Radionuclide Imaging Evaluation of the Patient with Trauma

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Trauma is now a major medical problem. Accidental injuries constitute the fourth leading cause of death in the United States, and the primary cause of death below the age of 37.

The costs of immediate medical and surgical care, prolonged hospitalization, and lost productivity amount to several billions of dollars annually.

Nuclear medicine techniques have an important place in the evaluation of the injured patient. In general, they are rapid and noninvasive. They can provide functional as well as anatomic information. The sensitivity is often greater than that of routine radiographic procedures, particularly in the evaluation of bone lesions. The accuracy of imaging in evaluating traumatic damage to the skull and abdominal organs approaches or equals that of angiography.

An awareness of the wide range of examinations available to the physician who must evaluate and treat the injured patient is necessary if these extremely useful techniques are to be utilized.

The following discussion will describe the radionuclide procedures used in diagnosis of trauma and their clinical usefulness. For review of the literature and extensive documentation of the studies and results explained below, the reader is referred to the articles listed at the conclusion of this discussion (1-4). Specific citations will not be made here, except for studies not included in these reviews.

I. Central Nervous System Trauma.

A. Brain Imaging: Radiographic examination of the skull provides minimal information in the patient with head trauma. The presence or absence of linear skull fracture has no demonstrable relationship to the presence of significant intracranial damage (5, 6). Contrast angiography is highly specific and provides high-resolution studies of the intracranial vascular tree and traumatic mass lesions. However, it is expensive and uncomfortable and has a significant morbidity.

Radionuclide studies are more revealing than plain films. They are also less expensive, less uncomfortable, and far less invasive than angiographic procedures and can provide useful information about intracranial blood flow and traumatic damage.

1. Extracerebral hematomas. Subdural hematomas are found in 55% to 70% of patients succumbing to head injuries. Epidural hematomas occur about one-fifth as frequently. The patient with an

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acute collection may be too seriously injured to be studied, but imaging studies can be quite useful in the patient with a chronic subdural or, more rarely, chronic epidural hematoma.

In subdural hematoma, caused by rupturing of cerebral veins passing through the subdural space en route to the venous sinuses, the blood first clots and may liquefy in two to four days. A fibrinous pseudomembrane forms during the next ten days, followed by development of a true fibrous membrane by three to four weeks.

The most popular radionuclide for evaluation of cerebral collections is ^{99m}Tc-pertechnetate. More recently, ^{99m}Tc-DTPA, -glucoheptonate, -diphosphonate, and -citrate have been successfully used and in selected cases may prove superior to pertechnetate (7, 8, 9). It is not certain whether the accumulation of nuclide in the subdural fluid or in the membrane accounts for the appearance of activity on the brain scan. Certainly, scans are more likely to be positive late in the course, when membranes are well-developed, than early, before they have formed.

The typical appearance of an extracerebral hematoma is a "hot" crescent seen on anterior and posterior static views, with little or no abnormality on lateral view (Fig 1). The crescent appearance is not specific, and can be seen in many intra- and extracranial lesions, including scalp trauma, skull fracture, craniotomy defect, unilateral Paget's disease, meningitis, cerebral contusion or hematoma, infarct, and tumor. False-positive crescents can be caused by rotation of the head. The intracerebral location of some of these conditions can often be determined on lateral views, where the circumscribed nature of the increased activity can be quite different from the diffuse increase seen in subdural hematoma. Of course, peripheral intracerebral lesions may be difficult to differentiate. Correlation with physical findings, radiography, and dynamic imaging (see below) is necessary in evaluating the crescent sign.

Another, much less common, appearance of a subdural hematoma is the "rim sign," a curvilinear area of increased activity adjacent to an area of decreased activity. It is probably caused by displacement and compression of normal brain by the extracerebral collection.

The appearance of epidural hematomas is less extensively documented because fewer patients have been studied. The patterns appear to be the same as those of subdural hematoma.

Extracranial lesions can often be ruled out or confirmed by performance of dynamic brain imaging (Fig 1). A bolus of 10 to 15 millicuries of the radionuclide is injected rapidly into a peripheral vein. The Oldendorf technique of arterial occlusion may be used, but is probably not neccessary for this purpose. A simple tourniquet and relatively quick injection of a high-activity, low-volume ($\sim$1 ml) bolus usually is adequate. The patient's head is positioned under the gamma camera before injection, usually in the anterior position unless a posterior site of injury indicates the need for a posterior study. Images are obtained every 2 to 3 seconds for 15 to 25 seconds. Static images in anterior, posterior, and both lateral positions are then obtained immediately and two to four hours later.

The diagnostic accuracy or sensitivity of the brain scan ranges from approximately 50% during the first ten days after trauma to 90% thereafter. The results in children are somewhat less impressive, in

