EVALUATION OF SPLEEN SIZE DURING ROUTINE LIVER IMAGING WITH ^{99m}Tc AND THE SCINTILLATION CAMERA

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The presence or absence of splenomegaly is important in the differential diagnosis of numerous hematologic, infectious and neoplastic conditions. Unfortunately, spleen size is not well evaluated on physical examination. In one necropsy series, few of the spleens weighing 200–600 gr were palpated during life although those palpated were definitely enlarged (*1*).

Spleen size can be evaluated by radiography. To visualize the entire organ requires special contrast studies (*2*), but the spleen tip can be seen on plain films of the abdomen in over 50% of patients (*1*). Height from the spleen tip to the diaphragm is the simplest measurement. Based on necropsy cases, it has been said that if the height of the spleen on routine antero-posterior supine films in an average size adult is greater than 15 cm (13.6 cm corrected for magnification), there is a 98% probability that the spleen will weigh over 200 gm (*3*).

The spleen can also be visualized by scanning or imaging following the administration of several radionuclides. Chromium-51-labeled red blood cells which have been damaged by heating or sensitized by exposure to appropriate antisera are rapidly taken up and sequestered by the spleen. Brief exposure of red blood cells to 1-mercuri-2-hydroxypropane (MPH) or 1-bromomercuri-2-hydroxypropane (BMHP) labeled with either ^{197}Hg or ^{203}Hg simultaneously damages and labels the cells which are then sequestered by the spleen (*4*). Both techniques give good splenic visualization.

Radioactive colloids which are phagocytized by cells of the reticuloendothelial system are concentrated in the spleen as well as the liver and bone marrow. After standard doses of ^{198}Au for liver scanning, the spleen may be seen, especially if there is hepatic or splenic disease. The spleen is routinely visualized when ^{99m}Tc-sulfur colloid is used for liver scanning or imaging. Petasnick and Gottschalk have pointed out that the use of ^{99m}Tc-sulfur colloid and the scintillation camera for liver imaging permits the routine subjective evaluation of spleen size. However, they did not attempt to make quantitative estimates (*5*).

The present study was carried out to determine whether spleen size could be quantitatively evaluated by simply measuring organ height on routine ^{99m}Tc-sulfur colloid liver images obtained with the scintillation camera and whether it would be possible to set clinically useful criteria for splenomegaly with this technique in the hospital population.

METHOD

All images were obtained with a Picker "Dynacamera" scintillation camera on Polaroid film. The entire field was calibrated with a ^{133}Ba point source placed on a rectangular grid at 5-cm intervals to give a correspondence between spleen size and the image size on the film. The calibration was done several times on different days and was also performed with the source 0, 12 and 25 cm from the camera face and through 5 cm of water. From the images of the grid, a transparent scale was constructed to measure the camera image in centimeters of actual grid size. A water-filled phantom of the abdomen containing an 8 cm "spleen" filled with dilute radiocolloid was imaged in various positions at varying distances from the collimator face and with varying intensity of the film image.

A retrospective study was then made of 321 consecutive routine liver imagings in 316 patients obtained in this laboratory over a 15-week period. The patients had been routinely imaged in anterior, right anterior oblique, right lateral and posterior views although in a few patients who could neither sit upright nor lie prone no posterior view was taken. The spleen was measured to the nearest centimeter as

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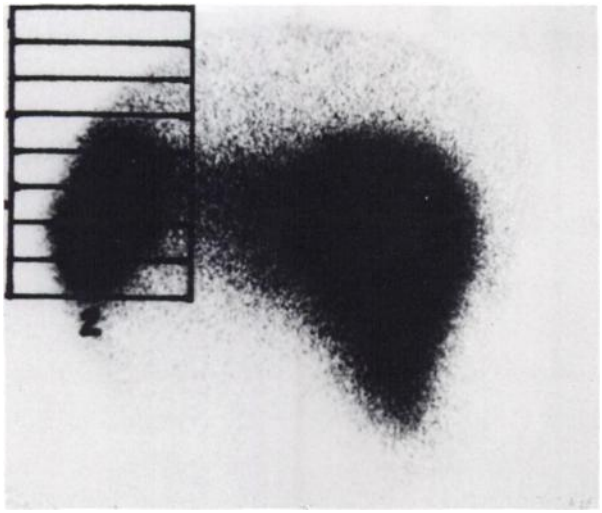

