleen. Similar to other organs, the spleen is subject to considerable variation in its normal shape and configuration. Lobulation and notches are frequent findings. On occasion, the spleen presents in two distinct pieces—the so-called "bipartite" spleen. In patients who have had left upper quadrant trauma, this may be a particularly troublesome finding that may require contrast angiography for clarification.

2. Overlap of left lobe of liver with spleen simulating a defect. In many patients the left hepatic lobe overlaps the upper splenic border and can cause an apparent defect on the superolateral border of the spleen (Fig 13). This is a very common pitfall that is frequently misinterpreted as a significant splenic lesion, particularly in trauma cases. Oblique views may not successfully separate the organs. We have found that a 30° caudad-angulated view with the patient in the prone position best separates the liver and spleen (27).

3. Accessory spleen masked by overlying left lobe of the liver. If a patient has had a therapeutic splenectomy for a hematological disorder, for example, idiopathic thrombocytopenia purpura, and continues to have difficulties, the presence of an accessory spleen must be excluded. Searches for such splenic tissue generally are undertaken with ^{99m}Tc-sulfur colloid as the initial tracer. Since this radiopharmaceutical is not spleen-specific, activity in the left

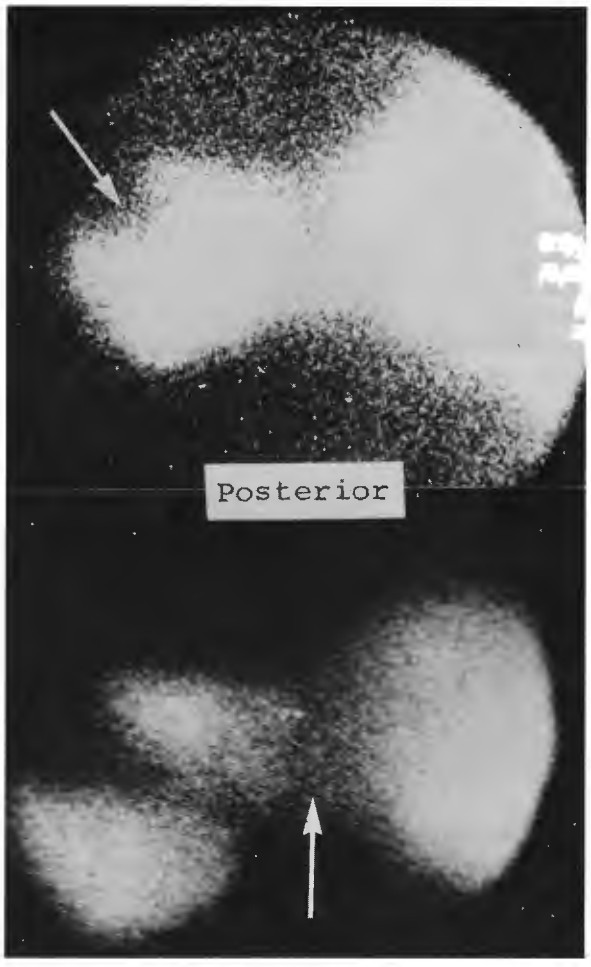

Fig 13—Overlap of left hepatic lobe and spleen simulating a splenic defect. On the initial study (*top*) in this 24-year-old male with a left upper quadrant stab wound, an apparent defect (*arrow*) is noted in the superolateral margin of the spleen. A slight obliquity (*bottom*) successfully separates left lobe of liver and spleen indicating that the suspect lesion was caused by an overlap of the two organs. Note that the medial portion of left lobe of liver (*arrow*) appears thinned due to attenuation of the photons by spine.

hepatic lobe conceivably might mask a splenunculus. Therefore, if the colloid study fails to demonstrate a spleen, a repeat study with ^{99m}Tc-or ^{51}Cr- labeled to heat denatured erythrocytes is needed. The tagged red cells are selectively sequestrated by splenic tissue, and no interfering hepatic activity is encountered.

VIII. Pancreas Imaging.

1. Poor visualization in fasting or debilitated patients with a normal pancreas. Poor visualization of the pancreas on a ^{75}Se-selenomethionine study may reflect either disease or merely not enough pancreatic stimulation (28). The patient should be prepared with overnight fasting followed by a well-balanced test meal. This will promote a profuse production of pancreatic enzymes and good uptake of the selenomethionine in most normal individuals (28). Absence of activity after such a protocol may be interpreted as pancreatic disease with a greater degree of confidence.

2. Overlapping liver activity. This is particularly troublesome in patients with hepatomegaly. Angling of the detector head towards the right upper quadrant as well as angulating the patient by raising the left flank and shoulder is a useful maneuver to correct this problem (28). The best solution is the use of subtraction technology, if it is available.

