

# RADIOCOLLOID SCANS IN EVALUATING SPLENIC RESPONSE TO EXTERNAL RADIATION

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***By use of  $^{99m}\text{Tc}$ -sulfur colloid, splenic size as well as liver/spleen ratio of radioactivity was determined after external radiation of the abdomen. In six patients receiving about 2,000 R whole-abdominal radiation, there was no atrophy of the spleen or abnormal distribution in the liver/spleen ratio of radioactivity (that is, the spleen was still functional). Serial studies in a 7-year-old boy with acute lymphoblastic leukemia in remission showed that 1,450 R splenic radiation did not result in any appreciable change in the length of the organ. In a woman with lymphosarcoma, a change in spleen size did not occur until a dose of 1,800 R was delivered. Another patient had apparently normal uptake of radiocolloid 5 years after 3,600 R. Hence the normal spleen and the spleen affected by other diseases may be far more resistant to external radiation than the spleen diseased with chronic myelocytic leukemia. Spleen scans can be useful in documenting the response of the organ to radiation.***

Since the report of Senn (1) that splenic irradiation could produce a remission of chronic myelocytic leukemia, there has been interest in the response of the spleen to external radiation. Despite this, little use has been made of radiocolloid scans to quantify radiation-induced changes in the organ. We have had the opportunity to perform spleen scans on six patients during or just after whole-abdominal radiation and on three patients who had radiation directed specifically to the spleen.

## MATERIALS AND METHODS

Spleen scans were performed after intravenous administration of 50  $\mu\text{Ci}$  of  $^{99m}\text{Tc}$ -sulfur colloid per kilogram of body weight. On patients seen on multiple occasions, the same type of scanning device

(rectilinear scanner or gamma camera) was used each time in order to have internal consistency. Anterior and posterior views of the spleen were obtained as well as the liver/spleen ratio of radioactivity per unit area. Scan length of the spleen was measured to the nearest centimeter. In six cases whole-abdominal radiation was delivered (2,000 R) because of ovarian carcinoma; the spleen was included in the radiation field. Scans were obtained either during (after 1,300 R delivered) or after external radiation. The six cases are summarized in Table 1. In three cases, external radiation was delivered specifically to the spleen. These cases are summarized below.

**Case 72-836.** A 73-year-old woman was referred to this center because of fatigue and a 30-lb weight loss. On physical examination she appeared thin and debilitated. The spleen was readily palpable but the remainder of the examination was negative. The blood hemoglobin concentration was 11.3 gm/100 ml. The white blood cell count was 2,800 with 77 polymorphonuclear leukocytes, 14 lymphocytes, 8 monocytes, and 1 eosinophil. The platelet count was 130,000. A bone marrow biopsy revealed numerous nodular masses of small lymphocytic cells that had displaced the fatty marrow. This was considered consistent with a small cell variant of lymphosarcoma. The Coombs test was negative. A  $^{51}\text{Cr}$ -red cell survival study revealed a spleen/liver ratio of 3:1, 24 hr after injection. The erythrocyte survival half-time was 8 days. A  $^{99m}\text{Tc}$ -sulfur colloid scan of the abdomen revealed the liver to be 14 cm in length whereas the spleen was 20 cm long. Because of the splenomegaly, shortened erythrocyte survival, elevated spleen/liver ratio of  $^{51}\text{Cr}$ , and the borderline abnormal hematologic picture, splenectomy was con-

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TABLE 1. DATA ON SPLEEN SCANS IN SIX WOMEN WHO WERE GIVEN WHOLE-ABDOMINAL RADIATION

Radiation case number	Age	Comment	Posterior spleen length (cm)	Time of scan after abdominal radiation completed	Posterior liver/spleen ratio
74-22	74	Stage II large right pelvic mucinous cystadenocarcinoma removed surgically. Given (6 MeV) 2,075 R whole abdomen over 22 days and 4,750 R to the pelvis.	10	2 months	1:1
74-91	66	Poorly differentiated papillary adenocarcinoma resected from wall of the sigmoid. Peritoneal fluid and the omentum were positive for tumor cells. Given 875 R preoperatively to the abdomen over 7 days (6 MeV). One month later, received 1,925 R whole abdomen and 3,825 R to pelvis.	11*	9 days	1:1
U†	70	Adenocarcinoma of right ovary. Given (4 MeV) 2,325 R whole abdomen over 1 month, and 4,322 R to the pelvis.	13	14 days	1.1:1
74-124	58	At exploratory laparotomy, a frozen pelvis and massive adhesions were found. A mixed mesodermal ovarian tumor on the left was fixed to the broad ligament. A Henschke tandem containing 30 mg radium was inserted for 50 hr. One month later, 2,200 R were delivered to the whole abdomen (6 MeV) and 4,450 R to the pelvis.	9	During therapy (after 1,450 R)	1.7:1
74-204	61	Tumor (anaplastic papillary carcinoma) was found in the pelvis, with encapsulated fluid and obliteration of the cul-de-sac. Given 2,150 R to the whole abdomen and 3,050 R to the pelvis (6 MeV) over 3 weeks.	9	5 days	1.5:1
74-233	49	Patient had prior removal of a thyroid nodule as well as a right radical mastectomy for carcinoma. A pelvic mass proved to be poorly differentiated papillary adenocarcinoma. Given 2,050 R to the whole abdomen and 4,500 R to the pelvis (6 MeV).	7	During therapy (after 1,300 R)	1.7:1