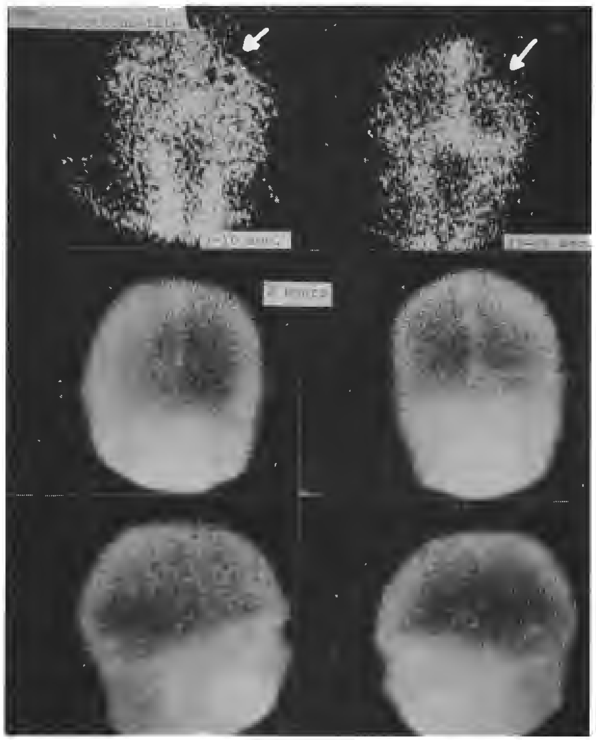


Fig 1—Right subdural hematoma. The initial 2 frames on top are from the early posterior radionuclide angiogram. Note peripheral avascular zone superiorly (*arrows*). The static views performed 2 hours later show a thickened right vascular rim on the sagittal projections associated with a diffuse increase in activity over the hemisphere on the right lateral view. Compare this latter finding with the normal left lateral view.

the range of 60% to 75%. Dynamic imaging has reportedly raised the diagnostic accuracy of early studies to nearly 100%, but in some series has been positive in only half of proven cases of subdural hematoma. The sensitivity of the examination is improved by obtaining images several hours after injection and repeating equivocal studies after several days. This also decreases the problem of false-positives because of soft tissue scalp trauma, which demonstrates rapidly diminishing activity over several days.

A negative study does not rule out the presence of a small subdural collection. The resolving capabilities of cerebral angiography are unquestionably higher and its sensitivity approaches 100%. Radionuclide imaging should diagnose collections of more than 1 cm in diameter. It may be difficult to appreciate subdural collections by imaging when they are located in the posterior fossa, under the temporal lobe, or in other unusual locations.

Bilateral small collections may be deceptive since the observer cannot compare one side to the other. This is a particular problem in children, in whom bilateral collections are more common than in adults. However, the striking thickness of the vascular rim can suggest the diagnosis (Fig 2). The study should not be called truly negative unless delayed views are obtained and are normal. The incidence of positive scans increases over one to four hours after injection, and equivocal studies can be definitely diagnostic if delayed imaging is performed.

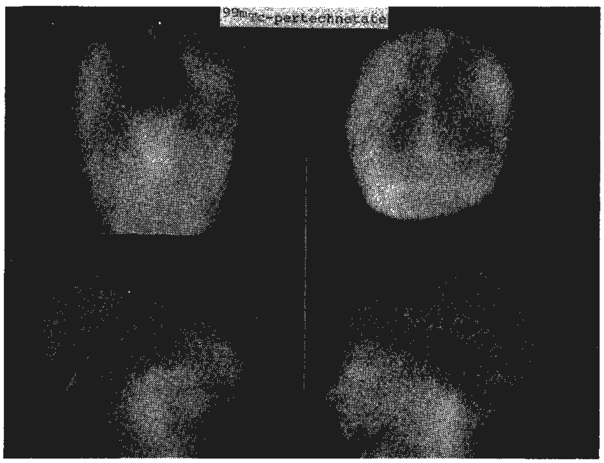


Fig 2—Bilateral subdural hematomas. This static scintiphotographic study was performed 2 hours following injection. Thickening of both vascular rims on the sagittal projections is associated with a diffuse increase in uptake over both hemispheres on the lateral views.

2. *Intracerebral hematoma and contusion.* Few cases of intracerebral hematoma have been reported, probably because the acute nature of the patient's condition often precludes radionuclide evaluation. However, the appearance of a well-defined area of increased activity within the brain, on all projections, has been described. The appearance is indistinguishable from tumor, abscess, or infarct, and the study must be interpreted in context and sometimes repeated. Again, delayed imaging will lead to more positive diagnosis. The sensitivity of the study is about 65% to 75%.

Contusion may present a similar appearance on imaging studies, but no definite mass can be seen when angiography is performed. The scan returns to normal over several weeks. More often, the scan in cases of contusion is normal.

3. *Radionuclide cisternography.* This is a more difficult and invasive procedure than brain scanning, and because of the risk of aseptic meningitis, causes a higher morbidity. However, in certain instances it can reveal very useful information. A small volume containing 0.5 to 1.0 millicuries of ^{111}In-DTPA is introduced directly into the subarachnoid space via lumbar or cisternal puncture. Sequential views in lateral and anterior positions over the spine and skull are necessary.

The study can be used to detect CSF leaks from the spinal canal (10) (Fig 3) or skull. In the latter case, nasal pledgets can be left in place for later counting as an aid in detecting leaks through the frontal sinuses, cribriform plate, sphenoid sinus, and petrous bone. If proper techniques are employed, the accuracy of the procedure is quite high (>90%). After a leak has been seen, rectilinear scanning may be performed for more exact correlation with skull x-rays in determining the surgical approach.

The syndrome of normal-pressure hydrocephalus can occur after traumatically induced subarachnoid bleeding. The mechanism is presumed to be obstruction of usual CSF absorption pathways by adhesions. Abnormal CSF flow patterns can be detected by radionuclide cisternography. Serial imaging at 1, 6, 24, and 48 hours demonstrates filling of dilated ventricles at 24 hours without the normal activity over the hemispheres, and ventricular stasis at 48 hours.