FIG. 1. Posterior image of "normal" spleen (reversed for clarity) with superimposed calibrated scale. Horizontal lines are 2 cm apart. This spleen was read as measuring 10 cm.

vertical height on the posterior image using the transparent scale (Fig. 1). If the posterior scan was not obtained or did not visualize the entire spleen, the anterior scan was used. Left lateral and left anterior oblique scans were also obtained on some patients. All measurements were made by the same person (RMS). In patients with normal liver scans or markedly enlarged spleens, the history, physical findings, laboratory studies and hospital course were reviewed from the charts.

The normal equivalent deviate (NED) plot was used to determine whether the frequency distribution of spleen sizes was consistent with a normal distribution. By the NED or probit method of analysis, the normal sigmoid curve of a cumulative frequency distribution is transformed into a straight line. If the plot is nonlinear, the population exhibits a skewed distribution (*6*).

RESULTS

The scintillation camera was found to provide an image in uniform linear scale over an 11-in. field. With the phantom spleen at a fixed distance from the detector, it was found that the estimated spleen length increased in a linear manner with increasing intensity of the film image. The maximum overestimation of spleen length was 1.0 cm when the film image had a very high intensity. The ideal image for accurate measurement was one in which the individual dots in the spleen image could just be distinguished in areas of maximum intensity. This is the usual splenic intensity observed on routine liver images. With a fixed intensity, the estimated spleen length also increased in linear fashion with increasing spleen-detector distance (i.e. with increasing loss of resolution). A spleen measuring 10 cm at a distance of 5 in. from the detector would appear to measure 9.7 cm at 3 in. and 10.3 cm at 7 in. from the detector. No difference in the estimated length of the phantom was observed whether it was imaged in the anterior, posterior, left lateral or left anterior oblique position.

The spleen was well visualized in 294 out of 321 imagings in 316 patients. Using the transparent scale, the image was measured to the nearest centimeter. In 27 images the spleen could not be measured, usually because the lateral portions of the organ were outside the camera field. In 20 patients, the anterior images were used. The major problem with the anterior images was that the upper portion of the image tended to be of very low intensity. Measurements of both anterior and posterior images correlated well.

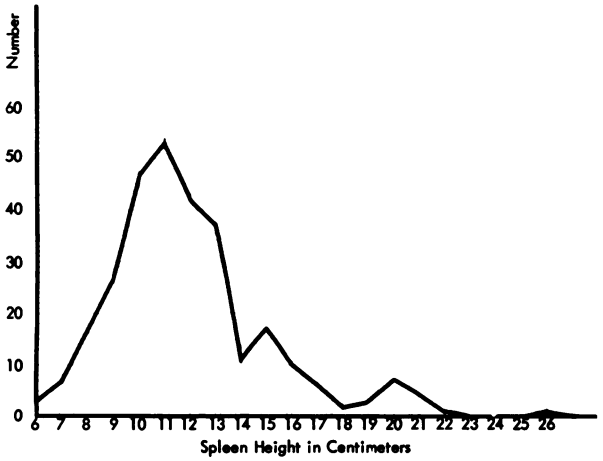

FIG. 2. Frequency distribution of spleen size in 294 scans.

