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Splenic Imaging

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Summary

Before the advent of ultrasonography and computed tomography the spleen was an organ generally neglected by the radiologist. Today, there are five possible ways of splenic imaging: (1) plain radiography, (2) ultrasonography, (3) spleen scintigraphy, (4) computed tomography, and (5) splenic arteriography. The potentials and limitations of these different imaging modalities are discussed. Based upon a recent retrospective analysis of 194 cases with focal splenic lesions, an algorithmic pathway is suggested, where real-time ultrasonography is used as the first imaging method. In equivocal or negative results it is followed by CT which is the most accurate and best reproducible method. Nuclear medicine offers several important non-imaging function tests (e.g. red cell and platelet survival) but splenic scintigraphy is of minor importance except for the detection of aberrant spleens and splenic tissue. Selective splenic arteriography is rarely necessary for diagnostic purposes except the study of portal circulation but may become valuable again for transcatheter embolization ("medical splenectomy").

Diagnostic radiology offers several possible ways to obtain information regarding *size, shape* and *position* of the spleen. Selective angiography demonstrates the *vascular anatomy* of the spleen and is readily combined with interventional measures such as transcatheter embolization therapy.

The newer imaging modalities of ultrasonography and computed tomography offer non-invasive means of investigating the *internal structure* of this organ. In addition, nuclear medicine provides information related to physiological aspects of *splenic function.*

Our contribution examines the various imaging modalities including their relative usefulness in the diagnostic work-up of splenic disease.

1 Methods of splenic imaging

1.1 Conventional diagnostic radiography:

The spleen is normally surrounded by a considerable amount of retroperitoneal and intra-abdominal fat which renders its contours visible on *plain film* of the left upper abdomen. The lateral and inferior margins of the spleen are usually well discernible allowing measurements of the longitudinal diameter.

Anger and coworkers recommended low kVp-technique (50–55 kVp) in the supine position, 1 m film-focus-distance, and deep inspiration for conventional plain films of the spleen. Measurements of splenic length were performed from the highest point of the left diaphragm to the lower splenic border which was clearly seen in 91 % of their cases. By this technique, they obtained normal splenic longitudinal diameter of 12,8 ± 1,9 cm in 486 patients (1). This finding is in agreement with *Burhenne's* review of the anatomic and radiologic literature. He states that the average spleen measures 12 to 13 cm in axial length with a normal range between 10 and 15 cm (2).

The medial border of the spleen is rarely visualized on plain radiographs. The splenic contours, including the medial one, are better seen on *conventional tomography*, particularly, if combined with excretory urography. Opacifications of the neighbouring hollow organs: stomach, small bowel, colon, and excretory urography may be useful in cases with massive splenic enlargement in order to determine the degree of displacement or indentation. These indirect signs, however, are nowadays of limited value since there are better means to define splenic size.

1.2 Selective splenic arteriography

Selective splenic arteriography by transfemoral or transaxillary approach demonstrates the vascular anatomy, and, in some cases, provides information regarding lesions within the spleen.

For diagnostic purposes this invasive imaging method has almost entirely been replaced by ultrasonography (US) and computed tomography (CT). It is currently performed mainly for the study of portal circulation and for interventional measures.

Embolization of the splenic artery in the treatment of bleeding esophageal varices (3) as well as partial splenic embolization in hypersplenism has been recommended (4, 5). Various embolic materials have been used for "medical splenectomy" including absorbable gelatin sponge (Gelfoam), cyanoacrylate, Ethibloc, metallic coils, Ivalon and detachable balloons.

Discussion of the value and of the hazards of transcatheter embolization of the spleen is outside the scope of this review article on splenic imaging but will in parts be covered in the chapter on circulatory dynamics and preservation of splenic function in this issue.

It is worth mentioning, however, that splenic angiography often results in very inhomogeneous contrast distribution in the early arterial phase, which may be mistaken for disease (Fig. 1).

Castellino and coworkers observed this patchy vascular pattern in two thirds of histologically normal spleens removed in the course of staging laparotomy for Hodgkin's disease. The reason for the inhomogeneous contrast distribution is not entirely clear. Differences in blood flow velocity within different compartments of the spleen are discussed.

The same observation has been made in dynamic CT of the normal spleen (7). Even in splenic trauma where angiography used to be the diagnostic method of choice it has been replaced by CT (8, 9, 10).

