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Subsegmentation of the human liver

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INTRODUCTION

Hjortsjo (1951) originated the concept that the liver was a segmental organ. Much work has been done in this field by Elias & Petty (1952) who made plastic casts of its ductal and vascular systems. Healey & Schroy (1953) and Healey (1954) also made detailed studies of liver segmentation using plastic casts. They stated that the liver could be divided into subsegments, each with its own ductal and vascular systems. The present study was aimed at establishing the normal topographical arrangement of human hepatic subsegments, paying special attention to variations from the normal arrangement. It is hoped that such knowledge about hepatic subsegments will be of value in the precise localization and surgical treatment of hepatic disorders.

MATERIALS AND METHODS

The material for the present study comprised 85 human livers obtained within 24 hours of death from subjects of all ages. Coloured corrosion casts of the portal vein, hepatic duct and hepatic artery were prepared, using an 18% butyl butyrate solution in acetone to which appropriate colouring matter was added. Hepatic subsegments were identified on the basis of the intrahepatic distributions of the portal vein, hepatic duct and hepatic artery.

RESULTS AND DISCUSSION

In every specimen branches of the hepatic duct, hepatic artery and portal vein supplied individual territories without anastomosis with neighbouring territorial vessels and ducts. Elias & Petty (1952) and Gans (1955) also observed such a strict territorial distribution. Segall (1923), however, described some insignificant anastomoses between right and left hepatic arteries.

The pattern and relationships of the hepatic duct, hepatic artery and portal vein clearly indicated that the liver is a lobar, segmental and subsegmental organ. The liver could be divided into right and left 'physiological' lobes by the 'functional plane' (Fig. 1) which, on the visceral surface of the liver, corresponds to a line extending from the gall bladder inferiorly to the fossa for the inferior vena cava superiorly. There were no anastomoses across this plane between the right and left sided blood vessels and the hepatic ducts. This bilaterality was first described by Cantlie (1898) and substantiated by McIndoe & Counseller (1927).

The right lobe was divided into an anterior and a posterior segment by a segmental fissure (Fig. 1); this was best seen while viewing the casts from the side. The fissure could not be discerned on the external surface of the fresh liver, although Healey & Schroy (1953) described it as extending from the junction of the superior and posterior

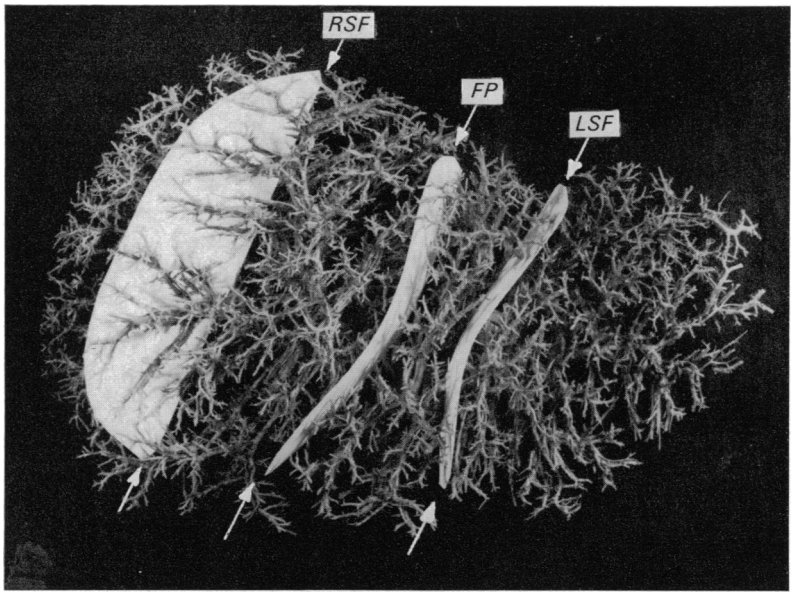
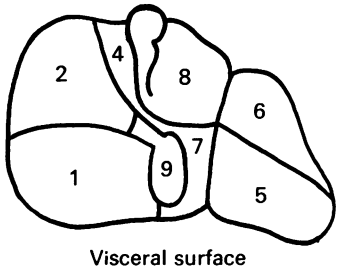
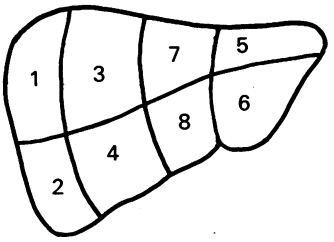


Fig. 1. The various planes in between the hepatic segments. *FP*, functional plane; *RSF*, right segmental fissure; *LSF*, left segmental fissure.

