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TUMOR LOCALIZATION WITH THE GAMMA CAMERA

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SECTION I

Introduction

Since its initial clinical application in the early 1960's, the gamma scintillation camera (Anger Camera) has been used to take advantage of the fact that it is able to "see" a wide field of view with highly acceptable resolution (1-4), and as a consequence, can image large organs rapidly. The Anger camera makes it easy to take multiple views of an organ, or to do dynamic studies (nuclide angiograms) with exposures ranging from 1 second or less to a few minutes when used with some of the newer metastable isotopes such as technetium-99m (5).

The purpose of this paper is to describe how these imaging capabilities have been exploited to enhance tumor detection in selected organ systems.

Brain--Dynamic Studies

Following a bolus injection of TcO_4^- in the antecubital vein, examination is made by obtaining serial exposures of the head at intervals ranging from 1 to 4 seconds depending upon the sophistication of the equipment available. The resulting nonselective "nuclide angiogram" has been empirically useful in many centers. Although complete evaluation of this technique has

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not yet been achieved, diagnostic patterns are beginning to emerge. Arterio-venous malformations for example, show rapid instant filling but then wash out as the procedure continues. Meningiomas, typically, are seen early on but persist through the wash-out phase, and they, however, can be quite variable in appearance. Most metastatic lesions and primary tumors, in contrast, show a gradual pick-up with persistence of activity. On occasion, the dynamic study reveals neoplasms that are not seen on the routine brain scan (see Figure 1a).

The examination seems particularly helpful in the early diagnosis of cerebralvascular accidents since the brain scan is commonly normal in these patients. The nuclide angiogram will often show initial decrease in activity in the ischemic or infarcted area followed by gradually increasing activity as the normal side diminishes. Sometimes "luxury perfusion" can also be identified.

In summary, the nuclide angiogram provides supplementary information to routine brain scanning which helps categorize lesions and on occasion may provide a diagnosis when the brain scan itself is negative.

Transmission Scintiphotography

This technique, introduced by Anger and McRae (6), utilizes the image formed when a large uniform source of activity is transmitted through the patient. The process is analogous to the production of a radiograph with the detector of the camera substituting for the roentgenographic film. Since the lungs transmit more readily than soft tissue, one can obtain a detailed outline of the lungs, outer cardiac contour, and diaphragms. This is particularly useful in detecting pericardial effusions, and in identifying the position of

the right hemidiaphragm when subdiaphragmatic hepatic disease is suspected. Using technetium-99m as the source of the transmission gamma rays and suitable broad field collimation, it is possible to obtain a transmission scan of the heart and lungs in 1/2 minute or less with a dose to the patient of approximately 10 millirads. It is also feasible to combine the transmission and routine emission scan on a single picture, thereby significantly enhancing the demonstration of a lesion. This technique is illustrated in Figure 1b,c,d which show a metastatic pericardial effusion, and also in Figure 1i which shows a hepatoma of the superior portion of the right lobe of the liver.

Recent Advances in Liver Scintiphotography

The multiple view liver scan is now a routine procedure in most institutions. Utilizing the speed of the Anger camera and the high photon flux provided by technetium sulfur colloid as a liver scanning agent, it has been possible to introduce additional diagnostic techniques. At the University of Chicago, for example, we studied the diagnostic value of the change in shape of the liver on inspiration and expiration (hepatic pliability) (7). Utilizing multi-millicurie quantities of technetium-99m sulfur colloid, it is possible to take 100,000 count anterior views of the liver with the patient holding his breath in either inspiration or expiration for 20 seconds or less. In the normal liver, the dome of the right lobe flattens noticeably. Hepatic pliability is lost, however, when the liver has a diffuse interstitial infiltrate (e.g., leukemia), when it shows diffuse fibrosis or edema, or when it is bound in place by an adhesive process such as extra-hepatic extension of metastatic carcinoma. The technique is illustrated in Figures 1e,f,g, and h.

Utilizing the high count rates from technetium colloid and the rapid imaging times possible with the camera we have introduced the technique of suspended respiration which permits imaging of the liver without the usual respiratory motion artifact (8). We currently give 6 millicuries of tracer and get 10^6 counts per exposure. This improves resolution so that some structures "blurred" with conventional scanning are more readily seen. An example is the appearance of dilated biliary ducts.