II. Liver and Spleen Injury.

The liver is injured in 5% to 10% of patients suffering blunt abdominal trauma, and is the most commonly injured organ in penetrating abdominal

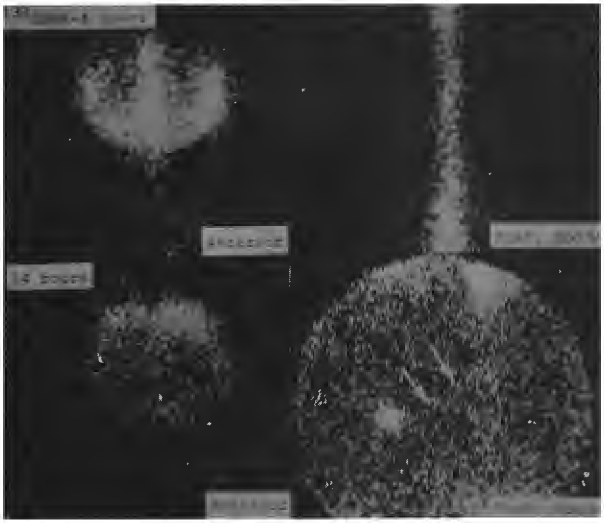


Fig 3—Spinal cerebrospinal fluid leak. The patient was a 50-year-old man who developed right lower extremity weakness following a stab wound of the low back. *Upper Left.* Posterior Anger camera scintiphoto of head 4 hours after intrathecal C1-C2 injection of ^{131}I-Human Serum Albumin shows normal distribution of activity in basal cisterns. *Upper Right.* Posterior view of the dorsolumbar spine at 4 hours shows normal uniform distribution of activity. *Lower Left.* Posterior view of head at 24 hours shows normal progression of tracer over convexity. *Lower right.* Posterior view of lumbosacral spine at 24 hours shows oblique band of activity (*arrows*) running between subarachnoid space and site of stab wound (hot spot marked by ^{57}Co source). Band represents CSF-cutaneous fistula.

trauma. The spleen is ruptured or lacerated twice as often as the liver in blunt abdominal trauma. The mortality of liver damage is higher than that of the spleen, accounting for as many as 30% of the deaths occurring after closed abdominal injury.

Clinical and laboratory data are often nonspecific, as are plain films of the abdomen. Radionuclide imaging is as reliable as angiography (see below) and does not require arterial puncture or injection of large doses of hyperosmotic media.

Examination is performed within a few minutes after injection of 1 to 3 millicuries of ^{99m}Tc-sulfur colloid. Anterior, posterior, and lateral views are absolutely necessary. Oblique and angled views are often needed for full evaluation of the spleen (see below). Some investigators have found dynamic imaging useful, but its role is less vital than in skull, renal, and vascular injury.

Laceration of a solid organ causes a linear or focal defect in the visualized activity (Figs 4, 5). A localized hematoma causes a round or wedge-shaped defect that, on appearance alone, can be indistinguishable from tumor, abscess, cyst, or infarct. A bipartite or accessory spleen may simulate transection, but this has not yet been a clinical problem in our experience. Subcapsular hematoma causes a flattening of the border of the liver or spleen, and separation of the organ from the body wall or diaphragm, but the latter is difficult to discern on radionuclide imaging, and variations in normal organ position can be deceptive. Patchy or inhomogeneous uptake may also be seen and, in the liver, must be differentiated from cirrhosis.

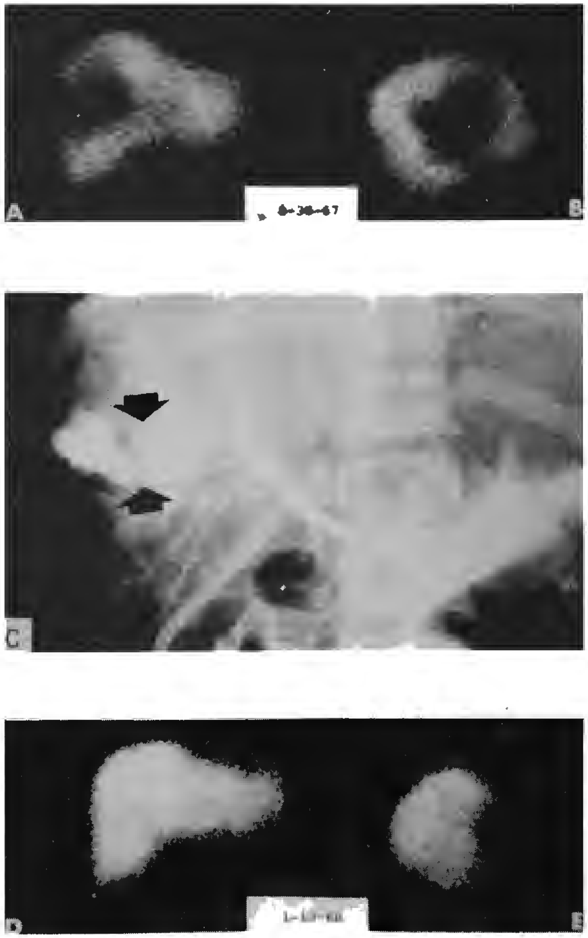


Fig 4—Liver laceration and hematoma in young male adult after motorcycle accident. *A* and *B* are anterior and right lateral ^{99m}Tc-sulfur colloid liver scintiphotos, respectively, which show a large right lobe defect. In *C*, selective hepatic angiography shows pooling of opaque material in a large cavity (*arrows*) which corresponds to the defect seen on scan. This represents pseudoaneurysm with hematoma formation. *D* and *E* are scintiphotos obtained 5 months after surgical repair. The tremendous regenerative ability of hepatic tissue is demonstrated.