\* Unchanged from study 2 months prior to radiation.  
† Radiation carried out at another hospital.

sidered. However, the debility of the patient ruled this out.

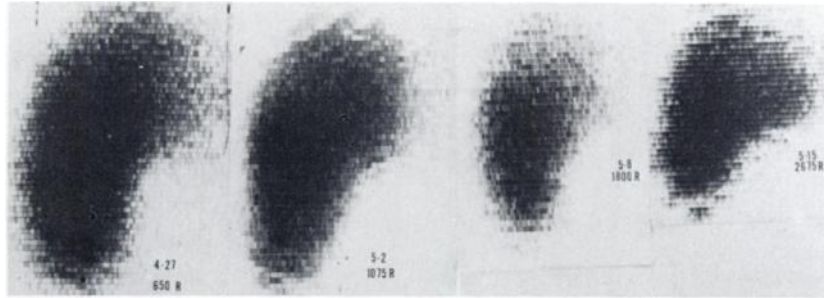
A course of external beam radiation therapy was begun. Using a 2-MeV Van de Graaff (HVL = 11.8 cm Cu), treatment was administered from anterior and then posterior ports, to a total splenic dose of 3,350 R over 32 days. Selected views of the serial spleen scans, carried out during the course of radiation, are shown in Fig. 1. The spleen decreased in size from about 20 to 15 cm. When seen 7 months later, a repeat scan showed the spleen to be 14 cm in length.

**Case 71-263.** The diagnosis of acute lymphoblastic leukemia in this patient was made at age 3, 4 years prior to the present episode. A remission in this boy was induced by use of vincristine, prednisone, and methotrexate. After tapering of the medications, intracranial and meningeal signs developed. These were treated with intrathecal methotrexate and whole-brain radiation of 1,050 R. Cyclic therapy

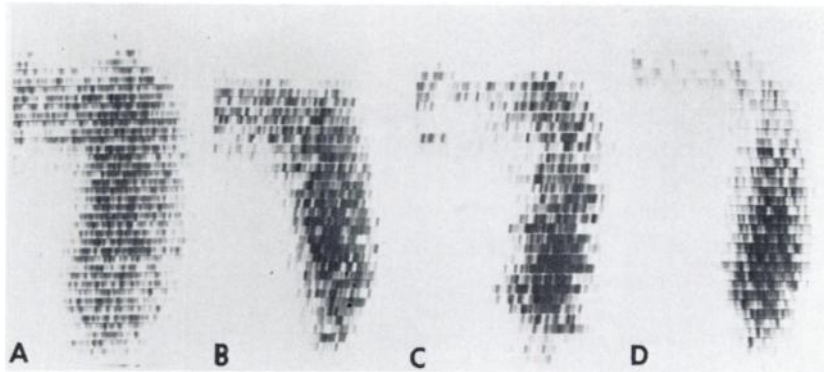
(methotrexate, then 6-mercaptopurine) was begun. Two years after the initial diagnosis, he was asymptomatic. The spleen tip was palpable only on inspiration. The spleen gradually increased in size until it was palpable 6 cm below the costal margin. Again using the 2-MeV Van de Graaff, anterior radiation was delivered to the spleen (14 sessions over 18 days, building up from initial doses of 25 R daily). The total dose was 1,450 R; the spleen scans are shown in Fig. 2.

**Case 74-201.** A 45-year-old woman noted a sub-mandibular mass. A report of a biopsy at another hospital was of a lymphoepithelial tumor. A repeat biopsy 1 year later was reported to be of a lymphocytic lymphosarcoma. Lymphangiography and liver function tests were reported as normal. Fever, night sweats, pruritis, and weight loss occurred. Sections of the prior biopsies were taken and interpreted as being consistent with Hodgkin's disease. The patient was treated with 3,600 R to the para-aortic nodes and

**FIG. 1.** Posterior spleen scans ( $^{99m}\text{Tc}$ -sulfur colloid) in 73-year-old woman with lymphosarcoma. Definite decrease in size of spleen did not occur until after dose of 1,075 R was administered to organ. Original length of spleen was 20 cm (about 15 cm after 1,800 R, plus lateral involution).



