

# Determination of liver volume by the use of a gamma camera connected with 1600 or 4096 channel analyser in diffuse liver diseases

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**SUMMARY** A method of *in vivo* calculation of liver volume using a gamma camera and a 1600 or 4096 channel analyser is described. Topographically, the maximum thickness giving the highest counts in matrix data in the right anterior oblique projection is measured as the maximum breadth in the right posterior oblique projection. Then the total counts given by the liver can be transformed to the volume. The necropsy criteria indicated that the errors were between  $-11.9$  to  $+14.7\%$  in 13 cases by the use of  $^{198}\text{Au}$ -colloid. In 20 selected normal control subjects, the mean of measured liver volumes was  $779 \pm 99 \text{ cm}^3/\text{m}^2$  of surface area. The volumetric calculation using  $^{99\text{m}}\text{Tc-Sn}$ -colloid or  $^{99\text{m}}\text{Tc-phytate}$  was compared with  $^{198}\text{Au}$ -colloid in the same patients. The results with  $^{99\text{m}}\text{Tc-Sn}$ -colloid were well correlated with those with  $^{198}\text{Au}$ -colloid, but the results with  $^{99\text{m}}\text{Tc-phytate}$  and  $^{198}\text{Au}$ -colloid were almost equal. It was concluded that, excluding rare severe cases of liver cirrhosis, liver volume can be measured with reasonable accuracy.

The determination of liver size is often important in the diagnosis and prognosis of liver disease. However, it has been found that the clinical estimation of liver size, under certain conditions, gives erroneous results (Zelman, 1951; Fiorioli, 1953; Nimeh, 1955; Fleischner and Sayegh, 1958; Walk, 1961). Studies involving necropsy criteria have indicated the fallibility of clinical palpation as a basis for estimating liver size (Rives *et al.*, 1937; Ratnoff and Patek, 1942; Reinberg and Lipson, 1950; Armas-Cruz *et al.*, 1951). Detailed radiographic and clinical methods for the measurement of liver volume have been reported in the literature (Lutz, 1953; Fiorioli, 1953; Nimeh, 1955; Fiorioli, 1959; Walk, 1961). Although these are more accurate than routine clinical techniques, in some cases the border of the liver is not easily identified and special procedures are required to improve visibility.

In the field of nuclear medicine, several methods have been also described. Yagan *et al.* (1962) used the multiple cut-off scintillation scanning technique which considers the liver to be made up of trapezoids. Each separate trapezoid was integrated by planimetry. In 48 cases the comparison with post-mortem

data indicated that the average deviation was  $11.5\%$ . However, the technique was too laborious to be used routinely. In the method described by Rollo and DeLand (1968), the liver was assumed to be composed of an ellipsoid (right lobe) and a paraboloid (left lobe), and the volumetric calculation was made by using linear measurements obtained from anterior and lateral liver scans. However, it is difficult to make the above assumption in the presence of deformity, which is usually present in chronic diffuse liver diseases.

Several investigators have used for evaluation of liver size, cross-sectional areas from anterior liver scans (Naftalis and Leevy, 1963; MacAfee *et al.*, 1965; Spencer and Banever, 1970). The measurements of the area can provide data in any configurations of the liver. Naftalis and Leevy (1963) demonstrated that scan size measured by planimetry correlated well with hepatic size at necropsy. However, when the anterior scan area is proportional to volume, the average thickness of each liver in the anterior-posterior direction should be the same. It remains to be determined to what extent scan area in the anterior-posterior direction represents volume of the liver. DeLand and North (1968), in their report of the examination of normal liver weight in 625 cases that

came to necropsy, found no correlation between frontal surface area of the liver, frontal plus lateral surface area, and liver weight.

In this report, a simple method of determining liver volume by using a gamma camera and a 1600 or 4096 channel analyser is described.