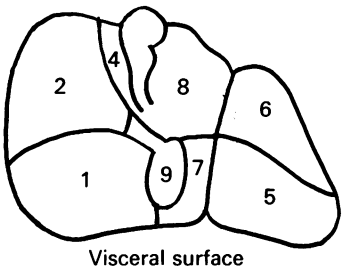


Visceral surface

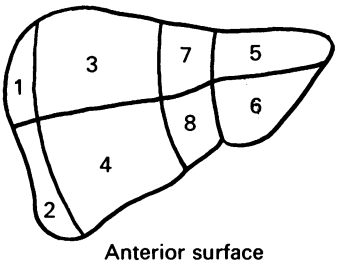


Anterior surface
41 cases (48·23 %)

Fig. 2



Visceral surface



Anterior surface
16 cases (19·82 %)

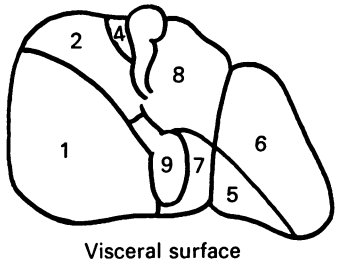
Fig. 3

Fig. 2. The commonest pattern in the sizes of the hepatic subsegments.

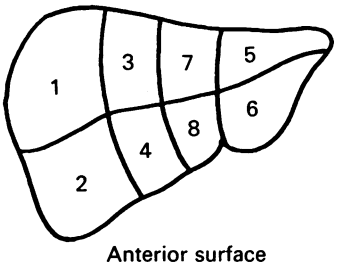
Figs. 3–17 show the variations in size of the hepatic subsegments from the commonest pattern.

Fig. 3. Relatively larger anterior superior and anterior inferior subsegments at the cost of relatively smaller posterior superior and posterior inferior ones on the anterior surface of the liver.

See p. 423 for explanation of numbering in Figs. 2–17.

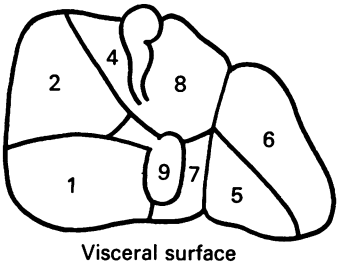


Visceral surface

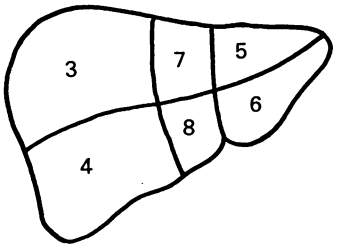


Anterior surface
2 cases (2·35 %)

Fig. 4



Visceral surface

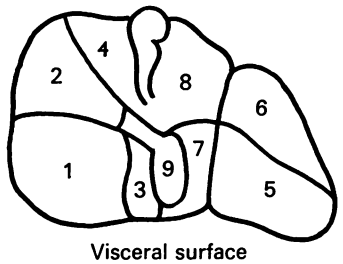


Anterior surface
1 case (1·18 %)

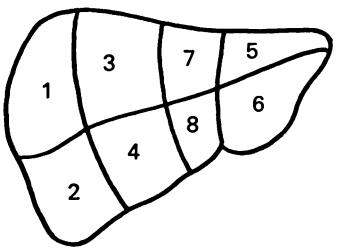
Fig. 5

Fig. 4. Relatively larger posterior superior and posterior inferior subsegments at the cost of relatively smaller anterior superior and anterior inferior ones on the anterior surface of the liver.

Fig. 5. The right lobe of the liver has two subsegments on the visceral surface, namely a posterior superior and a posterior inferior; and two on the anterior surface, viz. an anterior superior and an anterior inferior.

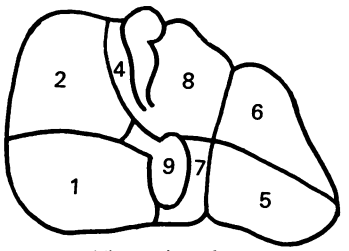


Visceral surface

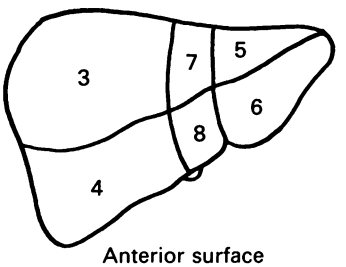


Anterior surface
2 cases (2·35 %)