1.3 Nuclear medicine

The ability of the spleen to phagocytose intravascular foreign particles and to recognize and destroy damaged erythrocytes is the basis of

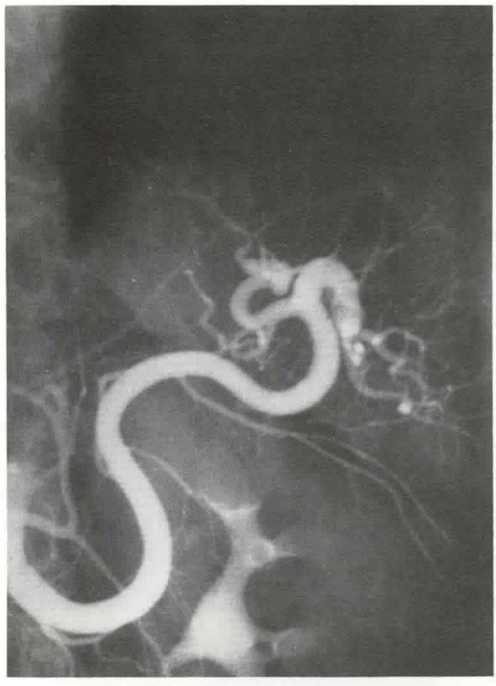


Fig. 1a

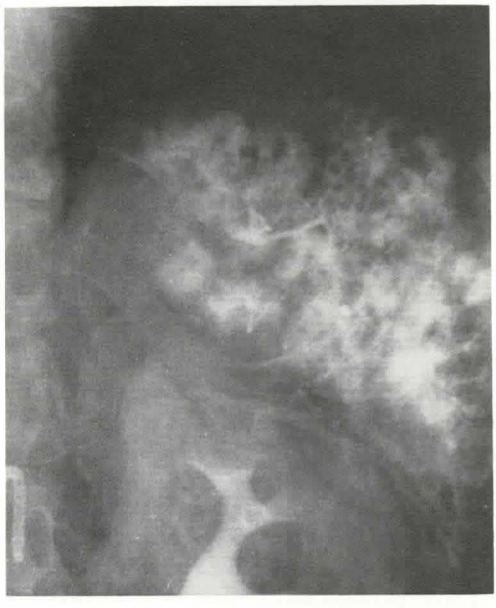


Fig. 1b

Fig. 1 Splenic arteriography. Normal findings
a) Early arterial phase demonstrating the characteristic curved course of the splenic artery and regular intrasplenic branching.
b) Late arterial phase showing inhomogenous contrast distribution due to variable rates of blood flow through different splenic compartments.

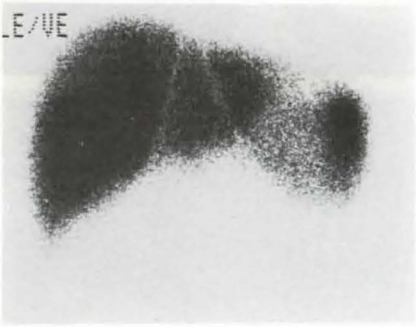
the present use of radiopharmaceuticals in spleen scintigraphy.

Chromium-51 labeled damaged erythrocytes first were utilized for splenic imaging by *Johnson* and *coworkers* (11). Currently, preference is given to technetium-99m to label autologous erythrocytes with cell membranes damaged either by heat or by an excess of tin (12, 13).

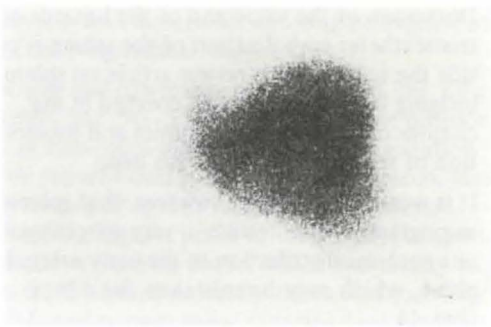
While most of the spleen scintigraphies are performed after i.v.-administration of radiocolloids, there is still a place for scintigraphy with radiolabeled damaged erythrocytes mainly for imaging accessory spleens or splenic tissue (splenosis) after posttraumatic splenectomy (15).