Method

EQUIPMENT AND MATERIALS

Pho/Gamma III (Nuclear, Chicago) was connected with a 1600 or 4096 channel analyser. The nuclides used were <sup>198</sup>Au-colloid (Dainabot Lab.), <sup>99m</sup>Tc-Sn-colloid (Dainabot Lab.), and <sup>99m</sup>Tc-phytate (Diagnostic Isotopes, Inc.).

MEASUREMENT RATIONALE

As shown by the transection at the 11th thoracic vertebra in Fig. 1, the liver image gives the maximum

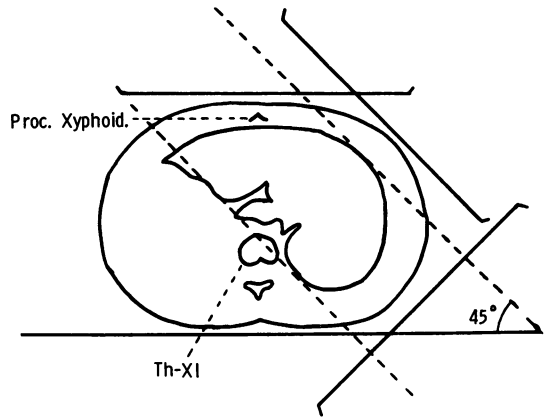
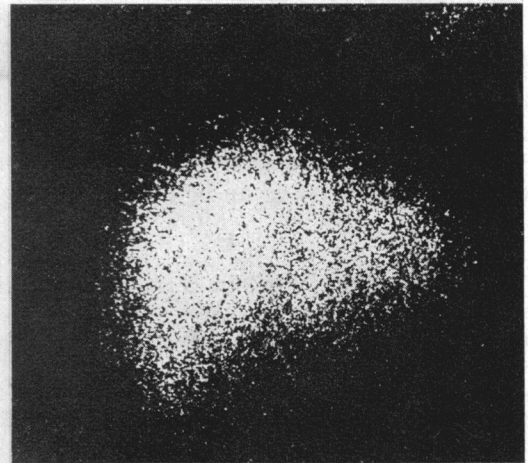


Fig. 1 Transection at the 11th thoracic vertebra.

40x40 numerical matrix representing scintiphotos in the right anterior projection.



40x40 numerical matrix representing scintiphotos in the right posterior oblique projection.

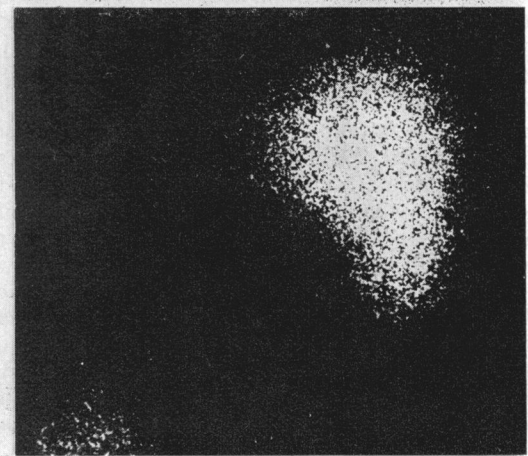


Fig. 2 Scintiphotos and numerical images (40 x 40 matrix) in the right anterior and right posterior oblique projections.

and minimum area in the right anterior oblique and right posterior oblique projections, while the maximum thickness of the liver in the right anterior oblique projection corresponds with the maximum width in the right posterior oblique projection. Then, as presented in Fig. 2, the thickness giving the maximum counts in matrix data in the right anterior oblique projection is measured as the maximum breadth in the right posterior oblique projection. Consequently, the total counts given by the liver can be transformed to the volume.