Fig. 6



Visceral surface

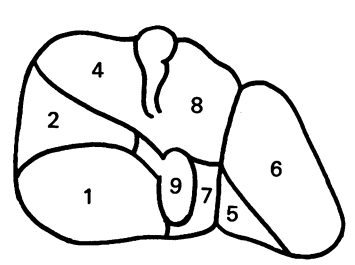


Anterior surface
7 cases (8·24 %)

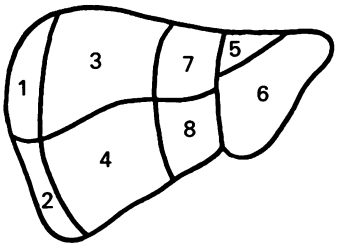
Fig. 7

Fig. 6. The presence of an anterior superior subsegment on the right side of the caudate lobe on the visceral surface of the liver. The anterior inferior subsegment is relatively larger, at the cost of a relatively smaller posterior inferior one, on the visceral surface of the liver.

Fig. 7. Right lobe of the liver has two subsegments on the anteror surface, namely an anterior superior and an anterior inferior.

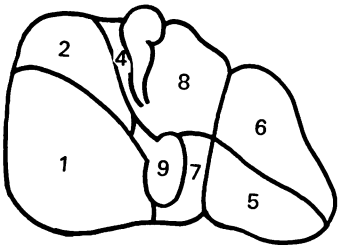


Visceral surface

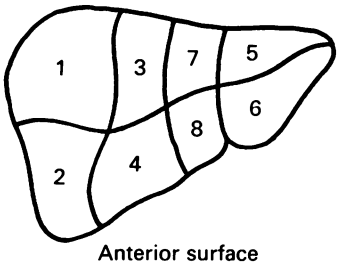


Anterior surface
1 case (1·18 %)

Fig. 8



Visceral surface



Anterior surface
1 case (1·18 %)

Fig. 9

Fig. 8. The anterior inferior subsegment is relatively larger, while the posterior superior one is relatively smaller, on the visceral surface of the liver. On the anterior surface of the right lobe of the liver, the anterior superior and anterior inferior subsegments are relatively larger, at the cost of relatively smaller posterior superior and posterior inferior ones. The same Figure depicts that the lateral inferior subsegment is relatively larger at the cost of a relatively smaller lateral superior one on both the aspects of the liver.

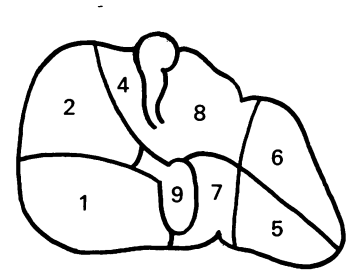
Fig. 9. The posterior superior subsegment is relatively larger on the visceral as well as on the anterior surface of the liver, at the cost of a relatively smaller posterior inferior one on the visceral surface, and an anterior superior one on the anterior surface of the liver.

surface downwards in an anterior direction and terminating just in front of the lower border of the liver.

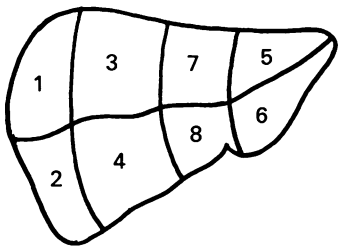
A segmental fissure was, however, discernible on the surface of the fresh left lobe (Fig. 1). It divided the left lobe into medial and lateral segments. It corresponded to the surface marking customarily used to divide the liver into right and left lobes, i.e. on the parietal surface the attachment of the falciform ligament, and on the visceral surface, the fissure for ligamentum venosum and ligamentum teres. However, in four cases (4·70 %), small branches of the medial segmental duct and blood vessels crossed to the left of the left segmental fissure (Fig. 10), and in two cases (2·35 %) the lateral segmental duct and blood vessels crossed to the right of the left segmental fissure (Fig. 13).

On the basis of its blood supply (arterial and portal) and biliary drainage, therefore, the liver was seen to consist of four segments: right anterior, right posterior, left medial and left lateral. Each of the four segments was divided into superior and inferior subsegments on the basis of the distribution of branches of the hepatic duct, hepatic artery and portal vein.