No false-negative results have been reported in diagnosing hepatic injury. The incidence of false-positive scans is quite low, on the order of 3% or less (Table 1). Because no clinically significant injury will apparently be missed, it is a suitable screening test for liver damage. Angiography can be reserved for equivocal cases or when precise anatomic definition is necessary for surgery.

Spleen imaging has led to a correct diagnosis in about 90% of more than 200 cases reviewed (Table 2). In terms of clinically significant splenic damage, the accuracy of the procedure is even higher. Intraparenchymal extravasation or "puddling" as seen on angiography is not a criterion for surgery if it is the only demonstrable abnormality; such a case accounts for one of the so-called "false-negative" cases reported. A proven subcapsular hematoma has been missed scintigraphically, since the expected flattening of the splenic border was not present.

Attention to positioning of the detector head and knowledge of the relationships of the left hepatic

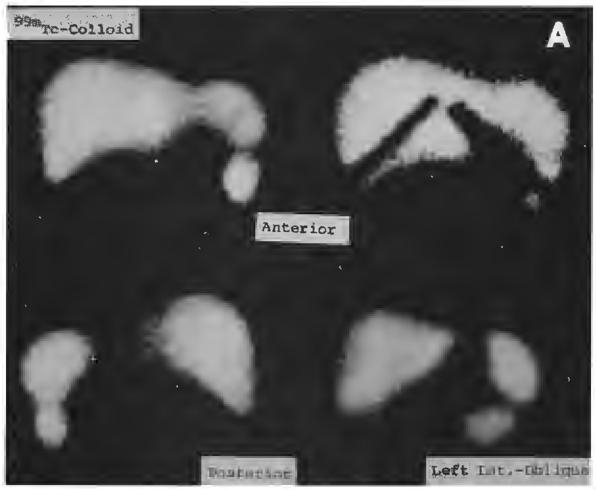


Fig 5—Ruptured spleen in a 9-year-old boy after trauma. *A*. ^{99m}Tc-sulfur colloid scintiphotos show a large spleen with a wide lucent band through the midportion. *B*. Selective celiac angiogram also shows the wide defect seen in the splenogram. *C*. Longitudinally cut surgical specimen confirms the rupture through the midbody of the spleen.

TABLE 1
Liver Imaging in Abdominal Trauma

Study	No. of Patients	True Negative	False Negative	True Positive	False Positive	% Correct
A	119	100	0	17	2	98.3
B	19	16	0	3	0	100
C	8	3	0	5	0	100
D	16	15	0	1	0	100
	162	134	0	26	2	98.7

lobe to the spleen can minimize the chance of false-positive diagnosis of spleen injury. Angling and obliquing the detector allows visual separation of the spleen from the overlapping left hepatic lobe, which, in the straight posterior postion, may simulate a wedge-shaped defect in the spleen (see accompanying article on pitfalls and artifacts in this issue). Rib impressions may also simulate lacerations, but can be suspected by the orientation of the defect and ruled out by obtaining views with a lead strip marker in place over the rib.

With an unequivocally normal study, further examination of the spleen and liver is usually unnecessary. A critically ill patient with a definitely abnormal scan requires surgery. In cases of equivocal imaging findings or atypical history or physical examination, angiography may be necessary for further evaluation. This is particularly important when there is a possibility of subcapsular hematoma, which can lead to delayed rupture. However, despite the superior resolution of angiography, sizable lesions may be missed, possibly because it is difficult to obtain multiple projections (Fig 6).

Any patient with trauma to the left upper quadrant should be evaluated for possible kidney injury in addition to splenic injury.

III. Genitourinary Tract Injury.

Although penetrating wounds and iatrogenic damage such as renal biopsy and surgery account for a number of renal injuries, about 90% are the result of blunt abdominal trauma, predominantly automobile accidents. Severe renal injury is not so often an immediate threat to life, as is severe hepatic or splenic injury, except in cases of penetrating injury. However, the late sequelae of renal parenchymal loss can be serious and include hydronephrosis, calcified hematoma, calculi, pseudocyst, and scarring and arterial injury leading to hypertension.

Minor renal damage occurs in the majority (65%) of instances of renal injury, according to the widely used classification of Hodges, et al. Contusion is the commonest minor injury. Major disruption of the parenchyma, with rupture of the capsule, extension into the collecting system, and/or segmental vascular occlusion accounts for 30% of renal injuries. Critical injury, with disruption of the renal hilus with its major vessels, is rare.

Although the intravenous urogram, preferably with a high dose of contrast media, is usually the first examination performed in the patient with suspected renal injury, studies of diagnostic quality cannot always be obtained. A rapidly running intravenous

TABLE 2
Spleen Imaging in Abdominal Trauma

Study	No. of Patients	True Negative	False Negative	True Positive	False Positive	% Correct
A	119	91	0	24	4	96.6
B	19	14	0	5	0	100
C	32	19	1	11	0	93.7
D	16	2	1	12	1	87.5*
E	16	9	0	7	0	100
	202	135	2	59	5	96.0

* False-positive can be avoided. False-negative was insignificant puddling. (see text).

