Articles

Subtraction Technique in the Diagnosis of Abdominal Abscesses

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The number of false-positive gallium scans (gallium in the gastrointestinal tract) and false-negative scans (gallium not labeling abdominal inflammatory masses) can be reduced by employing subtraction techniques that accurately localize isotopically labeled organs such as liver, spleen, stomach, upper gastrointestinal tract, kidney, and bladder, using a gamma camera with an on-line computer. A gallium scan is performed first. Then without repositioning, the patient receives a Tc-99m-labeled radiopharmaceutical to label liver, spleen, gastrointestinal tract, kidney, and bladder. Software that allows one to superimpose or subtract the Tc-99m-labeled organ onto the gallium scan, thus accurately defining its borders, is described. This method is helpful in evaluating regions of the abdomen generally obscured by normal gallium uptake in organs, such as liver or spleen, and in outlining abdominal masses with no gallium uptake.

Gallium scans are being used more frequently for diagnosing abdominal abscesses in postoperative patients. Interpretation of these scans can be difficult inasmuch as certain abscesses or accumulations of infected fluid may not be visualized on the scan, causing a false-negative result, or the retention of fecal material in the intestine may result in false-positive results. In addition, small abscesses with appropriate gallium uptake located near organs with high gallium uptake, such as liver and spleen, can be easily overlooked. To reduce the number of false-positive and false-negative results, we modified the subtraction techniques previously described by performing the scans with a gamma camera and an on-line computer (*1–3*).

Depending on the problem, an oral dose of Tc-99m may be given additionally to outline the stomach and duodenum. A liver–spleen, a kidney, or a bladder scan may also be done to define these organs as necessary. The technical aspects and the results achieved by our approach in the diagnosis of abdominal abscesses are described.

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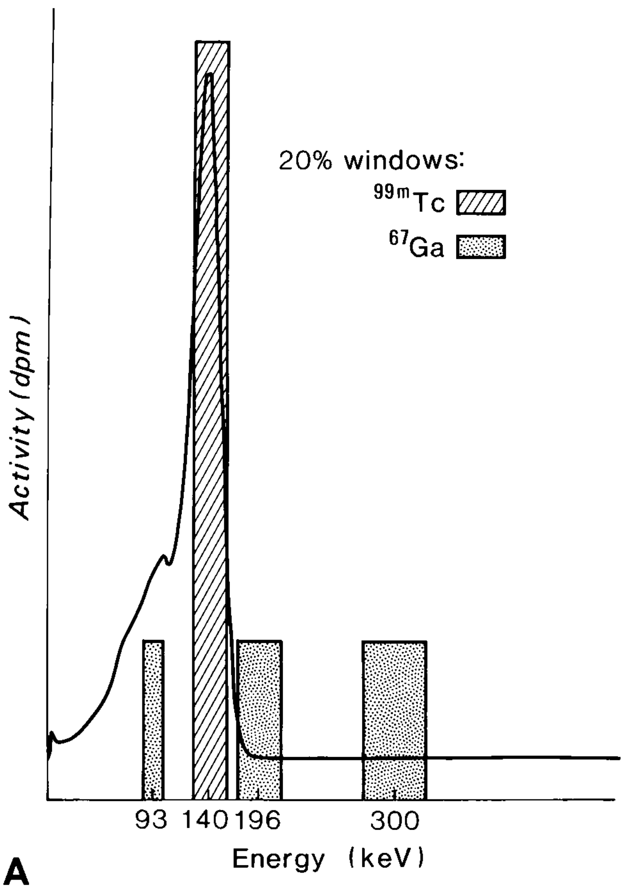
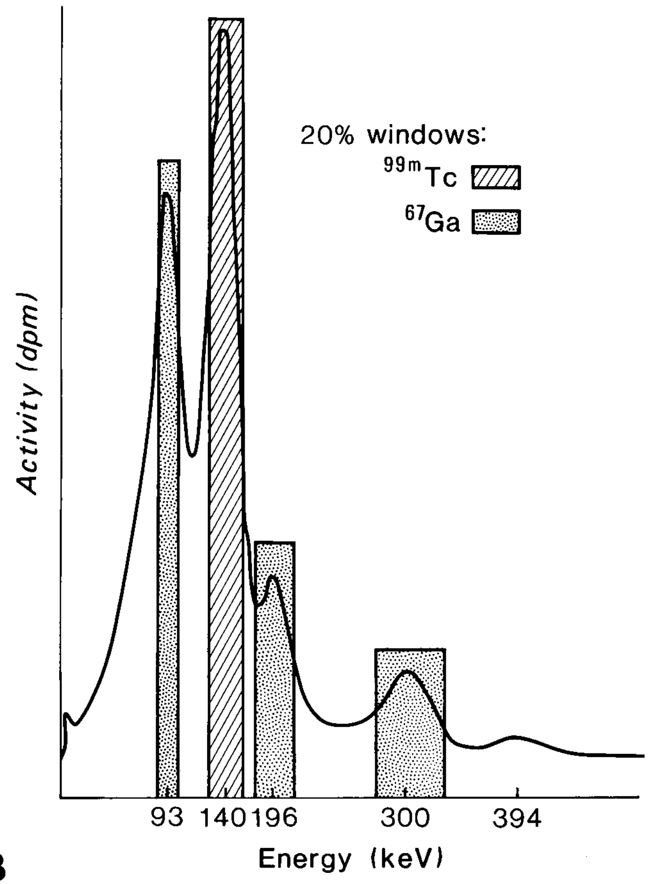
Subtraction Method