In addition to these eight subsegments the caudate lobe and process were considered as a ninth subsegment in all specimens despite some variation in the pattern of their blood supply and biliary drainage (Table 1, p. 420), e.g. the left portion of the caudate lobe was supplied by the transverse portion of the left branch of the portal vein in all cases (100 %) but in some (8·23 %) it also received an arterial supply from

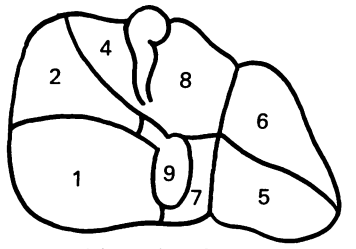


Visceral surface

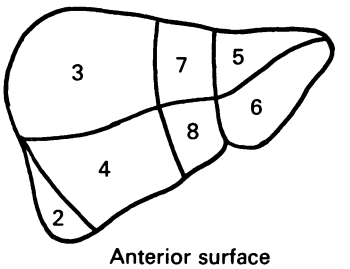


Anterior surface
4 cases (4·70 %)

Fig. 10



Visceral surface

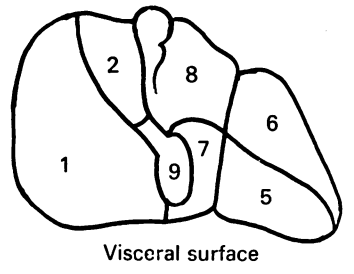


Anterior surface
1 case (1·18 %)

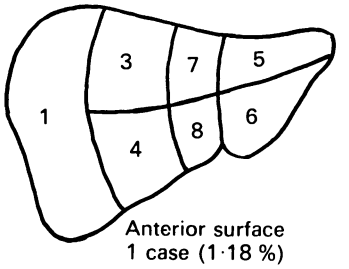
Fig. 11

Fig. 10. The medial segment of the liver is extending to the left of the left segmental fissure.

Fig. 11. A relatively larger anterior inferior subsegment on both surfaces of the liver at the cost of a relatively smaller posterior inferior one. On the anterior surface of the liver the anterior superior is relatively larger while the posterior superior is absent.

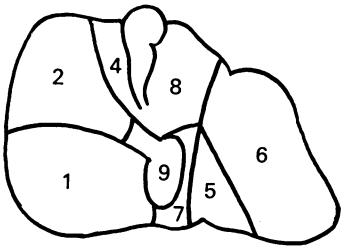


Visceral surface

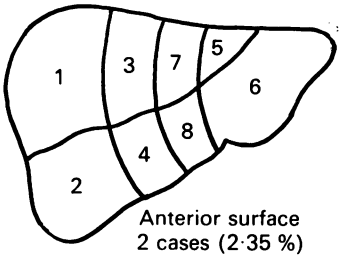


Anterior surface
1 case (1·18 %)

Fig. 12



Visceral surface

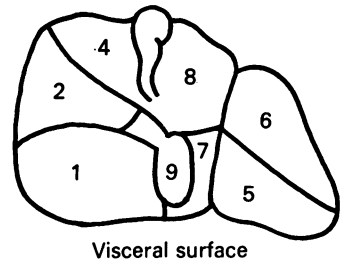


Anterior surface
2 cases (2·35 %)

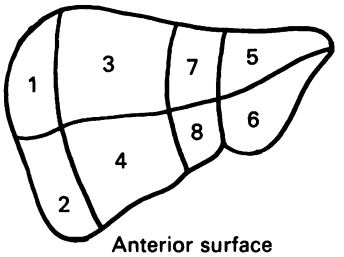
Fig. 13

Fig. 12. The largest posterior superior subsegment of the present series, which replaces most of the posterior inferior subsegment, except for a part of it on the visceral surface of the liver. There is no anterior inferior subsegment on the visceral surface of the liver.

Fig. 13. The lateral segment of the liver is extending to the right of the left segmental fissure. The lateral superior subsegment is relatively smaller, due to a relatively larger lateral inferior one on both aspects of the liver.

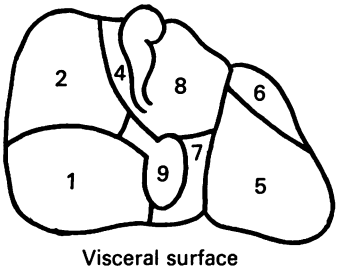


Visceral surface

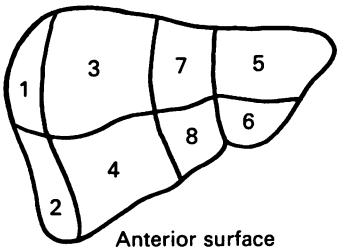


Anterior surface
2 cases (2·35 %)

Fig. 14



Visceral surface



Anterior surface
1 case (1·18 %)

Fig. 15

Fig. 14. A relatively larger anterior inferior subsegment at the cost of a relatively smaller posterior inferior one on the visceral surface of the liver.