3. Variations in shape and configuration of normal pancreas. The pancreas may exist in the transverse, pistol-shape, oblique, or horseshoe configurations. Sometimes, a defect is present in the midbody region as a result of the aorta or spine crossing over and thinning out the functioning tissue. Serial camera scintiphotos may show a changing concentration of activity in this region (28). Radionuclide aortography also may be used to correlate the aorta's position with the apparent defect on the scintigram.

IX. Kidney Imaging.

1. Size discrepancies on erect and prone studies. Ptotic kidneys may rotate on anteroposterior axis in the erect position. This foreshortening effect creates an impression of a smaller kidney when studied in the erect or sitting up position. Prone studies provide a safer means of assessing renal size.

2. Free radiopertechnetate in the stomach when using ^{99m}Tc-labeled agents. Most renal agents are prepared by reducing ^{99m}Tc from the +7 to +4 valence state with tin or some other suitable material. Pertechnetate (+7 state) may persist on rare occasions and its normal biologic localization in gastric mucosa may confuse interpretation of left kidney activity (29). Similarly, free ^{131}I may localize in the stomach on radioiodinated hippuran renal studies.

3. Liver accumulation of chlormerodrin in azotemia. When ^{197}Hg-chlormerodrin is used in renal studies, a small amount of hepatic activity usually is present. In azotemic patients, hepatic activity increases at the expense of renal excretion. Merging hepatic and renal activity may be misinterpreted as a large right kidney. As the azotemia worsens, the ability of the kidney to concentrate chlormerodrin is completely lost (Fig 14). At this stage, intense liver activity may be misinterpreted as a solitary right

kidney. In severe azotemia, ^{131}I-orthoiodohippurate is the agent of choice and its use should avoid any of the aforementioned problems (Fig 14).

4. False results after urography or angiography. High doses of organic iodides in the form of radiographic contrast media often cause transient changes in renal function that will effect the kidney's ability to concentrate subsequently administered radiopharmaceuticals. This is particularly true in patients with obstructive uropathy and, also, after selective renal artery studies. Optimally, the radionuclide studies should precede the radiographic studies. If this is not feasible, an interval of three or four days should be obtained between the studies.

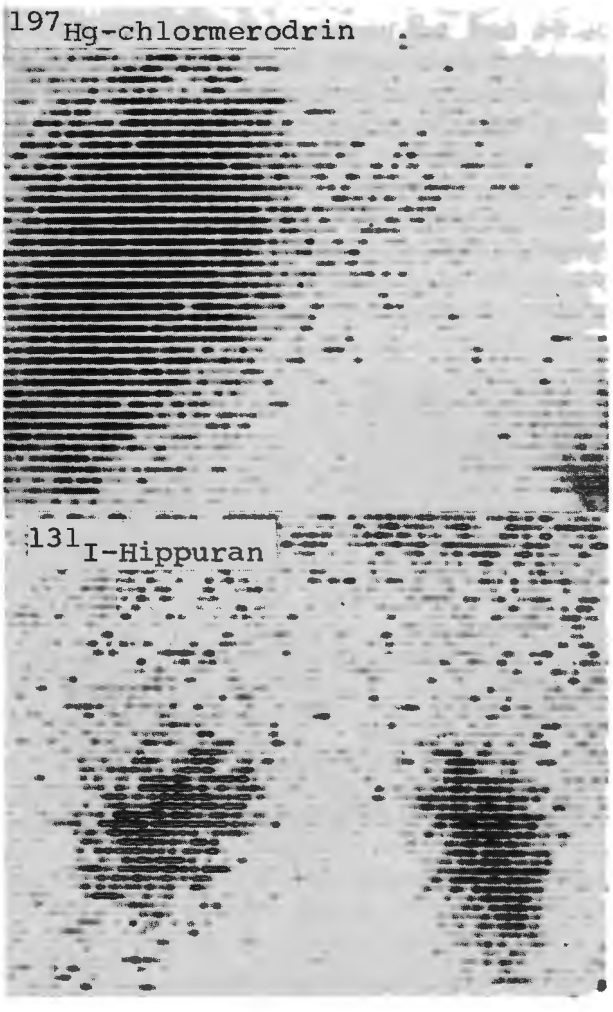

Fig 14—Pitfall in scanning azotemic patients with ^{197}Hg chlormerodrin. Patient shown had blood urea nitrogen of 112 mg/100 ml and plasma creatinine of 5.5 mg/100 ml. The ^{197}Hg chlormerodrin (*top*) has all been excreted by the liver. No renal concentration is evident. A frequent misinterpretation of this study is an enlarged solitary right kidney. The ^{131}I-Hippuran study (*bottom*) is successfully concentrated in both kidneys which are slightly smaller than normal.

X. Thyroid Imaging.

1. Poor uptake and image due to saturated iodine pool. In patients who have been taking iodide-containing medications or who have had radiographic examinations with organic iodide contrast media, the iodine pool is saturated. Subsequent administrations of tracer amounts of radioiodine within a few days will result in poor uptakes and images.