The subtraction technique is based on the imaging of sequential tissue concentrations, first after use of Ga-67 and then after use of Tc-99m. The ideal requirements include use of two radioisotopes with sufficient energy separation, so that differential pulse–height analysis can be performed. A rapid accumulation of the second radiopharmaceutical in tissue is also a requirement, so that images of the organ to be subtracted can be taken without repositioning the patient. Gallium-67 with energy levels of 93, 196, 300, and 394 keV and Tc-99m with an energy level of 140 keV are used. A significant crossover from gallium into the Tc-99m window is present, and correction for this must be applied (Fig. 1). Gallium-67 (5 mCi) as citrate is administered intravenously 30 to 48 hr before the imaging and subtraction procedure. Laxatives and enemas are given routinely.

At the time of the scan, the patient is placed in the supine position under the camera. An LFOV (Searle Radiographic Inc.) camera with a three-window capability and a medium-energy, parallel-hole collimator is interfaced to an MDS computer. Windows are set to include the 196-, 300-, and 394-keV peaks of gallium (Fig. 1). A 20% setting is used for each window. The sequence of steps taken is illustrated (Table 1). On the computer, an anterior static gallium frame is recorded for 1 million counts. This is followed by a 100-sec crossover static frame of Ga-67 into the Tc-99m window. For a liver subtraction, 4 mCi of Tc-99m sulfur colloid is injected intravenously without changing the patient's position, and 5 min later, a 500,000-count frame is again collected using only the Tc-99m window.

Using the computer, the sulfur colloid frame is corrected for Ga-67 crossover first by multiplying the 100-sec crossover frame by the time it takes for the Tc-