Red cell and platelet survival is determined by probe counting of chromium-51 kinetics over the spleen. Various other non-imaging radionuclide studies are available as routine procedures in nuclear medicine (14). The most widely used radiopharmaceutical for spleen scintigraphy is Tc^{99m}-sulfur colloid. Preparation of radiocolloid by means of commercial kits results in particles of approximately 200 μm average diameter. In normal humans only 5 to 10 % of i.v.-administered Tc^{99m}-sulfur colloid is taken up by reticulo-endothelial cells of the spleen while 80–90 % of the radiocolloid goes to the liver and 3–5 % to the bone marrow.

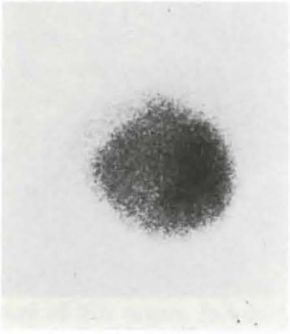
Routine views consist of an anterior and posterior view of the left upper quadrant and a lateral view of the spleen and left lobe of the liver (14) (Fig. 2). As in conventional radiography spleen size is best determined by measuring the longitudinal diameter in the posterior view. By this technique the normal value is



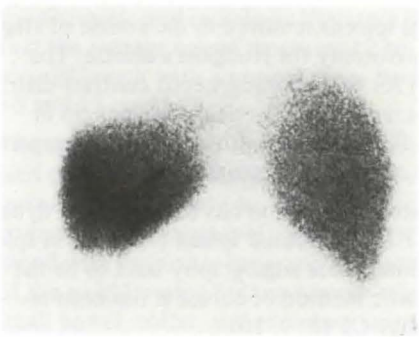
a) Supine position



b) Right lateral decubitus



c) Left lateral decubitus



d) Prone position

Fig. 2 Liver and spleen scintigraphy (Tc^{99m} sulfur colloid). Four standard projections. Normal findings.

Note that only a small amount of the radioactive material is taken up by the reticulo-endothelial cells of the spleen.

10,7 ± 1,7 cm with a maximum normal length of 14 cm (16).

1.4 Ultrasonography

The normal spleen may be difficult to visualize with compound technique because of its posterior and superior location in the left upper quadrant and the interposition of ribs.

The examination is much easier with real-time imaging since the spleen may be accessed from a posterolateral left lower intercostal approach, both in transverse and coronal sections, even with the patient supine. Occasionally, a right-lateral decubitus position with oblique scanning along the axis of the organ gives the best results (17).

In real-time ultrasonography one can observe the image while the patient slowly takes a deep breath in order to determine the best degree of inspiration to visualize the spleen (18). At our institution, only real-time ultrasonography is utilized for splenic imaging. Linear array scanner with rectangular format and electronically phased array sector scanners, both with 3.5 MHz transducers, are equally well suited.

The normal spleen reveals homogeneous, low level echoes throughout which tend to be of slightly lower intensity than those that originate from normal hepatic parenchyma (19) (Fig. 3).

Unlike of the liver, internal vasculature cannot ordinarily be identified except for patients with splenomegaly, where vessels of the splenic hilum can be clearly seen.

The contours along superior and lateral border are usually well defined and smooth. The undersurface and medial aspect may show focal impressions by adjacent viscera. Determination of splenic size, once again, is more easily performed by real-time imaging than by compound techniques. Both ultrasonographic methods, however, allow not only the determination of longitudinal diameter but also transverse diameter and thickness of the spleen. Thus, even volume measurements can be obtained (20). The average adult spleen measures approx. 12,5 cm in length, 7,5 cm in transverse diameter and 3,5 cm in thickness (17). Fortunately, most diseases cause enlargement of the spleen rendering it better visible for ultrasonographic imaging. However, focal defects in malignant lymphoma may also occur in normal sized spleens (21).

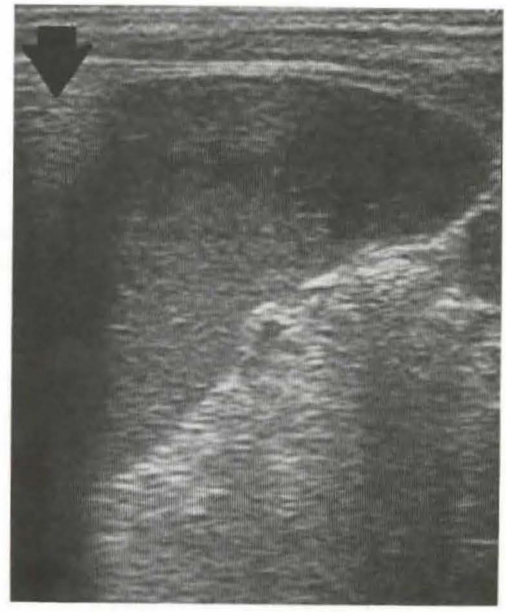


Fig. 3 Real-time ultrasonography of a normal sized spleen. Longitudinal section in supine position. The upper portion is overshadowed by air in the lower lung fields.