2. Failure to palpate nodules at the time the scan is performed. A vague history of a palpated nodule in the right lobe is insufficient data to accurately assess whether the nodule is functional or not. Nodules should be palpated with the immobilized patient on the scanning bed. It should then be transcribed directly to the scan image. Such one-to-one relationships are best obtained with rectilinear scanner. By knowing exactly where a nodule is, one is able to offer an accurate interpretation. In order for a nodule to be considered functional, it must concentrate greater activity than the surrounding tissue.

3. Pertechnetate uptake in nodules "cold" on iodine scans. The categorization of functional or nonfunctional nodules is a radioiodine classification. Pertechnetate is handled quite differently from iodine in that the thyroid traps, but does not organify it. Therefore, a nodule may exhibit activity with the former, but not the latter (Fig 15). Such a nodule is to be considered "cold" and conceivably may represent a carcinoma. All nodules of the thyroid should be evaluated with radioiodine.

4. Retrosternal functioning tissue unappreciated with low-energy gamma nuclides. Iodine-125 has achieved some popularity as a thyroid imaging agent. Since it possesses very low energy imaging photons (~ 27 kev), it is inappropriate for studies in the thorax, for example, to search for retrosternal goiter. Although ^{99m}Tc-pertechnetate with its 140 kev gamma photon or ^{123}I with its 190 kev gamma photon may suffice, the 364 kev gamma photon of Iodine-131 appears best for this specific purpose.

XI. Blood Pool Studies.

1. Excessive contrast enhancement on rectilinear scan cardiac blood pool studies. The detection of a pericardial effusion using the rectilinear scanning method depends upon a comparison of the transverse diameters of the cardiac blood pool activity and the

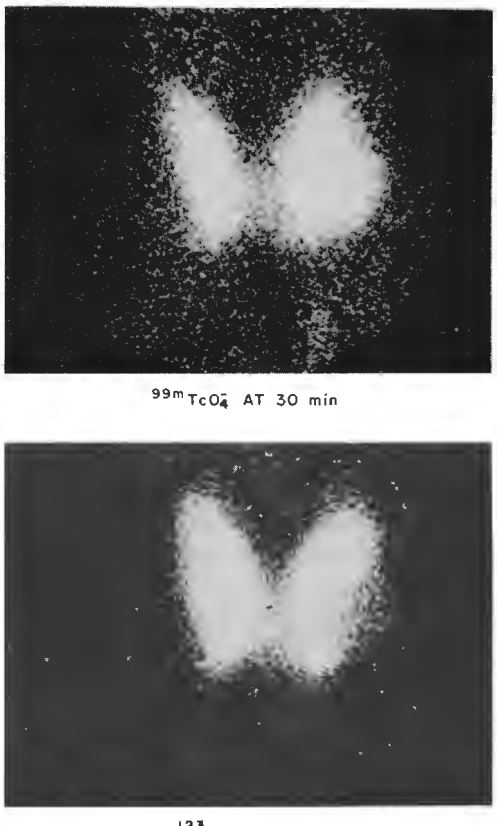

Fig 15—Technetium-99m-pertechnetate concentrating in a thyroid nodule that is "cold" on Iodine-123 scan. Patient had palpable nodule in low lateral portion of left thyroid lobe. The radioiodine scintiphoto (*bottom*) shows this nodule to be hypofunctional ("cold"), while the pertechnetate study reveals good function in the same area. (See text for explanation). The nodule turned out to be an adenoma, but the diagnosis of carcinoma could not have been excluded.

cardiac silhouette as seen on a 6-foot supine chest radiograph. Excessive contrast enhancement can falsely "shrink" the size of the radionuclide blood pool and create the erroneous impression of an effusion in cases where it might not exist.

2. Leakage of pertechnetate into pericardial effusions. If ^{99m}Tc-pertechnetate is used as the tracer for blood pool studies, diagnostic images should be obtained within the first 20 to 30 minutes after injection. Studies obtained at one hour or later may be falsely negative since pertechnetate slowly diffuses into pericardial effusions masking the "halo" that is observed in positive camera studies (30).

3. Poor labeling of Indium-113m chloride to transferrin in patients with receptor site saturation. When ^{113m}In chloride is used as the tracer for a blood pool study (particularly placental localization), it binds in vivo to transferrin, a serum globulin that is essential to the transport of iron. In cases of excessive iron ingestion or hemochromatosis, the transferrin receptor sites are bound. Subsequently administered ^{113m}In chloride will remain unbound and will appear in the kidneys. The desired blood pool will not be well visualized (31).

Case shown in Figure 8 courtesy Charles J. Blatt, MD.

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Figure 15 is reproduced from Atkins H, *The Thyroid in Clinical Scintillation Imaging*, Freeman LM, Johnson PJ (eds), New York, Grune & Stratton, 1975, by permission.

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