#### CALCULATION OF LIVER VOLUME USING

##### $^{198}\text{Au}$ -COLLOID

Since  $^{99\text{m}}\text{Tc-Sn}$ -colloid was not easily available to the present authors until recently, 150 to 200  $\mu\text{Ci}$   $^{198}\text{Au}$ -colloid had been used for obtaining scintiphotos. The calculation of hepatic volume was made initially by the use of  $^{198}\text{Au}$ -colloid. After the injection of the above dose of  $^{198}\text{Au}$ -colloid, 50,000 counts were collected over the liver in right anterior oblique projection in the supine position, stored as a  $40 \times 40$  matrix. It was thought that, for the volumetric calculation, amounts of low counts in the view field, which originated from extrahepatic removal of the colloid, had to be evaluated and subtracted from the total collected counts. The region of the liver in the  $40 \times 40$  matrix was roughly determined by comparing the simultaneously obtained photograph in cases with no or only slight spleen visualization. The sum of the counts in the region other than the liver was obtained. In the examination of 41 cases this ranged from 3.33 to 14.62% of total counts with a mean value of 8.15 as listed in Table 1. The value of 8% has been used routinely in the present laboratory.

The maximum width of liver image in the right posterior oblique projection was measured from a photograph using a ruler. As shown in Fig. 3, the dense part was assumed to be bordered.

A correction of peak counts for random-count fluctuations was necessary. A peak count was smoothed by the averaging of that value with the surrounding eight neighbours. Ratios of a mean of five or six peak counts to a mean of smoothed ones ranged from 0.82 to 0.94 with a mean value of 0.88 in 42 cases of a  $5 \times 10^4$  collection. In 24 cases of a  $2 \times 10^4$  collection the mean ratio was  $0.80 \pm 0.18$  and in 14 cases of a  $10 \times 10^4$  collection,  $0.93 \pm 0.15$  was obtained.

Finally, the calculation of the volume of the liver was made by the following equation:

$$\text{Volume} = \frac{\text{total net counts} \times 0.92}{\text{mean of five or six peaks counts} \times 0.88} \times \text{max. breadth in right posterior oblique projection} \times \text{one-cell area}$$

where 0.88 is a constant for smoothing in the case of

Case no.	Liver findings	% of total counts
71-023	Normal	7.90
71-024	Normal	12.02
71-028	Cirrhosis	14.62
71-032	Normal	8.79
71-039	C.H.	10.54
71-047	C.H.	9.89
71-106	Cirrhosis	5.81
71-108	Cirrhosis	9.50
71-109	Cirrhosis	12.90
71-111	Cirrhosis	7.97
71-116	Normal	6.07
71-121	C.H.	7.16
71-128	Cirrhosis	6.40
71-129	C.H.	5.72
71-133	S.H.	7.27
71-138	S.H.	6.07
71-141	Fatty Liver	4.83
71-143	Cirrhosis	6.18
71-144	T.H.	6.86
71-147	Hepatomegaly	6.86
71-150	C.H.	5.66
71-151	C.H.	9.78
71-152	C.H.	5.94
71-158	C.H.	7.40
71-159	S.H.	7.11
71-165	S.H.	10.60
71-172	C.H.	3.75
71-189	S.H.	6.30
71-190	S.H.	9.28
71-191	Cirrhosis	5.20
71-193	S.H.	11.00
71-212	S.H.	10.23
71-218	Congestion	3.33
71-221	Cirrhosis	7.35
71-226	C.H.	12.56
71-240	S.H.	10.14
71-252	C.H.	7.92
71-260	C.H.	8.83
71-261	Cirrhosis	12.80
71-277	Cholangitis	6.90
72-039	C.H.	8.82
Total: 41 cases	Mean $\pm$ SD = 8.15 $\pm$ 2.61	

C.H.: chronic hepatitis. S.H.: serum hepatitis. T.H.: toxic hepatitis.

Table 1 Evaluation of amounts of low counts from tissues other than liver in view field of gamma camera in right anterior oblique projection with use of  $^{198}\text{Au}$ -colloid

the  $5 \times 10^4$  counts collection as described above. The value of 0.93 and 0.80 were used when the total collected counts were  $10 \times 10^4$  and  $2 \times 10^4$ , respectively. When a 4096 channel analyser was used, about 15 peak counts were averaged. One-cell area was measured using five point sources forming a square with a 12.7 cm (5 in.) diagonal and a centre, as shown in Fig. 4.