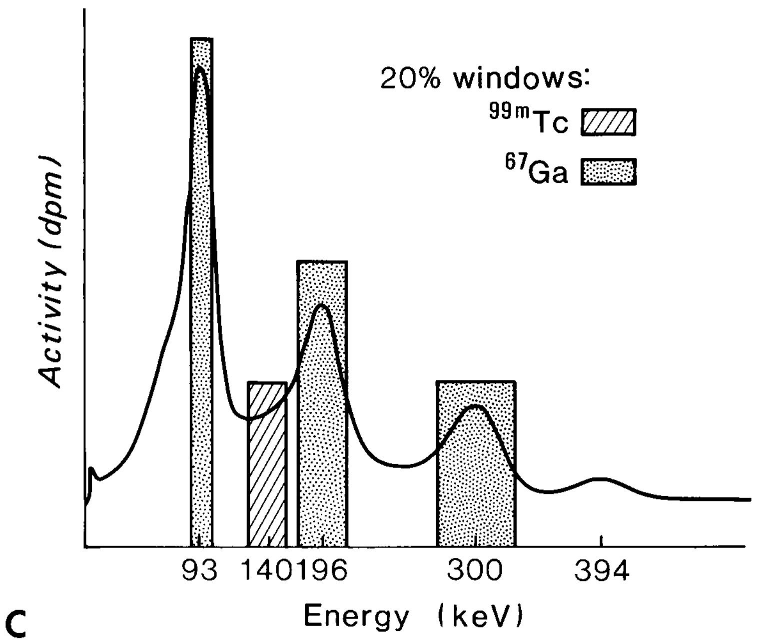


FIG. 1. (A) Technetium-99m spectrum superimposed on window settings for gallium-67 and technetium. Note crossover from Tc-99m into the 93-keV window generally used for gallium imaging. When using Ga-67 and Tc-99m together, as in our studies, the lower gallium peak should not be used for making the gallium image. (B) Technetium and gallium spectrum superimposed on window settings for 20% windows for three gallium peaks and one technetium peak Note that the lower gallium peak is not used in subtraction pictures. (C) Gallium spectrum superimposed on window settings used for gallium scans and technetium scans. Note the significant crossover from gallium into the technetium window.

99m sulfur colloid frame to be accumulated and then by subtracting the corrected crossover frame. The corrected Tc-99m sulfur colloid frame is then normalized. This is accomplished by making the maximal counts of Ga-67 over the liver equal to 100% and the maximal counts of Tc-99m over a similar area of liver equal to 100%. The percentages of Tc-99m counts are subtracted from the percentages of Ga-67 counts for each pixel in the subtraction process. Pixels with Tc-99m activity that exceeds gallium activity are rarely encountered with this

TABLE 1. Flow Chart of Data Acquisition and Computer Processing For Gallium Scan and Liver Subtraction

Day	Patient	LFOV camera	Computer	
1	Ga-67 citrate, 5 mCi intravenously			
3	Supine position, anterior abdominal view	Ga-67 window, 1,000,000 counts		Normalize subtraction
		Tc-99m window, 100-sec crossover		
	Tc-99m, 4 mCi intravenously	Tc-99m window, 500,000 counts	subtract	

setting, with the spleen a possible exception. They appear as white areas similar to those regions where the normalized activity is equal to 1. The different pictures are illustrated (Fig. 2).

Software by Medical Data Systems was used for this program, which is illustrated in the Appendix.

Other abdominal organs that can be easily labeled with this technique are kidney and bladder, using Tc-99m DTPA (10 mCi intravenously) and the upper gastrointestinal tract with Tc-99m orally applied in water. In the latter situation, 1 mCi of [^{99m}Tc] pertechnetate is administered orally in a shielded cup with water and a straw is used to avoid spillage.

Results

The number of equivocal scans in our laboratory was approximately 8% before subtraction procedures were employed. The use of subtraction reduced this to about 2% (Table 2). The subtraction technique was particularly useful in the presence of subdiaphragmatic or subhepatic abscesses because it allowed better comparison of liver size and shape on sulfur colloid and gallium scans than was possible with visual comparison. In these situations, an abscess may be missed on the gallium scan because activity in the abscess is indistinguishable from activity in the liver parenchyma. Also, if there is an unusual shape of the liver on the gallium scan, the liver subtraction technique increased the confidence in the diagnosis. The following are some different situations in which subtraction was helpful in the diagnosis of an abdominal abscess:

1. Normal study (Fig. 3).
2. Liver subtraction technique for the evaluation of intrahepatic lesions.

Example: A 71-year-old man presented with a palpable abdominal mass. Arteriography showed it to be a

TABLE 2. Results of Gallium Scans Performed for Detection of Abdominal Abcesses or Tumors, Without and With Subtraction Technique

	Scans				
				Percent abnormal	
Technique	No.	Percent normal	Percent equivocal	Infection	Tumor
Without subtraction*	344	46	8	30	16
With subtraction†	163	48	2	42	8

*August 1975 to July 1976 (12 months).
†August 1976 to January 1977 (6 months).

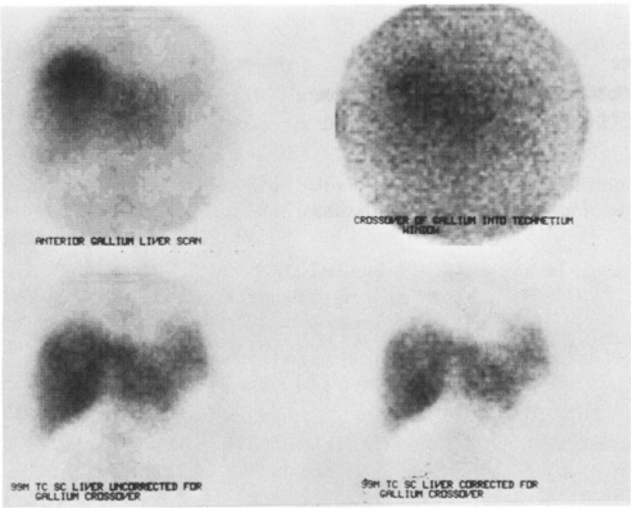


FIG. 2. Computer-generated gallium scan of upper abdomen, with 1 million counts, three upper windows (raw data), the 100-sec crossover image from gallium into the Tc-99m window, the Tc-99m-sulfur colloid liver scan (500,000 counts, Tc-99m window), and the subtraction image.