1.5 Computed tomography (CT)

The spleen is well demonstrated on CT scans of the abdomen in virtually every patient as an ovoid shadow with sharply defined borders and homogeneous soft tissue density. The hilum is usually directed anteromedially and the splenic artery and vein can be seen entering the spleen in this region in all but the thinnest of patients without intravenous contrast material. The close relationship between the spleen and neighbouring organs and their influence upon splenic shape is best demonstrated by CT. Measurements of splenic size can be performed as well or better as with other imaging modalities but experience shows that this is rarely needed.

In contrast, CT scans display so much variation in position and shape of the spleen from one patient to the next that measurements of this sort are of doubtful value (22).

As a rule of thumb, the total length should be under 14–15 cm and the splenic tip should not extend caudally as far as the tip of the right lobe of the liver (23). Precise volume determinations can be made if necessary by adding the volumes of contiguous slices (24).

Absolute attenuation values of the spleen are rather variable but a constant relationship between the density measurements of liver and spleen tissue was found in 100 normal adults. In this study CT values were consistently higher for the liver than for the spleen (25).

Sometimes it is useful to administer contrast material intravenously when it is difficult to separate the spleen from contiguous structures. Scans performed immediately after a bolus injection are helpful in evaluating soft tissue densities in the splenic hilar and retropancreatic region which might be due to normal splenic vasculature. However, one must be aware that inhomogeneous enhancement in dynamic CT does not indicate focal disease but reflects the variable rates of blood flow through different splenic compartments (7) (Fig. 4).

When the injection is made slowly, or several minutes after bolus injection, a uniform increase in density of splenic parenchyma results.

Attempts have been made to increase the attenuation values of liver and spleen selectively by means of i.v.-administered emulsified liposoluble contrast materials (EOE-13). While this compound, indeed, facilitates the detection of small focal defects, it is still hampered by marked side effects and, so far, has not been recommended for general use (26).

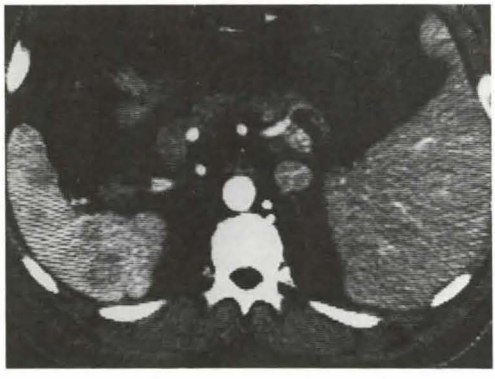
2 Normal variants and congenital anomalies

The spectrum of normal variations in size, shape and position of the spleen is very wide. These findings remained undetected by conventional radiographic examinations and it was CT and ultrasonography which brought this fact to our attention.

The spleen is rather soft and pliable in texture so that left upper abdominal masses can cause considerable displacement and deformity in its shape.

Change of position occurs after surgical removal of adjacent organs and from laxity of suspensory splenic ligaments ("wandering spleen").

The upside-down spleen is a variant in which



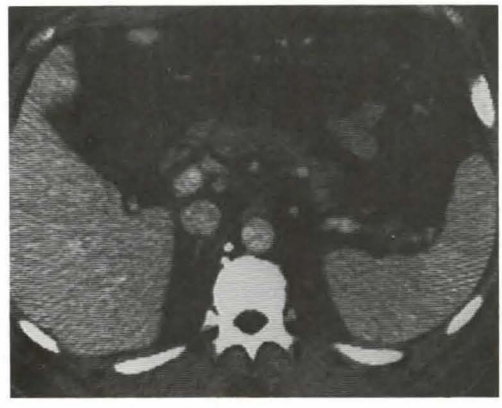


Fig. 4 Dynamic CT of the normal spleen

a) Immediately after i.v. bolus injection of 30 ml contrast medium. Hypodense focal areas due to lower blood flow rates ("compartmentation").

b) One minute after i.v. bolus injection. Homogeneous contrast distribution pattern.

the splenic hilum is directed superiorly toward the medial or lateral portion of the left hemidiaphragm (27).