## Results

### COMPARISON OF *in vivo* CALCULATED LIVER VOLUME WITH POST-MORTEM WEIGHT

From January 1971 to February 1975 the *in vivo* calculation of liver volume was attempted in 1396 cases. Among them 13 cases are listed in Table 2 for a comparison with the weight at post-mortem exami-

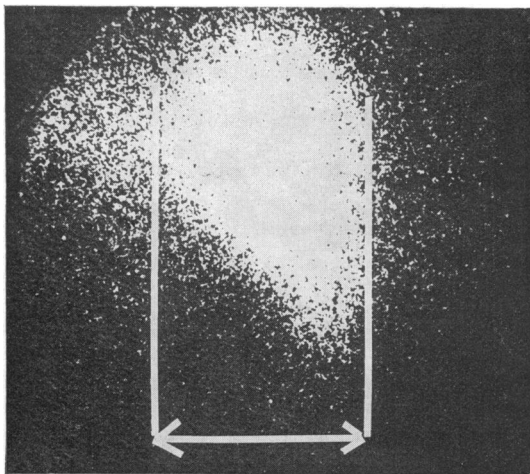


Fig. 3 The border used for measurements of the maximum breadth of liver image in the right posterior oblique projection.

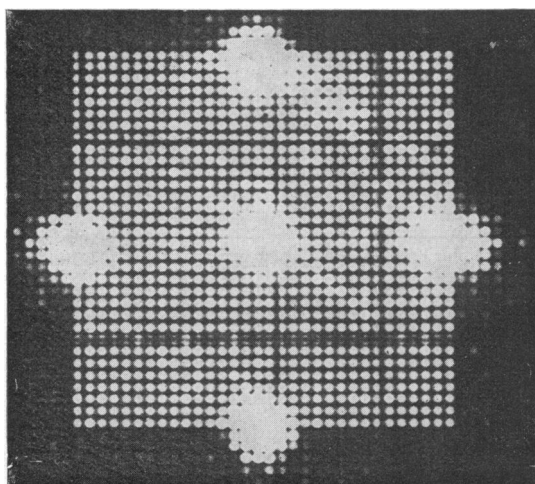


Fig. 4 Five points sources forming a square with a 12.7 cm diagonal and a centre for the measurements of a one-cell matrix area.

nation. In these cases the post-mortem examination was performed in less than six months after the *in vivo* calculation, during which no change of liver size was recorded in the clinical charts. The deviations from the liver weight at post-mortem examinations were between  $-11.9$  to  $+11.7\%$  with the average of  $6.3\%$ .

**RESULTS IN NORMAL CONTROL SUBJECTS**  
Twenty-one subjects, ages ranging between 20 to 60

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years, (11 males and 10 females) were selected as normal controls on the basis of the following criteria: (1) no history of liver disease or abnormal results from liver function tests; (2) no evidence of cardiovascular disease; (3) no evidence of systemic diseases of the liver, such as infection, lymphoma, leukaemia, or collagen disease.

The measured liver volumes ranged from  $596$  to  $961$   $\text{cm}^3/\text{m}^2$  of body surface area. The averaged value was  $779 \pm 99$   $\text{cm}^3/\text{m}^2$ .