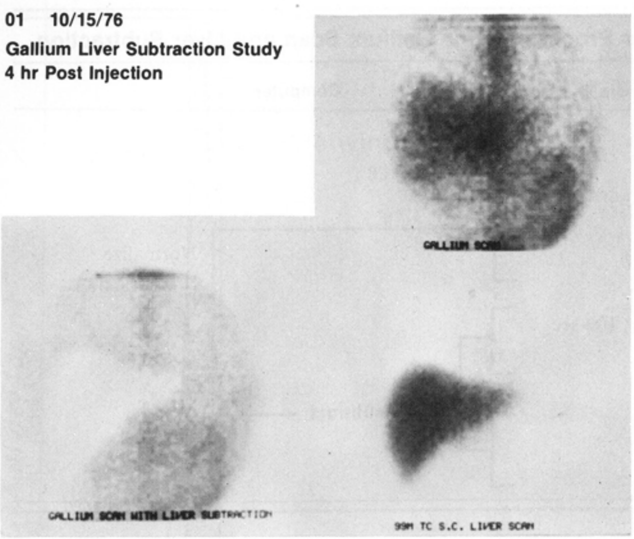


FIG. 3. Liver subtraction in normal study.

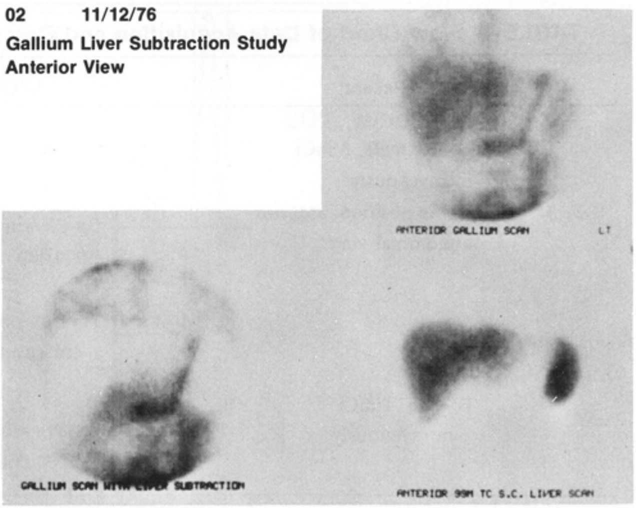


FIG. 5. Liver subtraction showing periphepatic abscess with extension into left upper quadrant.

vascular tumor involving almost the entire left lobe and part of the right lobe. Biopsy revealed a hepatocellular hepatoma. A gallium scan showed an area of increased uptake in the region of the tumor. Liver subtraction showed not only that the increased gallium uptake corresponded to a filling defect in the liver, but also that the gallium uptake extended beyond the boundaries of the liver as seen on the liver scan. Additionally, the actual tumor size was outlined better (Fig. 4).

3. Liver subtraction technique for the evaluation of perihepatic lesions.

Example: A 42-year-old man presented with signs and symptoms of an abdominal abscess after splenectomy and distal pancreatectomy for a ruptured pancreatic pseudocyst. A gallium scan showed uptake in the epigastrium and left upper quadrant, which was difficult to differentiate from spleen and liver. Liver subtraction showed extrahepatic gallium uptake located in the epigastrium and left upper quandrant, suggestive of abscess extending into the chest. Abdominal exploration showed a left thoracic empyema originating from the region of the pancreatic pseudocyst (Fig. 5).