Accessory spleens are found in 10 % to 30 % of unselected autopsy cases (28). They occur most frequently in the hilar region and may be completely isolated from the spleen or connected to it by a thin band of tissue. They vary from small deposits to nodules of 2–3 cm in diameter and they may resemble a pseudotumor in ultrasonography as well as in CT. Clinically they are of no significance except for patients after splenectomy where they tend to grow and may cause recurrence of clinical problems when splenectomy was performed for hematologic disorders.

Asplenia and *polysplenia* may occur as isolated anomalies but commonly are associated with cardiac defects, partial situs inversus and various other congenital abnormalities (29).

Detection of aberrant splenic tissue may be possible by CT but is probably most efficiently done by radionuclide scanning with radiolabeled damaged erythrocytes.

3 *Pathologic conditions*

3.1 Splenomegaly

Enlargement of the spleen may be subdivided into three categories depending upon the assessed splenic volume:

mild splenomegaly	150 – 500 ml
moderate splenomegaly	500 – 1000 ml
massive splenomegaly	over 1000 ml

The causes for splenomegaly are manifold (14, 19).

Imaging of an enlarged spleen can be performed by all the discussed methods. However, the amount of additional information which might help to differentiate the specific cause of splenomegaly varies considerably.

Plain radiographs of the left upper abdomen are sufficiently accurate to determine splenic size and to provide a reproducible, cost effective means of follow-up examination during the course of therapy, particularly in those institutions where experience with real-time ultrasonography is still limited.

At our institution, and increasingly in most other places, real-time ultrasonography is considered to be the method of choice for its accuracy, cost, and risk (2, 21). Although it does not determine the specific cause of splenic enlargement in all instances, there are usually at least indirect indicators of the underlying disease state.

Real-time ultrasonography is able to detect focal and cystic lesions within an enlarged spleen and, occasionally, even in normal sized spleens. Analysis of different echo patterns and correlation with certain diseases has been attempted, but these data are heavily debated and must still be considered preliminary (17, 19). A promising way of stochastic frequency-domain tissue characterization by analysis of digitized backscattered ultrasonic waveforms has recently been reported by *Sommer* and coworkers. They found statistically significant differences between normal and pathologic splenic tissue *in vivo* (30).

Radionuclide scanning is an alternative imaging modality. However, except for the non-imaging function studies mentioned, it really does not offer additional information to a good sonographic study.

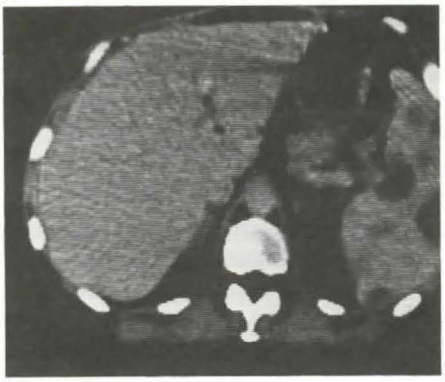
Computed tomography should be carried out in equivocal US-studies and to rule out a separate left upper quadrant mass (2).

CT demonstrates best the changes in shape associated with splenic enlargement. The concavity of the visceral surface is often lost when the spleen assumes a more globular shape (22).

More than any other imaging modality CT helps to evaluate the cause of splenomegaly by analysis of other abdominal structures (liver, lymph nodes) and of the splenic cross sections. A homogeneous increased density can be seen in hemochromatosis (31).

3.2 Focal involvement in malignant lymphoma

The spleen is often affected in patients with lymphoma of both Hodgkin's and non-Hodgkin's types. Diffuse involvement in normal sized spleens may occasionally be diagnosed by an increased echogenicity in US. However, a normal finding in US, CT and radionuclide scanning does not exclude microscopic involvement of the spleen. Focal defects in malignant lymphoma