**COMPARISON OF *in vivo* CALCULATIONS OF LIVER VOLUME BY USE OF  $^{198}\text{Au}$ -COLLOID,  $^{99\text{m}}\text{Tc}$ -SN-COLLOID, AND  $^{99\text{m}}\text{Tc}$ -PHYTATE**

In the present laboratory,  $^{198}\text{Au}$ -colloid has been used for measuring hepatic fractional clearance as an index of hepatic blood flow (Fujii *et al.*, 1974). As mentioned above, because of the recent increase in availability,  $^{99\text{m}}\text{Tc}$ -Sn-colloid or  $^{99\text{m}}\text{Tc}$ -phytate has since been used for obtaining scintigraphic image and about  $20\mu\text{Ci}$   $^{198}\text{Au}$ -colloid for the measurement of hepatic fractional clearance. Among the patients given  $^{99\text{m}}\text{Tc}$ -Sn-colloid, 14 patients with no or only slight spleen and bone-marrow visualisation were selected and subjected to two volumetric calculations of the liver. Twenty-thousand counts were collected in the range of  $^{198}\text{Au}$  activity and 50,000 counts in the range of  $^{99\text{m}}\text{Tc}$  activity. The preset window of gamma camera (Pho/Gamma III) was  $25\%$  and 1000 hole collimator was used in both counts. In this study, smoothing of peak counts was made in each case after the numerical data of the image were read out. The results are shown in Table 3. In most of the cases, calculated liver volumes were greater in the range of  $^{99\text{m}}\text{Tc}$  activity than in the range of  $^{198}\text{Au}$  activity.

With the use of  $^{99\text{m}}\text{Tc}$ -phytate, the same comparisons were made in another 21 patients, cases with spleens greatly visible in the detector field being excluded. As shown in Table 4, the results of the two calculations were almost equal.

**Discussion**

DeLand and North (1968), in a study of 625 necropsies of adults without evidence of liver disease, reported that the relationship between liver weight and body surface area can be described by the equation: liver weight (kg) =  $1.02$  body surface area ( $\text{m}^2$ ) -  $0.22$  and the relative standard deviation of liver weight was  $16\%$ . According to this description, normal liver weight (g) per surface area ( $\text{m}^2$ ) can be estimated as  $800 \pm 128$   $\text{gm}/\text{m}^2$ .

In the present study, a sufficient number of determinations of liver volumes was not done in

Case no.	Patients	Liver volume measured in vivo (a) (cm <sup>3</sup> )	Liver weight at necropsy (b) (g)	Difference a-b — b (%)	Interval between (a) (b)	Liver findings	Dose of <sup>198</sup> Au-colloid (μCi)
71-026	T.U.	1830	1770	+ 2.8	5.8M	Cholestasis	150
72-071	S.K.	1525	1300	+14.7	5.8M	Cirrhosis	150
72-196	S.D.	1445	1280	+11.4	1.3M	Portal cirrhosis	150
72-276	T.K.	1558	1530	+ 1.9	6D	Congestive cirrhosis	150
72-301	T.K.	1717	1805	- 4.9	2.0M	Amyloidosis	150
72-328	R.S.	1656	1800	-11.9	3.7M	Multiple myeloma	150
72-369	R.T.	1372	1300	+ 5.5	5.5M	Leukemia	200
72-554	K.O.	1140	1150	- 0.8	4.8M	Amyloidosis	200
73-374	S.T.	1461	1355	+ 7.8	7D	Acute hepatitis	40
73-451	K.O.	1778	1910	- 6.9	2.4M	Acute leukaemia	20
73-468	R.K.	2174	1970	+ 4.6	2.0M	Acute leukaemia	20
73-480	H.O.	1807	1860	- 2.8	14D	Lymphosarcoma	15
74-047	Y.I.	1628	1670	- 2.5	5.9M	Leukaemia	20