4. Liver subtraction technique for evaluation of subdiaphragmatic abscess.

Example: A 76-year-old woman with a history of carcinoma of the head of the pancreas, for which a Whipple procedure was performed, had an obstructed jejunum and underwent reoperation. After the operation, fever and signs of intra-abdominal infection developed. Liver scan showed decreased uptake in the dome of the

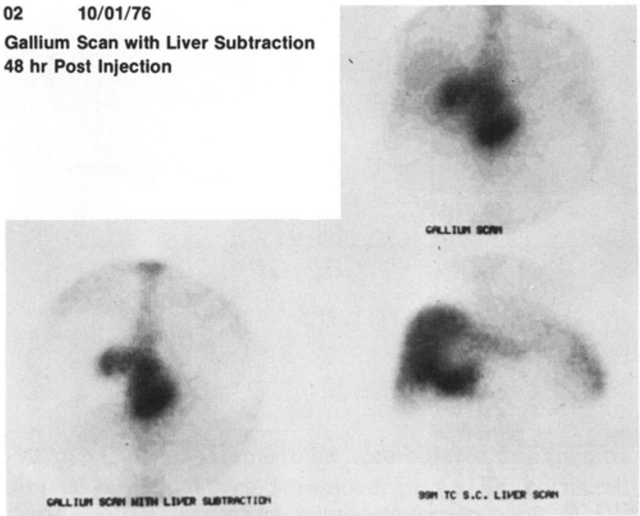


FIG. 4. Liver subtraction showing intrahepatic lesion.

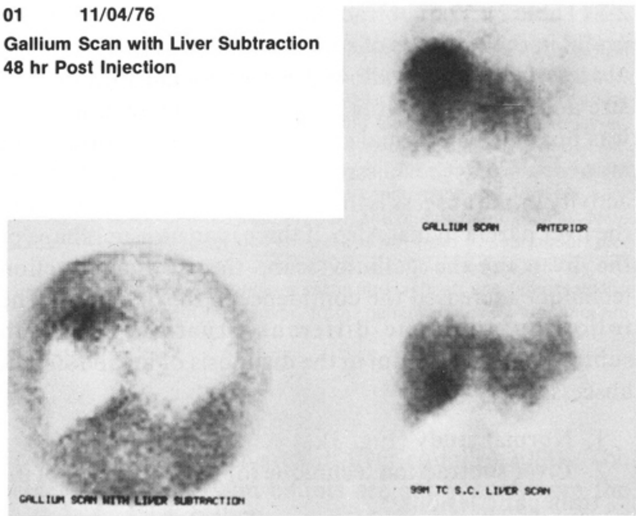


FIG. 6. Liver subtraction demonstrating subdiaphragmatic abscess.

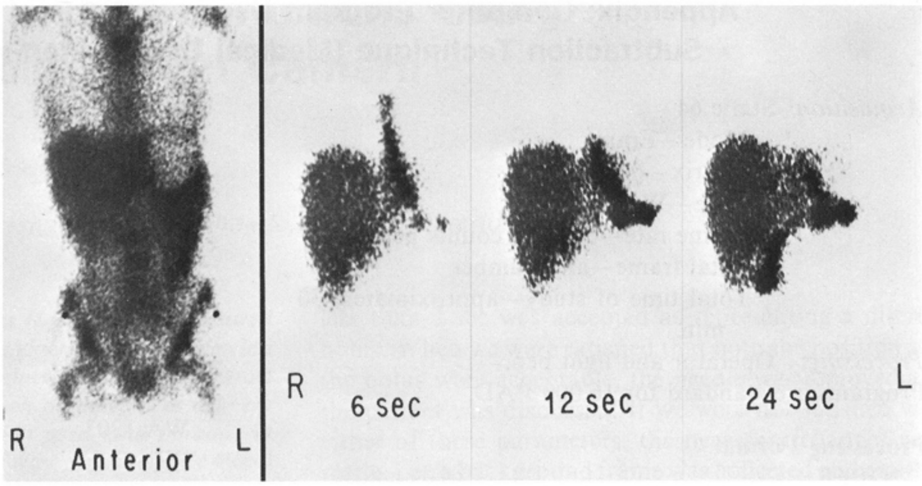


FIG. 7. Delineation of stomach and duodenum with orally administered technetium to assist in defining a gallium-negative hematoma in left upper quadrant: [By permission of J.B. Lippincott Co. (see Ref. 4).]

right lobe. Gallium scan showed increased uptake in this area, consistent with hepatic abscess (Fig. 6).