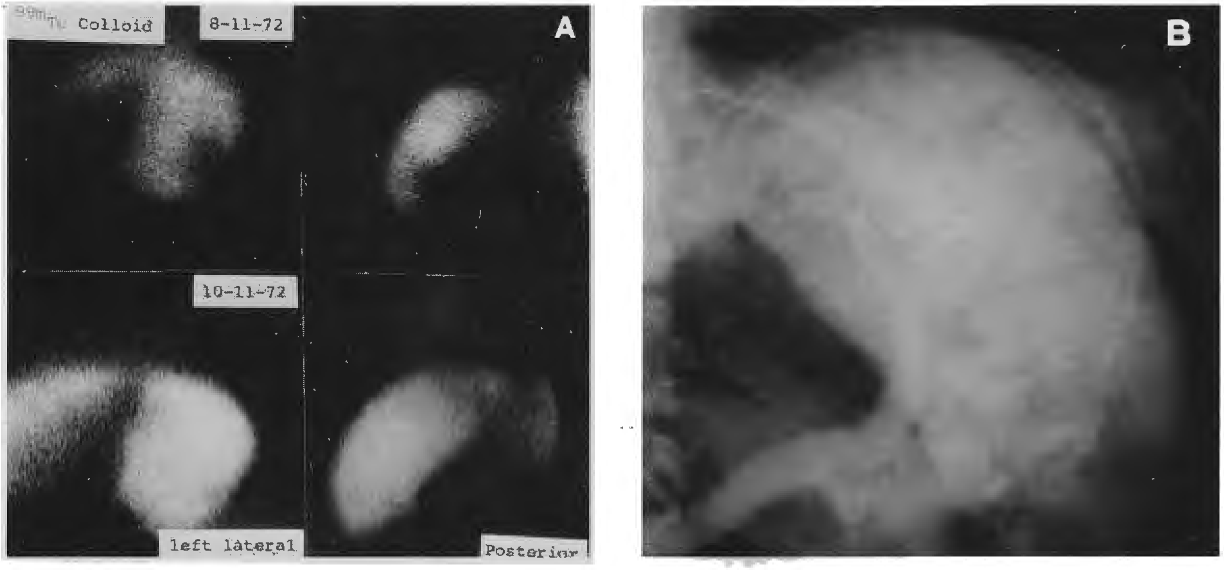


Fig 6—Minor nonsurgical spleen injury in 33-year-old man after stab wound. *A*. A ^{99m}Tc-colloid study at the time of injury (*top row*) shows a focal area of decreased uptake along the posteromedial border. Angiogram performed at this time is shown in 6*B*. Repeat radionuclide study two months later (*bottom row*) in the same left lateral and posterior veiws show disappearance of the abnormality. *B*. Selective splenic angiogram (late phase) at time of injury in anteroposterior position fails to show the abnormality seen on the scintigraphic study. Apparent lucencies over the lower portion of the spleen represent bowel gas.

line can cause significant dilution of the contrast media, and overlying gas and feces can interfere with interpretation.

Radionuclide examination, in dynamic and static modes, provides information about the vascular supply of the kidney, parenchymal integrity, and excretory function, combining some aspects of both urography and angiography. For dynamic imaging, a 10 to 15 millicurie bolus of one of the ^{99m}Tc-labeled renal agents is injected rapidly into a peripheral vein, preferably the antecubital. Beginning 6 seconds after injection, 2- to 3-second exposures are obtained until approximately 30 seconds after injection. If rapidly filtered ^{99m}Tc-Sn-DTPA is used, immediate and serial scintiphotos over a 30-minute period are made. If one of the agents that is fixed to the tubules is used (^{99m}Tc-iron-ascorbate, ^{99m}Tc-glucoheptonate, or ^{99m}Tc-DMSA), one- and two-hour static delayed images are obtained. The ^{99m}Tc-labeled compounds have largely replaced ^{197}Hg-chlormerodrin as cortical imaging agents because of more favorable physical characteristics.

The posterior view is used for renal imaging. A diverging collimator is helpful for imaging large adult patients, in order to image both kidneys simultaneously in one field, but is not necessary in the average adult or in children. Delayed imaging of the bladder is done in the anterior position.

The commonest renal injury, cortical contusion, may cause early diminished blood flow on dynamic imaging and persistent defect or sometimes generalized decreased activity on delayed imaging (Fig 7). A persistent focal defect is difficult or impossible to differentiate from infarct or hematoma. Infarct will remain as a defect on follow-up imaging, while contusion may resolve over two to four weeks (Fig 7). Hematoma may resolve or progress to infarct.

If no activity is seen to reach the kidney on dynamic and subsequent static imaging, renal arterial occlusion or other disruption of the renal hilus must be suspected. This is an indication for immediate surgical intervention to attempt salvage of renal function. Arteriovenous fistula caused by trauma or renal biopsy is apparent on dynamic imaging as an area of early intense activity and rapid washout.

A fragment of lacerated or fractured kidney may demonstrate diminished perfusion early and increased activity late, but the associated linear defect dividing the kidney into more than one fragment often distinguishes this pattern from contusion.