Mean ± SD: 6.3 ± 4.3

Table 2 Comparison of in vivo calculated liver volumes with post-mortem weight

Case no.	Calculated volume by		Calculation ratios (b/a)	Case no.	Calculated volume by		Calculation ratios (b/a)			
	<sup>198</sup> Au-colloid (a) cm <sup>3</sup>	<sup>99m</sup> Tc-Sn-colloid (b) cm <sup>3</sup>			<sup>198</sup> Au-colloid (a) cm <sup>3</sup>	<sup>99m</sup> Tc-phytate (b) cm <sup>3</sup>				
73-489	1578	1546	0.98	74-274	1750	1820	1.040			
73-490	1063	1065	1.00	74-275	1848	1783	0.965			
73-495	1494	1524	1.02	74-277	1755	1637	0.933			
73-496	1389	1488	1.07	74-279	1834	1571	0.857			
74-114	1187	1517	1.28	74-284	1339	1273	0.951			
74-118	945	1131	1.20	74-285	1675	1618	0.966			
74-119	1618	2067	1.28	74-289	1450	1440	0.933			
74-123	1057	1303	1.23	74-292	1410	1228	0.969			
74-124	913	1027	1.13	74-293	1193	1193	1.000			
74-128	1237	1547	1.25	74-295	1278	1329	1.040			
74-129	1120	1291	1.15	74-296	1312	1325	1.010			
74-156	1707	1905	1.12	74-297	1264	1328	1.051			
74-161	1650	2242	1.36	74-298	1284	1409	1.097			
74-164	1792	2225	1.24	74-299	1333	1368	1.026			
Total number of cases: 14      Mean ± SD = 1.16 ± 0.12				74-300				938	930	0.992
Correlation coefficient between (a) and (b): r = 0.91 (p > 0.01)				74-302				1319	1314	0.996
				74-303				1569	1569	1.000
				74-304				1742	1722	0.989
				74-305				1557	1485	0.954
				74-308				1215	1257	1.035
				74-309				1367	1349	0.987
				Total number of cases: 21      Mean ± SD = 0.988 ± 0.057						
				Correlation coefficient between (a) and (b); r = 0.93 (P < 0.01)						

Table 3 Comparison of in vivo calculated liver volume with use of <sup>198</sup>Au-colloid and <sup>99m</sup>Tc-Sn-colloid

normal subjects to establish an adequate range but the results compare favourably with the reported normal range.

The above-described method is based on the assumptions that the maximum thickness of the liver in right anterior oblique projection can be measured from a right posterior oblique projection on a scintiphotograph and that radioactive colloid is distributed evenly throughout the liver. In most cases, the site of the maximum thickness is found in the right lobe but in many severe cases of liver cirrhosis, the right lobe becomes atrophic and the site is found in the left lobe. In the latter cases, the thickness is possibly overestimated from a right posterior oblique projection. Uneven radioactivity within the lobe is found also in cases with an enhanced state of liver

Table 4 Comparison of in vivo calculated liver volume with use of <sup>198</sup>Au-colloid and <sup>99m</sup>Tc-phytate

cirrhosis. In the present study, the peak counts were found in the left lobe in a case of amyloidosis (case no. 72-301), in which the difference between the *in vivo* calculation and the post-mortem examination was -4.9%. Uneven radioactivity was found in a case of liver cirrhosis (case no. 72-276), and the difference was 1.9%. However, the accuracy of the method has not been tested in a sufficient number of such severe cases and greater error could occur with extremely advanced hepatic dysfunction. Increased radioactivity in tissues other than the liver is a

source of error. This can be minimized by matrix area selection. However, since bone marrow is lying behind the liver, increased activities from the bone marrow, which commonly occur in patients with severe liver cirrhosis, cannot be fully removed by area selection. In those cases, error would be increased. However, in our opinion, it is in only a few of these cases that the calculated value would be considered unreliable.

The results of comparison of the use of  $^{198}\text{Au}$ -colloid with  $^{99\text{m}}\text{Tc}$ -Sn-colloid and  $^{99\text{m}}\text{Tc}$ -phytate indicated that  $^{99\text{m}}\text{Tc}$ -Sn-colloid is distributed to extrahepatic and extrasplenic tissues in more considerable quantities than  $^{198}\text{Au}$ -colloid, making selection of liver area in a matrix necessary. The distributions of  $^{198}\text{Au}$ -colloid and  $^{99\text{m}}\text{Tc}$ -phytate seem to be similar, and the same value of extrahepatic uptake (8% in most cases) can be used in the volumetric calculation.

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