**FIG. 2.** Anterior spleen scans ( $^{99m}\text{Tc}$ -sulfur colloid) in 7-year-old boy with acute lymphoblastic leukemia. Scans represent (A) control, (B) after 225 R, (C) after 625 R, and (D) after 1,450 R. Although there may be some lateral involution of spleen, length (14 cm) has not appreciably changed. (Case 71-263).



the spleen (6 MeV). Five years later, a spleen scan was performed after intravenous administration of 4.5 mCi of  $^{99m}\text{Tc}$ -sulfur colloid. The spleen was 12 cm in length and accumulated the radiocolloid with a normal liver/spleen ratio of activity.

**DISCUSSION**

Each of the patients received whole-abdominal radiation. That is, the portal extended from the highest point of the diaphragm down to the obturator foramen; laterally, the portal cleared the skin on both sides. The radiation dose to the whole abdomen was kept at approximately 2,100 R in order to avoid renal complications. None of the patients had urinary tract symptoms from the radiation and only spot urine samples were monitored.

The radiation in each case was delivered half from the anterior, half from the posterior, and in a fractionated manner. That is, the dose was about 150 R per day for 5 days, followed by 2 days rest. It thus took approximately 3 weeks to complete administration of a dose of 2,100 R. There has been much comment on the desirability of expressing the results of fractionated radiation therapy in terms of a unit expressing the biologic effect. One such unit is the ret (rad equivalent therapy). Uses of and problems with this unit have been pointed out (2). Consider a whole-abdominal dose of 2,100 R with 150 R per day for 5 days, 2 days rest, another 5 days of therapy, 2 days rest, and then 4 days therapy (14 treatment days out of 18 total). The ret dose calculation is as follows:

$$\text{Ret} = \text{DN}^{-0.24} \text{T}^{-0.11},$$

where D is the conventional dose, N is the number of treatment days (14) over the time T (18 total days). Hence:

$$\text{Ret} = 2,100 (14)^{-0.24} (18)^{-0.11}$$

$$\text{Ret} = 811.$$

Although it would be useful to monitor the splenic response at many different doses, we are limited by the practicalities of the clinical situation. Summarizing the experience of many centers, however, may result in a coherent picture of the alterations produced in the human spleen by irradiation. One point to remember is that all functions of the spleen may not be equally radiosensitive. Szur and coworkers (3) studied the spleen after irradiation in three cases showing myelosclerosis and splenomegaly. Radiation abolished splenic accumulation of radioiron but not the ability to take up  $^{99m}\text{Tc}$ -sulfur colloid.

The dramatic response of the spleen to external radiation in chronic myelocytic leukemia (1) has perhaps colored our view of the radiation sensitivity of this organ. There was no loss of function (ability to accumulate  $^{99m}\text{Tc}$ -sulfur colloid) in any of the cases followed here. In six women with presumably normal spleens, after about 2,000 R radiation to the whole abdomen, splenic accumulation of the radioactive colloid was normal, as shown by a liver/spleen ratio of activity in the normal range. In the one patient scanned before and after radiation, there was

no change in spleen size. The boy with acute lymphoblastic leukemia showed no remission of splenomegaly after 1,450 R directed to the spleen. The woman with lymphosarcoma did have a decrease in splenic size after radiation but this was not noted until 1,800 R had been delivered. Another patient we have seen 5 years after 3,600 R were directed to the spleen had apparently normal uptake of the radiocolloid.

Spleen scanning has been infrequently used to follow the response of this organ to radiation. Sharma and coworkers published spleen scans (4) (done with  $^{51}\text{Cr}$ -erythrocytes) in one case after 500 R external radiation for chronic myelocytic leukemia, and in two patients after using 7 mCi of  $^{32}\text{P}$  parenterally for polycythemia. Ariel and Padula (5) used  $^{51}\text{Cr}$ -erythrocyte spleen scans during internal irradiation of the organ by  $^{90}\text{Y}$  microspheres introduced through the splenic artery. The radiation doses delivered in these cases were large (estimated up to 122,000 rads by the beta-ray emission of  $^{90}\text{Y}$ ).

Technetium-99m-sulfur colloid provides a convenient means of visualizing reticuloendothelial function in the spleen. As shown by these cases, it may

be useful in documenting the splenic response to external radiation. The spleen affected by diseases other than chronic myelocytic leukemia may be more resistant to external radiation than has been appreciated.

#### ACKNOWLEDGMENT

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