Extravasation of activity can be seen in

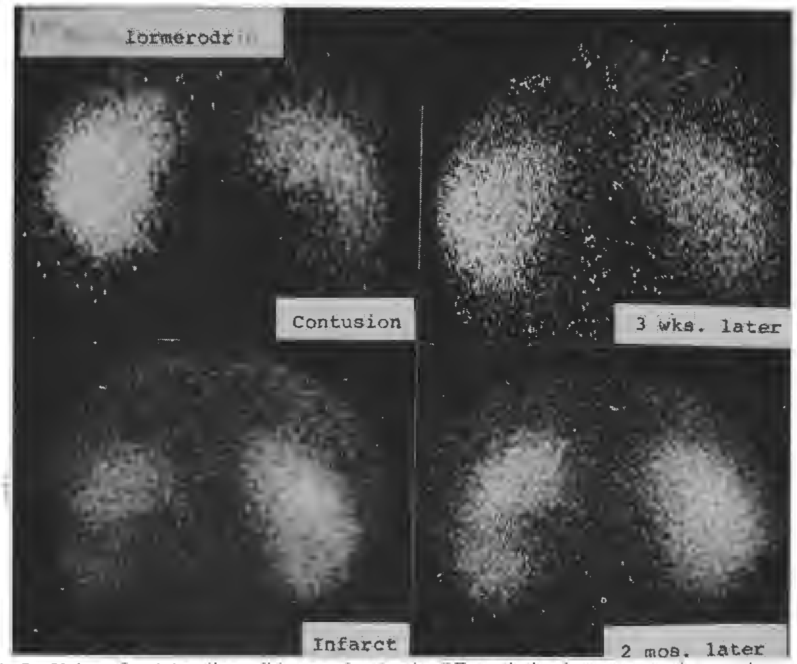


Fig 7—Value of serial radionuclide examination in differentiating between renal contusion and infarction. Posterior ^{197}Hg-chlormerodrin scintigraphy following blunt trauma (*top row*) shows diminished activity in the medial portion and lower half of the right kidney. Repeat study 3 weeks later demonstrates considerable improvement in the appearance of this contused kidney. Sequential radiochlormerodrin study in another patient with blunt trauma (*bottom row*) shows a band of decreased activity through the midportion of the left kidney, which remains relatively unchanged after 2 months. Subsequent studies showed no change over 4 additional months. An area of contused parenchyma seen below the infarct shows marked improvement on the 2-month study. This patient is being followed closely for the possible development of hypertension.

parenchymal and pelvocalyceal tears (Fig 8), and the chances of demonstrating it are increased if early and late scintiphotos are obtained. Extrarenal collections such as retroperitoneal hematoma, urinoma, and lymphocele (following renal transplant) cause voids in the visualized background activity and distort the urinary tract structures by their mass.

When total nonfunction of a kidney is seen on urography, and on dynamic and static renal imaging with a cortical agent, radiohippuran studies may be useful in determining the presence of functioning renal tissue. Hippuran I-131 is also useful in measuring renal function in cases where post-traumatic compromise is suspected and in following renal function in these cases.

Radionuclide examination compares favorably to angiography in detection and delineation of renal injury. It is reportedly superior to aortography in diagnosing mild to moderate renal injury such as contusion. Selective catheterization increases the diagnostic accuracy of contrast angiography, but also increases the morbidity of the procedure. Radionuclide imaging often is superior to urography in defining the extent of damage, and sometimes demonstrates injury that would be unsuspected from urography alone. The development of ultrasonography provides a method to determine the presence or absence of a kidney that shows no function on urography. This noninvasive technique, with the virtually noninvasive radionuclide techniques described, can decrease the instances when angiography is required for renal evaluation after trauma.

IV. Peripheral Vascular Injury.

Dynamic imaging can be useful in evaluation of acute vascular injury and its sequelae. The basic principle, as with other dynamic imaging procedures described above, is rapid introduction of high-specific-activity radionuclide in a small volume (less than 1 ml). Usually ^{99m}Tc-pertechnetate is used. However, when it is desirable to obtain multiple views of an injured area, the first injection may be made with a substance which is removed by an organ

Fig 8—Renal laceration. Renal scintiphoto performed one minute after injection of ^{99m}Tc-iron-ascorbate shows a "cold" area at the lower pole of the right kidney. A follow-up study one hour later clearly shows the laceration at the lower tip of the kidney with activity leaking into the area of hematoma.

during one pass through the circulation, for example, ^{99m}Tc-S-colloid by the liver. The background radioactivity is then reduced, and the second injection can be made with pertechnetate. Scintiphotos are obtained every 2 to 3 seconds for 15 to 25 seconds, and a static image of 300,000 counts is obtained at conclusion of the dynamic phase. A data processor allowing subsequent playback and analysis can be helpful in this as in other dynamic examinations, but is not absolutely necessary for clinical usefulness.

Extravasation into a paravascular hematoma can be seen early as an irregular collection of activity adjacent to a vessel. The activity may increase in intensity in static images. A well-defined circular area of early increased activity in the vicinity of a major vessel suggests pseudoaneurysm, not an uncommon finding several weeks after trauma (Fig 9). Traumatic arteriovenous fistula, as described in the section on urinary tract injury, presents a picture of early activity in the fistula and draining vein, with early washout. Iatrogenic arteriovenous shunts for dialysis can be studied in the same way. Traumatic occlusion of an artery will cause deficient activity in the area of its supply.

The venous system can also be visualized, if injection is made into the vein distal to the site of injury. Technetium-99m-MAA or microspheres are used for venous studies. Collateral circulation and actual sites of thrombosis or other occlusion can be demonstrated.

V. Skeletal Trauma.

The extensive use of radionuclide imaging in benign bone disease is a relatively new phenomenon, facilitated by the development of ^{99m}Tc-labeled phosphate complexes (polyphosphate, diphosphonate, and pyrophosphate). These compounds are relatively inexpensive, widely available, have convenient physical characteristics, and yield a low patient radiation dose, thus overcoming most of the objectionable qualities of previously used compounds. The body of literature on radionuclide imaging findings in trauma is small, much of the experience having been gained incidentally in study of malignant disease with ^{85}Sr, ^{87m}Sr, and ^{18}F.