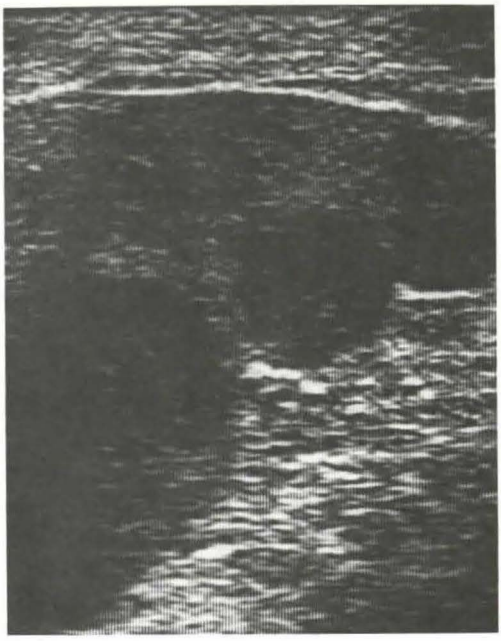


Fig. 5 Non-Hodgkin's lymphoma with nodular infiltration of the spleen

a) Above, real-time ultrasonography: round echo-poor lesions bulging the surface of the enlarged spleen

b) Right, corresponding CT scan without contrast enhancement: several hypodense areas within an enlarged spleen

can be demonstrated with either imaging methods. Ultrasonography reveals echo poor lesions which morphologically are not separable from focal defects of other origin (e.g. infarcts, metastases, abscesses without gas formation) (Fig. 5).

The same holds true for radionuclide scanning as far as the differentiation of focal defects is concerned. The detection rate in nuclear medicine is lower than in US because of its lower spatial resolution.

CT detects focal defects with a high degree of accuracy. In 55 histologically proven cases with nodular splenic involvement in malignant lymphoma (34 Hodgkin's disease, 19 non-Hodgkin's lymphoma) CT was positive in 52 cases. In 11 cases nodular involvement was seen in normal sized spleens.

The differentiation between nodular involvement in malignant lymphoma and other causes of focal defects is better with CT than with any other imaging modality. It is worth mentioning that in three of our patients the spleen harboured the first and only manifestation of a non-Hodgkin's lymphoma, which was diagnosed by CT prior to operation (Fig. 6).

3.3 Metastases

Metastatic involvement of the spleen is rarely diagnosed radiologically although it is not uncommon at autopsy. Clinical significance of that diagnosis is very limited since most patients already have liver metastases at the time splenic metastases are discovered.

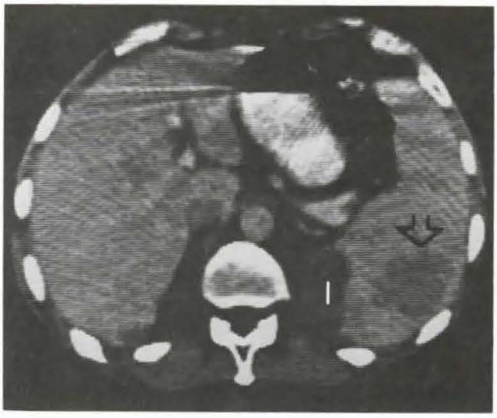


Fig. 6 CT of the abdomen. Enlarged spleen with nodular, hypodense lesion caused by chronic lymphatic leukemia (⇓) and a somewhat triangular defect due to splenic infarction (I). Findings confirmed at autopsy.

Thus, this finding would not alter the patient's therapy. The only exception to that rule is Hodgkin's disease where splenic involvement without hepatic disease is a frequent finding.

The most common primary tumor in splenic metastases is malignant melanoma. Other malignancies that metastasize to the spleen are carcinoma of the ovary, lung, breast, pancreas, and stomach (32).

3.4 Primary tumors of the spleen

Primary tumors of the spleen are extremely rare. In our own series of 194 cases with splenomegaly and/or focal lesions of the spleen only one malignant primary tumor was encountered.

3.5 Splenic cysts

Most splenic cysts are posttraumatic in origin. Histologically, the do not contain en epithelial lining and therefore are best referred to as pseudocysts (22).

Other cystic formations of the spleen include congenital epidermoid cysts and parasitic cysts from echinococcal infection. The latter often contain extensive calcifications within their wall.

Ultrasonographically, the well defined cystic lesion is pathognomic in most cases. In real-time studies one finds, occasionally, small moving particles within the fluid content of the cyst ("snow flurry") which sediment when the patient stops moving.

These particles represent remaining cellular elements from old liquified intrasplenic hematoma. CT examination shows a sharply demarcated cystic mass surrounded by splenic parenchyma or a thin pseudocapsule with attenuation values similar to or slightly above that of water (Fig. 7).