5. Stomach and upper gastrointestinal imaging subtraction for the evaluation of areas negative on gallium scan.

Example: A 29-year-old woman experienced left abdominal pain after splenectomy and removal of a large cystadenoma of the pancreas. A gallium scan showed little activity in the region of the left epigastrium. The stomach, when labeled with Tc-99m given orally, was displaced medially, indicating a mass in the left upper quadrant. At laparotomy, a left subdiaphragmatic hematoma containing 500 ml of cloudy, sterile fluid was removed [Fig. 7 (*4*)].

6. The subtraction technique also has been used to evaluate perinephric lesions and lesions around the bladder, Tc-99m DTPA being used instead of sulfur colloid as previously described.

Discussion

Dual isotope subtraction techniques using modern scanners and simultaneous subtraction techniques have been reported by Damron, Beihn, and others (*1–3*). The effectiveness of this method to recognize abdominal abscesses is well noted in the literature (*3*). Damron et al. state that the subtraction technique resulted in 53% more abscesses being diagnosed (*3*). Combined liver–lung scanning is another method used with less success in the detection of subdiaphragmatic abscesses (*5–7*).

The method described herein uses sequential labeling of tissues, a gamma camera, and a computer. This program allows for a better crossover correction than would be possible with the dual isotope scanner, which is desirable when gallium is used. The patient should be able to remain on the imaging table, without moving, for about 30 min. The method is applicable in labeling solid organs such as liver, spleen, and kidney for subtraction from the gallium scan; it thereby enhances the interpretation of the gallium scan in detecting abscesses in the subdiaphragmatic regions, as well as in and around liver, spleen, and kidney. Oral Tc-99m outlines the stomach. Its position in the upper abdomen may be helpful in delineating "cold" areas on the gallium scan. In addition, gallium may be used orally to delineate intraluminal collections of gallium such as those produced by fistulas, blind loops, and the bladder. If catheterization is to be avoided, the bladder can be viewed after Tc-99m DTPA is administered intravenously.

In most gallium scans, subtraction techniques are not necessary for diagnosis of an abdominal abscess. However, in a few cases, the use of the subtraction technique can be helpful in increasing the confidence in an otherwise doubtful diagnosis because it allows visualization of an abscess, which otherwise would have been missed. This technique is another example of how one can capitalize on existing computer equipment to improve diagnostic results.

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Appendix: Computer Program Used for the Ga-67 and Tc-99m Subtraction Technique (Medical Data Systems Programs)

Acquisition: Static 64
Mode—Frame
Matrix—64 × 64
Type—Word
Frame rate—500,000 counts per frame
Total frame—any number
Total time of study—approximately 30 min.

Processing: Operator and light pen.
Programs are standard for 16,000 PAD.

Processing Format

*OPER

RD: 1	Read first 500,000 counts of gallium liver area.
AF: 2	Add second 500,000 counts of gallium liver area.
WRITE: 1200	Store 1,000,000 counts of gallium liver area. A picture of this frame is made.

*OPER

CL	
RD: 3	Read 100-sec crossover frame.
MU: 0.6	Multiply by the time of the 500,000 Tc-99m sulfur colloid frame. e.g.: 60 sec
WRITE: 1201	Save the corrected Tc-99m sulfur colloid liver frame.

*OPER

CL	
RD: 4	Read the 500,000 Tc-99m sulfur colloid liver frame.
SF: 1201	Subtract the corrected crossover frame.
WRITE: 1202	Save the corrected Tc-99m sulfur colloid liver frame. A picture of this frame is made.
LP	Light pen is used for defining areas.
AD: 1	Define the area of the liver from the Tc-99m sulfur colloid liver frame.
WA:1203	Save the defined liver area.
PR	Print out the number of counts in the defined liver area. e.g.: 50,000 counts
RD: 1200	Read the gallium liver area frame.
RA: 1203	Read the predefined liver area.
PR	Print out the number of counts in the gallium liver area. e.g.: 30,000 counts

A ratio of the Ga-67 to Tc-99m sulfur colloid liver area is determined: e.g., 30,000/50,000 = 0.6.

*OPER

CL	
RD: 1202	Read the corrected Tc-99m sulfur colloid liver frame.
MU: 0.6	Multiply by 0.6 to normalize the Tc-99m sulfur colloid liver area.
SF: 1200	Subtract the gallium liver frame to obtain a subtracted image. A picture of this frame is made for the patient's record.