With the ^{99m}Tc agents, bone imaging is performed two to four hours after intravenous administration of 10 millicuries of the phosphate complex in adults, or appropriately smaller doses in children. Total body scanning with a high-speed, dual-probe scanner or camera with moving table or detector accessories is desirable for potentially generalized problems. Localized studies are usually performed on the gamma camera, which yields high-resolution images with these compounds.

A useful area of examination in acute trauma is in detection of a bone bruise or fracture that may be difficult to detect radiographically, such as in the ribs, or in the vertebral column (Fig 10). In children, fractures may be difficult to detect because of incomplete ossification of the skeleton. Such sites of trauma can be appreciated on imaging studies, which depend on the hyperemia associated with reaction to trauma, rather than on mineral density of the bone. The pattern of injury in the appropriate context may suggest child abuse at a time when radiography is equivocal.

After two to three days, both actual fractures and periosteal or superficial bone injury without fracture may be "hot" despite negative radiographs (Fig 10). The activity decreases in intensity over a period of several months to years. The pattern of activity involving multiple bones can help distinguish trauma from osteomyelitis, which also can cause intensely "hot" uptake, but is not commonly multifocal.

Imaging is particularly valuable in following the

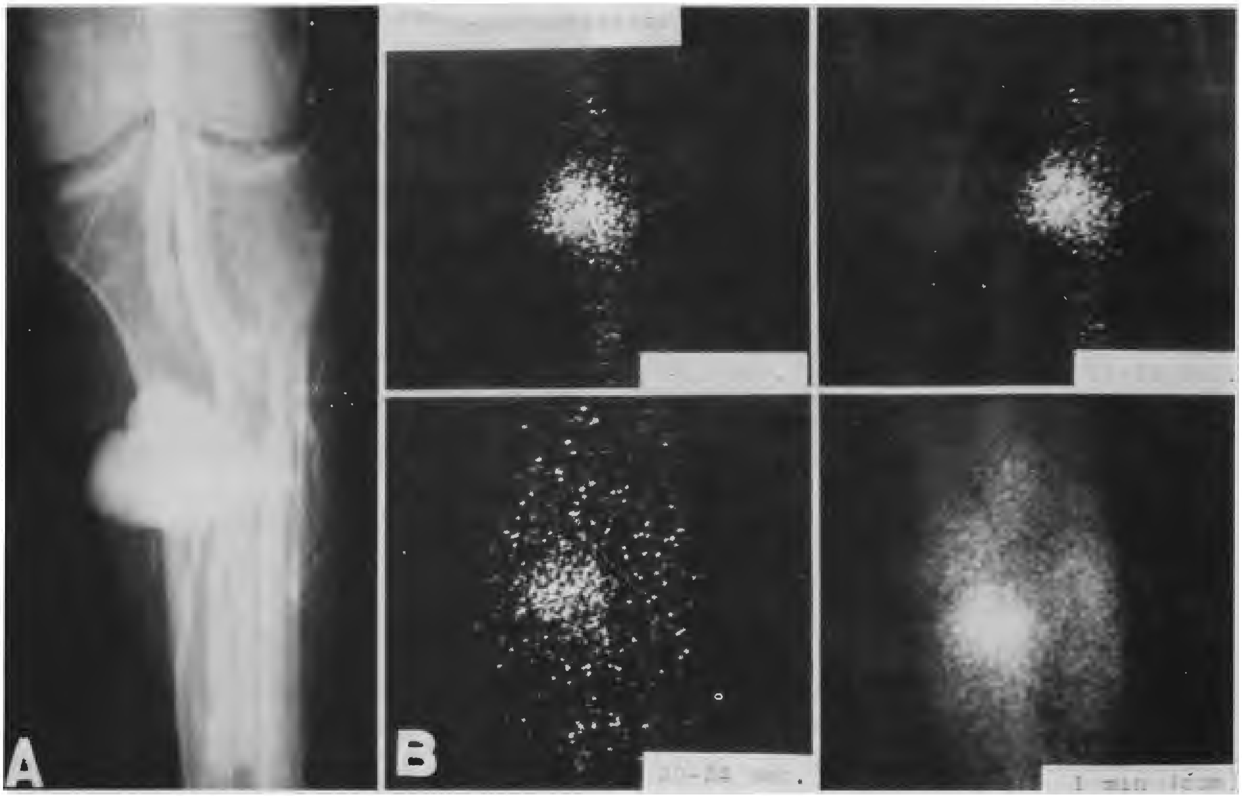


Fig 9—Pseudoaneurysm of left peroneal artery after stab wound. *A*. Angiogram demonstrates the presence of a large pseudoaneurysm with arteriovenous shunting in the distribution of the left peroneal artery. *B*. Serial scintiphotos performed over the knee area following a bolus injection of ^{99m}Tc-pertechnetate reveal a large collection of activity which remains long after the vessels empty. A one-minute static cumulative image shown at the lower right contrasts with the background vascular activity in the muscle mass of the leg.

healing process after accidental fracture or iatrogenic trauma such as osteotomy or bone graft. Activity bridging the gap in the bone will appear before radiographically visible bony bridging. Failure of this to occur predicts nonunion or pseudarthrosis formation.

The possibility of aseptic necrosis of the femoral head following subcapital fracture may be accurately predicted by demonstrating diminished activity early, with failure of activity to return after several weeks. Revascularization of an area of aseptic necrosis causes increased activity (11).