We recently reviewed a series of 32 jaundiced patients for whom roentgen, surgical, or autopsy correlation of the status of the biliary tree was available. The entire series was interpreted by one of us (A.G.) without benefit of clinical history or laboratory findings, and before the series was analyzed to ascertain diagnostic patterns of biliary duct dilatation. The scintiphotos were judged to show definite, equivocal, or no biliary dilatation. Of the 9 cases called definite, all had biliary dilatation, and of the 16 patients interpreted as definite or equivocal, 14 had a dilated biliary tree. In contrast, in only 4 of 16 cases believed to show no ectasia, was the biliary tree dilated. In short, an overall accuracy of 80% was possible before the series was critically studied for relevant diagnostic patterns. Presumably, future interpretations will be even more accurate. An example is shown in Figure 1j.

Finally, the relative uptake of technetium-99m colloid in liver, spleen, and bone marrow may have useful and accurate diagnostic implications. We have just completed a review of all our liver and spleen scans for 1969. This yielded 154 cases whose initial referral diagnosis was suspected cirrhosis, anemia, or hematopoietic proliferative neoplasm. These were interpreted (by A.G.) as unknowns to assess the presence of increased bone marrow uptake, organ size, and the relative uptake of liver versus spleen.

When the spleen showed diminished uptake compared to the liver--regardless of spleen size, and when the bone marrow uptake was not increased, 19 of 21 patients had hematopoietic proliferative neoplasm (e.g., leukemia, Hodgkin's disease, malignant lymphoma). None of these cases had cirrhosis (see Figure 1k). On the other hand, when the spleen showed increased uptake compared to the liver, again, regardless of spleen size, and when this was accompanied by increased bone marrow uptake, 9 of 12 patients had cirrhosis (5 with anemia, and 4 without anemia), the other 3 had anemia. None of the group had a hematopoietic proliferative neoplasm (see Figure 1l).

In short, the speed of the camera with multi-millicurie doses of technetium-sulfur-colloid makes multiple-view liver scanning feasible. This in turn permits additional views of the posterior spleen and bone marrow to be included with the routine liver scan. It appears that the relative uptake of colloid in these 3 segments of the RE system can be utilized as an additional diagnostic adjunct.

Pancreas Imaging with the Gamma Camera

Since the introduction of selenium-75 selenomethionine in 1961 by Blau and Manske (9) pancreas scanning has been widely attempted, and frequently widely criticized. This is in part because the count rates available with this nuclide are extremely low, and consequently, the images generated are of relatively poor diagnostic quality. At the University of Chicago, it was our initial opinion that pancreas scanning was of questionable diagnostic value, but we have recently had occasion to review 82 consecutive pancreatic scans, and have found the results to be much more valuable than anticipated.

Although several pre-examination protocols have been utilized, e.g., administration of drugs like pancreozymin, secretin, cecekin, glutamic acid,

amino acid infusion, glucose, probanthine, atropine, and morphine, used alone or in combination with special high protein meals, we employed none of these but simply examined the patient following a regular breakfast. It is essential, however, to avoid fasting prior to the study, for this augments hepatic protein synthesis which results in increased uptake in the liver, and decreased tracer in the pancreas.

Our technique, illustrated in Figure 2, consists of the intravenous administration of 250 μ c of selenium-75 selenomethionine approximately 1/2 hour after breakfast, followed by serial 10-minute anterior views taken with the gamma camera for up to 1 hour. Immediately following the study most patients had technetium colloid liver scans, and in 47 cases liver subtraction was performed utilizing a 1600-channel analyzer in conjunction with the gamma camera.

For this review, the scans were interpreted (by A.G.), without knowledge of the clinical history, as normal, faint or incomplete visualization, or non-visualization. The clinical correlation was made from autopsy, surgery, or the patient's subsequent course.

The pancreas was well visualized in 41 cases, nonvisualized in 22 cases, and faintly or partially visualized in 19 cases. Eight cases were eliminated from the study because of inadequate follow-up. (Four were normally visualized, 3 nonvisualized, and one faintly visualized.)

In patients with good visualization, the diagnosis of normal pancreas could be confirmed in 32 of 37, the remaining 5 cases had chronic pancreatitis. In the 19 cases in which the pancreas was not visualized--9 had carcinoma originating in or invading the pancreas, 7 had chronic pancreatitis, and 3 were considered normal. In the 18 cases in which the pancreas was visualized only partially or faintly--the majority (10) had chronic pancreatitis or pseudocysts, 5 had carcinoma, and 3 were normal.

Analysis of the imaging method showed that the best visualization was most often obtained in the first 40 minutes, and even when the best view occurred later, earlier pictures would have been adequate for diagnosis.

The subtraction technique was also critically evaluated and found to be essential in only one case, and corroborative in 20 of the total of 47 subtractions performed.