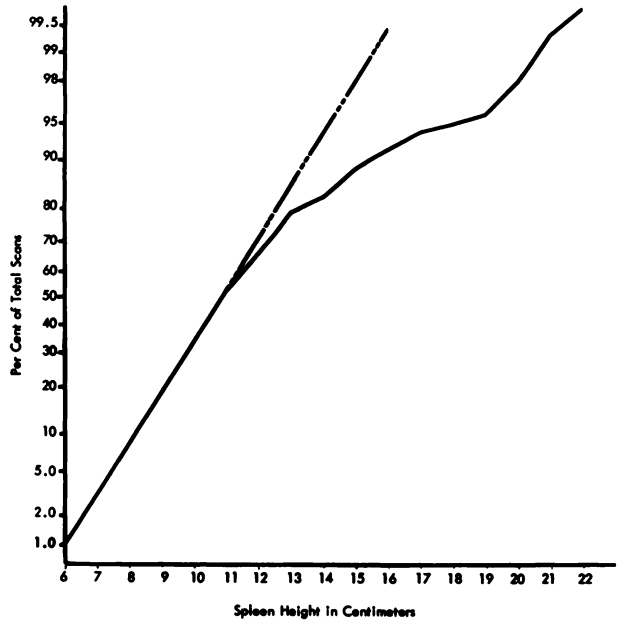

FIG. 3. Normal equivalent deviate plot of cumulative frequency distribution of spleen sizes.

In a few patients with irregular uptake of radiocolloid in large livers, it was difficult to distinguish the spleen from the left lobe of the liver. In these patients additional views were helpful, particularly the left anterior oblique.

The estimated height of the 294 spleens ranged from 6 to 26 cm, with a mode of 11 cm and a mean of 11.9 cm (Fig. 2). From 6 through 11 cm the frequencies formed a normal distribution by NED plot (Fig. 3). Through 13 cm the distribution was nearly consistent with the normal distribution. Above 13 cm the frequency distribution was irregular. There were fewer spleens of 14 cm and more spleens in the range of 18–22 cm than predicted by a normal distribution. The mean height of the 232 spleens measuring 13 cm or less was 10.7 ± 1.7 cm. The largest 5% of the spleens (15 images on 14 patients) were 19–26 cm. Only eight of these 14 patients had ever been noted to have a palpable spleen.

Since radionuclide liver images are not obtained in individuals without suspicion of disease involving the liver or spleen, the patients imaged in this laboratory were not necessarily representative of the "normal" adult hospital population. An attempt was made to determine which of the patients in this series had no evidence of disease involving the liver or spleen. Charts on patients with normal liver scans were reviewed and those with no clinical hepatosplenomegaly, with normal liver function tests and with no history of diseases known to be associated with splenomegaly were selected.

Twenty four of the 316 patients met these criteria and were considered to be the closest approximation, within this series, to "normal" hospitalized adults. Twenty of the twenty four had known extrahepatic malignancy and were scanned to rule out liver metastases. Spleen height in this subgroup of 24 patients ranged from 8 to 14 cm with a mean of 10.6 ± 1.7 cm. This is almost identical to the mean and standard deviation of the 232 spleens in the general group which were 13 cm in height or less. The distribution of the 24 spleens was symmetrical but not normal by NED plot.

DISCUSSION

This study is an attempt to develop simple screening criteria for the presence or absence of significant splenomegaly on routine liver images. Unlike ^{198}Au, ^{99m}Tc-sulfur colloid permits visualization of the spleen in virtually every instance. With the scintillation camera it is possible to rapidly and conveniently take multiple views of the liver and spleen, including oblique views if these are necessary for complete splenic visualization.

It is possible to calibrate the camera field and to make a transparent scale that can be used to estimate the dimensions of the spleen from its image on the film. Variation in estimated spleen size with intensity of the film image can be minimized by using a relatively constant low intensity for the spleen image on the photo to be measured. The slight increase in image size which occurs with increasing spleen-detector distance can be minimized by using the posterior image for measurement since in this position the distance is relatively constant from patient to patient.

The decision to use spleen height alone as an index of spleen size was based on a desire to use the simplest possible measurement. A good correlation ($r = 0.88$) between spleen height on abdominal x-rays and spleen weight has been described in the radiologic literature (*3*), and a study showing an even better correlation ($r = 0.96$) between spleen length on posterior rectilinear scan and spleen weight at subsequent splenectomy or necropsy has recently been published in abstract form (*7*).