3.6 Trauma to the spleen

The spleen is a common site of injury in cases of blunt or penetrating abdominal trauma. Splenic rupture is a surgical emergency that has a significant mortality rate. Splenectomy used to be the treatment of choice; however, currently partial splenectomy or suturing of lacerations is attempted in order to avoid the sequela of postsplenectomy infection (33).

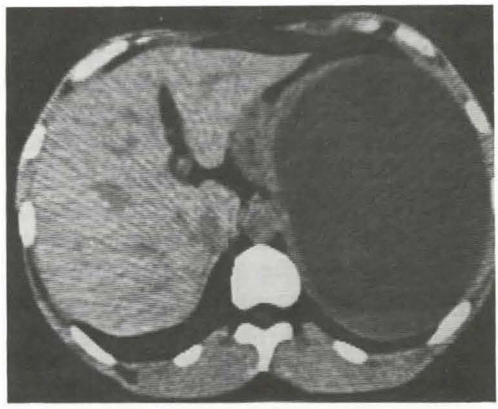


Fig. 7 CT of the abdomen. Large posttraumatic pseudocyst of the spleen.

A plain radiograph of the abdomen and chest is still probably the best initial radiographic examination in an injured person. Nonetheless, the classical plain film findings such as rib fractures, elevated left hemidiaphragm and splenic enlargement with loss of definition in the left upper quadrant are only present in about 20 % of patients with splenic rupture (34).

Real-time ultrasonography can give far more specific information provided there is not too much bowel gas overlying the left upper quadrant. The sonographic examination is further hampered by soft tissue injuries and bony fractures.

Sonographic signs of splenic injury include progressive enlargement and splenomegaly. A double contour to the spleen may be indicative of extravasated blood in a confined space between splenic parenchyma and the intact splenic capsule (17).

Enlargement of the spleen associated with free intraperitoneal fluid is the most reliable radiologic sign of splenic injury (2).

Fluid adjacent to the spleen and free in the peritoneal cavity may be detected with either real-time ultrasonography or CT.

Real-time ultrasonography is certainly faster and more widely available than CT. Its physical drawbacks have been mentioned.

CT has the advantage of being able to differentiate between fresh blood and fluid of other

origin by means of density measurements. In addition, concomitant intra- or extraperitoneal injuries including fractures can be diagnosed at the same if one utilizes the digital imaging facilities built into the newer CT-machines.

Contrast enhanced CT-studies help to differentiate subcapsular splenic hematomas particularly if one to two days old and isodense as compared to the intact splenic tissue.

Selective angiography of the splenic artery as an emergency study has been replaced by the two non-invasive imaging methods.

Radionuclide scanning is rarely used in the acute case but may detect subcapsular or intrasplenic hematomas as an incidental finding in patients presenting with left upper abdominal pain (14).

3.7 Inflammatory processes

Most splenic abscesses occur as part of a generalized infection, usually in immune-compromised hosts. This serious disease carries a 60 % mortality rate, mainly because it is often not diagnosed until the time of operation or autopsy (35).

The lesion can be detected by real-time ultrasonography, but there are no specific sonographic signs which allow separation from other focal defects. US-guided fine needle biopsy is a diagnostic possibility (19). CT appearance of splenic abscesses is similar to abscesses in other locations.

Typically, there is a hypodense or cystic lesion within the spleen, with attenuation values between 20–40 HU. The lesion itself does not enhance after i.v. contrast administration, but the rim may show contrast enhancement. The abscess may contain gas or reveal layering of material of different densities. Gas formation has also been seen after transcatheter embolization (36).

Homogeneous splenic enlargement also occurs in the course of inflammatory diseases. To rule out abscess formation real-time ultrasonography, CT and radionuclide scanning are equally well suited.

Healed granulomatous disease of the spleen can result in small punctate calcifications which are easily diagnosed on plain film and by CT.

3.8 Splenic infarct

Acute infarction causes a wedge shaped low density area, the base at the splenic capsule and apex directed toward the hilum (Fig. 8). This rather pathognomonic appearance in angiographic CT studies and in radionuclide scanning could not be confirmed sonographically. Here the infarcts appeared as rounded sonolucent structures which could not be distinguished from other focal lesions of the spleen.