In conclusion, a normal pancreas scan is a reliable test of pancreatic normality (~90% in this series). Furthermore, none of the 14 cases with carcinoma had a normal study. When the examination was abnormal, however, it was impossible to distinguish between different pathologic entities--especially between carcinoma and pancreatitis. Finally, the lack of subtraction equipment should not deter an institution from using the procedure.

The relative speed of the Anger camera makes it possible to produce a series of 10-minute serial photographs to replace the single rectilinear scan which frequently takes 40 minutes to perform. It is our experience and the experience of others (10), that portions of the pancreas are best viewed on different serial films, so that the normality of the pancreas is assessed from an amalgamation of separate views. We feel that this method permits accurate identification of the pancreas more readily than the single rectilinear scan.

In conclusion, this paper has presented examples wherein the Anger camera has been exploited for its inherent speed of imaging to increase the sophistication of scanning techniques.

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Figure 1A: 1-second anterior view of the brain following a bolus intravenous injection of 10 mc of pertechnetate-99m in the antecubital vein. This exposure, made in the arterial phase, shows beginning nuclide concentration in an orbital meningioma (arrow). This lesion continued to accumulate activity throughout the course of this angiogram. The tumor was not visible on routine brain scan.

Figure 1B: Heart blood pool study with technetium albumin. The heart blood pool is the "golf club" shaped area of activity in the middle of the picture. The activity in the lower portion of the picture is the patient's liver. The separation of the heart blood pool from the liver is indicative of a pericardial effusion.

Figure 1C: Transmission scan of the same patient. In this case, the air-filled lungs transmit the gamma rays much more readily than the heart, liver, or the lateral body wall. Consequently, the outer margin of the heart is well outlined.

Figure 1D: Combined emission and transmission scan--i.e., super position of pictures 1B and 1C. This yields the best definition of the pericardial effusion which is now seen as the blank band surrounding the heart blood pool. The etiology in this case was metastatic thyroid carcinoma.

Figure 1E: 20-second expiration anterior view of the liver using technetium colloid. The black band at the anterior margin of the right lobe is a strip of lead placed on the costal margin. The black hole in the middle of the portion is a slug of lead placed on the xyphoid.

Figure 1F: Similar to 1E except the view was taken in deep inspiration.

Note the descent of the liver and the marked flattening of the dome of the right lobe. We have called this change in shape "hepatic pliability."

Figures E and F represent the normal appearance.

Figure 1G: Expiration view of a patient with atypical Hodgkins disease with extensive diffuse hepatic infiltration.

Figure 1H: Inspiration view of the same patient seen in 1G; note that the liver did not change shape, i.e., pliability was lost.

Figure 1I: Transmission-emission study of a patient with a hepatoma of the superior aspect of the right lobe of the liver. The top of the dome of the liver (arrow) is replaced by tumor, and normally would not be seen. The extent of the lesion, however, is completely appreciated by adding the transmission scan. This delineates the lung and right hemidiaphragm thereby completely outlining the hepatic tumor.

Figure 1J: Appearance of dilated biliary ducts on an anterior view of the liver made with suspended respiration. The biliary duct system (arrows) is definitely but vaguely seen as a band of decreased activity in the mid-portion of the liver proceeding obliquely upward from the left lobe to the mid-portion of the right lobe.

Figure 1K: Posterior view of the liver following injection of technetium colloid. The spleen, the lower margin of which is shown by the arrow, has much less uptake than the liver. The entire posterior liver is not included in the field of view, but the medial aspect of the posterior liver is readily seen as the area of intense activity to the reader's right. This patient has a malignant lymphoma with splenic involvement.

Figure 1L: A posterior view of the liver and spleen shows the spleen to have a marked increase in uptake of technetium colloid as compared with the posterior liver. The spleen is seen as the bright object on the viewer's left, the posterior liver on the viewer's right. Note the extensive uptake in the bone marrow as compared with Figure 1K. These findings are seen most frequently in cirrhosis and anemia.

Figure 2: This illustrates the technique of examination of the pancreas. Notice that the pancreas is rapidly visualized in the first 10 minutes, and that the junction between the body and tale which appears as a void on later scintiphotographs (the aorta fits into this notch) is best visualized on the earliest examination. In addition, it is commonly true that the tale is best demonstrated on earlier scintiphotographs whereas the head may be best visualized later. In this case, however, the pancreas is well seen on all views and is entirely normal.

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0-10 min

10-20 min

20-30 min

30-38 min

38-46 min