A number of more complicated means of estimating spleen weight from scan images have been described. Spleen area on both lateral and posterior scan correlates well with the weight of the excised spleen (*8*), and formulas relating spleen weight to spleen area, both as a power function and as a linear function, have been developed (*9*). A simplified method of calculating spleen area from its length and width on posterior scan has also been proposed (*10*). However, precise estimation of spleen weight appears to have little advantage for screening purposes. The normal adult spleen is said to weigh 150 gm (*11*), but when it is measured or weighed at necropsy there is much variation in size. In a necropsy series of 2,000 patients dying violent deaths and 2,000 patients dying of chronic diseases not associated with splenomegaly, most histologically normal spleens in patients less than 65 years old weighed between 100 and 250 gm. In patients over 65 years old, spleen size decreased progressively with advancing age. Some normal spleens weighed as little as 50 gm or as much as 400 gm (*12*).

Although most of our patients had liver imaging performed because of known or suspected disease of the liver or spleen, spleen height in 232 of the total 294 conformed to a normal frequency distribution and appeared to for ma subgroup distinct from the larger spleens. The mean spleen height in this subgroup was 10.7 ± 1.7 cm. In a second subgroup of 24 patients, most of whom had liver imaging performed because of extrahepatic malignancy but who had no evidence of liver disease or splenomegaly, the mean spleen height was almost exactly the same:

10.6 ± 1.7 cm. These values for spleen height were assumed to be those of a normal adult hospital population. They can be compared to a mean spleen length of 10.0 ± 1.5 cm measured on rectilinear posterior scans performed in 26 healthy normal volunteers (*7*).

A useful upper limit of normal for spleen height in the hospital population might be taken as 2 s.d. above the subgroup means; this would be 14 cm. Thus 95% of normal spleens would be 14 cm or less in height, and 99% would be 15 cm or less. This upper limit of normal is in keeping with the radiologic literature (*3*).

The following criteria are therefore proposed for categorizing spleen size on the basis of scintillation camera images:

6–14 cm in height—normal
15–18 cm in height—enlarged
19 cm in height or larger—markedly enlarged

SUMMARY

Spleen size was evaluated by measuring vertical height of the scintillation camera image with a calibrated scale in 321 routine liver scans using ^{99m}Tc-sulfur colloid. The upper limit of normal spleen height approximated 14 cm.

REFERENCES

1. RIEMENSCHNEIDER PA, WHALEN JP: The relative accuracy of estimation of enlargement of the liver and spleen by radiologic and clinical methods. *Amer J Roentgen* 94: 462–468, 1965

2. RÖSCH J: Roentgenologic possibilities in spleen diagnosis. *Amer J Roentgen* 94: 453–461, 1965

3. WHITLEY JE, MAYNARD CD, RHYNE AL: A computer approach to the prediction of spleen weight from routine films. *Radiology* 86: 73–76, 1966

4. WAGNER HN: Splenic scanning. *Northwest Med* 63: 767–770, 1964

5. PETASNICK JP, GOTTSCHALK A: Spleen scintiphotography with technetium-99m sulfur colloid and the gamma ray scintillation camera. *J Nucl Med* 7: 733–739, 1966

6. MOORE JF, CRAMER FB, KNOWLES RG: *Statistics for Medical Students and Investigators in the Clinical and Biological Sciences,* The Blakiston Co., New York, 1951, pp. 21–27, 93–94.

7. LARSON SM, TUELL SH, MOORES KD, et al: Dimensions of the normal spleen and prediction of spleen weight. *J Nucl Med* 11: 341, 1970

8. HOLZBACH RT, CLARK RE, SHIPLEY RA, et al: Evaluation of spleen size by radioactive scanning. *J Lab Clin Med* 60: 902–913, 1962

9. SPENCER RP: Relationship of surface area on roentgenograms and radioisotopic scan to organ volumes. *J Nucl Med* 8: 785–791, 1967

10. SAMUELS LS: Estimation of spleen weight from posterior radioisotope scans. *J Canad Ass Radiol* 20: 192–193, 1969

11. ROBBINS SL: *Pathology,* 3rd ed., W. B. Saunders Co., Philadelphia, 1967, p. 684

12. KRUMBHAAR EB, LIPPINCOTT SW: The postmortem weight of the "normal" human spleen at different ages. *Amer J Med Sci* 197: 344–358, 1939