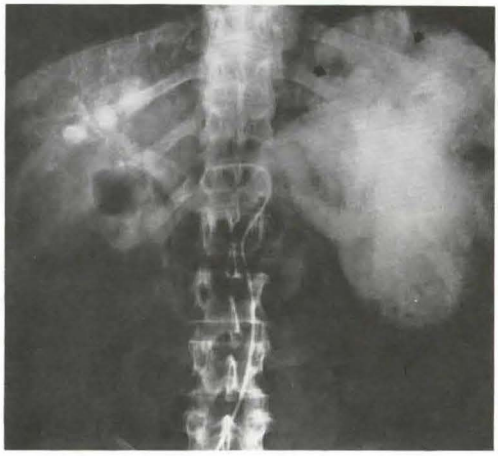


Fig. 8 Splenic arteriography, venous phase. Visualization of splenic and portal vein. Splenomegaly. Multiple wedge-shaped infarctions (⬇) subsequent to first step of transcatheter embolization using lyophilised dura mater particles.

4 Discussion and conclusions

Before the advent of ultrasonography and computed tomography the spleen was an organ almost always neglected by the radiologist unless injured, enlarged, or calcified. The attitude towards splenic imaging certainly has changed since modern non-invasive methods allow better distinction of diverse types of splenic pathology.

There are five possible ways of splenic imaging namely (1) plain radiography of the left upper abdomen, (2) ultrasonography, (3) nuclear medicine, (4) computed tomography and (5) splenic arteriography.

In a recent overview *Burhenne* suggested a differential selection of imaging modalities depending upon the clinical question to be answered (2). We recommended use of real-time ultrasonography as the first diagnostic step independent of the clinical question whenever the patient seems to be sufficiently cooperative for an ultrasonographic study. Very obese patients and those with skin wounds or bony fractures in the left upper abdomen must often be excluded.

The main advantage of real-time ultrasonography is its ability to visualize the spleen as well as the adjacent organs. Furthermore it is a sensitive way to detect fluid collections within the peritoneal cavity. Real-time ultrasonography in the hands of an experienced investigator is highly accurate and rapidly performed at reasonable costs. Thus, it is best suited for screening and for follow-up studies.

Computed tomography is currently considered the most reliable imaging method. Compared to real-time ultrasonography it is significantly less operator dependent, more reproducible and easier for referring physicians to comprehend. Its spatial resolution is higher than that of real-time ultrasonography and it can be carried out in injured patients provided they are able to hold their breath for one to five seconds depending upon the type of CT machine used. Focal lesions are oftentimes better seen in contrast enhanced scans. The problem of "pseudolesions" due to variable rates of blood flow in different splenic compartments must be kept in mind (7).

Lack of focal lesions in a normal sized or enlarged spleen does not exclude involvement in lymphomatous disease.

We recommend CT imaging of the spleen in equivocal or negative ultrasonographic studies as the second step. CT is also performed in lymphoma patients as part of their initial staging which is mainly directed toward the detection of retroperitoneal and mesenteric lymph node enlargement.

Nuclear medicine tests study physiologic or pathologic *function* of the spleen. In most instances these function tests are carried out by probe counting rather than by imaging methods. However, the detection of accessory spleens or splenic tissue after posttraumatic splenectomy can be performed with scintigraphy using radiolabeled damaged red blood cells. At our institution these are the only ramaining indications for selective spleen scintigraphy.

Plain films of the left upper abdomen with or without conventional tomography are rarely taken for splenic imaging. However, the splenic size, location, and contours can be analyzed in all emergency cases where plain radiographs of the entire abdomen are performed.

Similarly, the need for splenic arteriography has markedly decreased. Since most trauma cases involving the spleen currently are accurately diagnosed by CT very little indication remains for selective splenic arteriography. Beside equivocal findings in CT or real-time ultrasonography which might require an angiographic investigation most of our selective splenic arteriographics are performed for the indirect visualization of the portal vein. Occasionally, the catheter approach is used for partial or total embolization of the splenic artery ("medical splenectomy").

Thus, we suggest real-time ultrasonography as the first imaging modality to be used in suspected splenic pathology. If equivocal and/or negative, computed tomography should be next study. Splenic function is best investigated by non-imaging methods in nuclear medicine. Splenic scintigraphy offers no additional information, except for the detection of aberrant spleens or splenic tissue. Conventional radiography and selective splenic arteriography both currently play a minor role in splenic imaging.

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