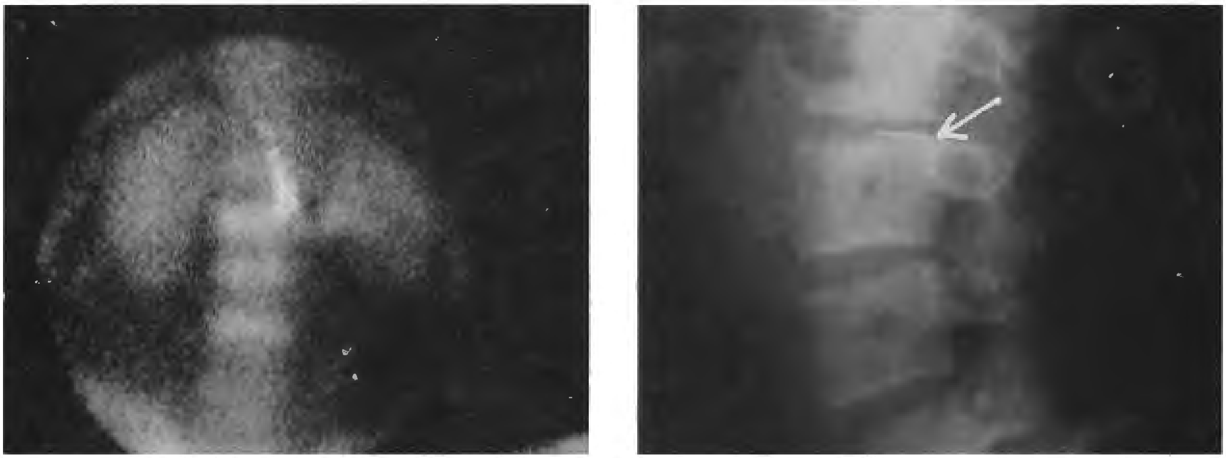
Artifacts of increased activity may be seen in soft tissue injury such as incisions or organizing hematomas, as well as in ectopic bone formation, following trauma and other insults. It is common to see diffusely increased activity over the upper hemithorax after mastectomy. Although this may be partly due to decreased photon attenuation by the smaller mass of overlying soft tissue, the absence of improved rib definition suggests that it is actually soft tissue activity. It must be differentiated from tumor recurrence, which can cause localized increased activity, and from malignant pleural effusion. The latter is generally more diffuse and is present on both posterior and anterior views.

Radiation injury to the bone, as to other organs, ultimately causes a sharply defined field of diminished uptake, although in the early post-irradiation period, activity may be greater than normal.

The ^{99m}Tc-phosphates are excreted by the kidney. Therefore, urine contamination must be avoided, especially in bone imaging of the pelvis and lower extremities, where it is likely to occur in the severely ill patient. The bladder should be empty in pelvic studies to avoid obscuring information.

VI. Chest Injury.

The methods of evaluating vascular and bone injury have already been described. Imaging has been used in evaluation of hemothorax and pulmonary contusion, but these studies do not actually add to the diagnostic capabilities of conventional radiography.



A. B.

Fig 10—Multiple spinal fractures seen on scintiphoto with only one fracture demonstrable on x-ray. The patient was a fireman who leaped out of a window landing on his feet. *A*. Posterior ^{99m}Tc-pyrophosphate bone scintiphoto 4 days after injury shows 4 active lumbar vertebral bodies. *B*. Lateral lumbar spine x-ray shows disruption of L3 superior vertebral plate (*arrow*). Multiple views failed to show any other evidence of fracture.

Traumatic hemopericardium, like other pericardial fluid collections, can be diagnosed by demonstrating a clear "halo" around the heart, separating it from lung and liver activity, during dynamic and static studies after administration of 10 to 15 millicuries of ^{99m}Tc-pertechnetate.

Fat embolism and "shock lung" cause multiple perfusion defects or diffuse inhomogeneity of activity on routine lung imaging with ^{99m}Tc-labeled macroaggregates of albumin or microspheres. Although the imaging findings are indistinguishable from pulmonary emboli of other etiologies, in the appropriate clinical setting the study may confirm the diagnosis.

Inhalation studies with ^{133}Xe may help to diagnose burns of the respiratory tract. Areas of delayed filling and slow washout suggest obstruction to air flow. This may be seen in chronic obstructive lung disease, foreign body, or bronchiectasis, but in the appropriate setting can confirm a suspicion of tracheobronchial injury or edema related to smoke or fume inhalation. If ^{133}Xe in saline is injected intravenously, perfusion defects can be documented, and subsequent rebreathing permits evaluation of ventilation patterns.

Conclusion. Radionuclide imaging provides useful functional and anatomic information about many organ systems, especially when dynamic and static phases are utilized. In any but the most acute patient in need of immediate lifesaving therapy and direct surgical intervention, these studies might well be considered a routine part of the evaluation. In many cases, invasive procedures such as angiography, myelography, and bronchography may be avoided, or at least limited in time and extent. Acceptably low radiation doses make multiple and follow-up studies reasonable.

By facilitating early treatment of traumatic injury in many cases, and by eliminating expensive and complicated procedures in others, the more widespread utilization of these techniques can help to decrease the tremendous human and economic costs of trauma.

Table 1 and Table 2 are adapted from Gilday and Alderson, *Seminars in Nuclear Medicine* (4:357–370, 1974).
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