Fig. 15. The anterior superior and anterior inferior subsegments are relatively larger at the cost of relatively smaller posterior superior and posterior inferior ones on the anterior surface of the liver. The lateral superior area covers a relatively larger territory on both aspects of the liver, at the cost of a relatively smaller lateral inferior territory.

the right hepatic arterial system and in 10 cases (11·77 %) it drained into the right hepatic ductal system.

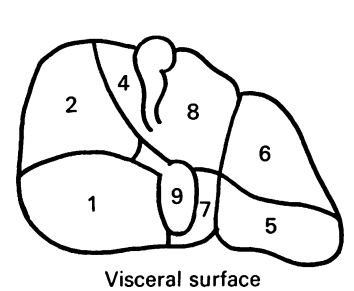
The commonest distribution pattern of these nine subsegments, as observed in 41 cases (48·23 %), is shown in Figure 2. The nine specific subsegments were present in all the specimens, but their relative sizes varied somewhat as is shown in Tables 2 and 3 (pp. 421, 422).

Similar hepatic subsegments were described by Healey & Schroy (1953), but without mentioning any variations in the patterns. Their observations were based on casts of the hepatic duct only. Healey (1954), in his extended study, observed similar patterns after injecting the hepatic duct, hepatic artery and portal vein, but again did not describe the variations in the sizes of the subsegments.

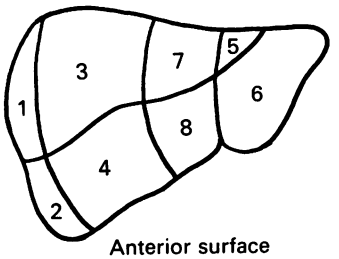
Goldsmith & Woodburne (1957), Braash (1958) and Bilbey & Rappaport (1960) studied the hepatic veins as well, and they observed the latter in planes which were intersegmental with respect to the portal vein, hepatic duct and hepatic artery. They described a pattern of subsegments similar to that of Healey & Schroy (1953). The above workers also observed variations in the subsegmental patterns, but they did not describe the types of variations in the subsegments in a way which would be useful for accurate localization and efficient surgical treatment of hepatic disorders.

Hjortsjo (1951), Elias & Petty (1952), Gans (1955), Reifferscheid (1957), Faller & Ungvary (1964), Platzer & Maurer (1966) and Kune (1969) have also described segmental patterns of the liver, and all have observed different and varying patterns.

In the present study, it has been observed that in approximately half of the cases there was uniformity in the subsegmental pattern. In other cases there was slight size

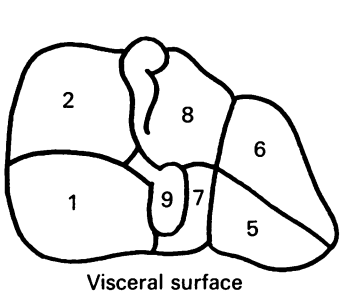


Visceral surface

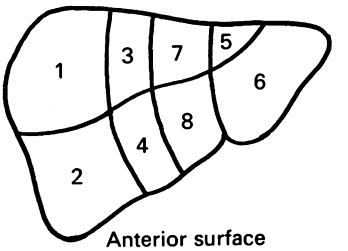


Anterior surface
1 case (1·18 %)

Fig. 16



Visceral surface



Anterior surface
2 cases (2·35 %)

Fig. 17

Fig. 16. The posterior superior subsegment is relatively larger, while anterior inferior and posterior inferior ones are relatively smaller, on the visceral surface of the liver. Anterior superior and anterior inferior subsegments are occupying larger territories at the cost of relatively smaller posterior superior and posterior inferior ones on the anterior surface of the liver. The lateral inferior territory is relatively larger at the cost of a relatively smaller lateral superior territory on both aspects of the liver.

Fig. 17. Posterior superior and posterior inferior subsegments are relatively larger, at the cost of relatively smaller anterior superior and anterior inferior ones on the anterior surface of the liver. In the same figure, the lateral inferior territory is relatively larger at the cost of a relatively smaller lateral superior one on both aspects of the liver.

variation, while in others again there was marked variation in the sizes of the subsegments from the commonest pattern. Therefore, resection of a portion of the liver should not be performed blindly. It should be well planned, and it would appear to be essential to perform either cholangiography or porto-venography to identify the subsegments before operating.

SUMMARY

Subsegmental patterns in 85 human livers have been studied after preparing corrosion casts of the hepatic duct, hepatic artery and portal vein by injecting coloured butyl butyrate solution. A subsegment was identified by the independence of its vessels and ducts from those of its neighbours. In the present study nine hepatic subsegments have been observed: (1) posterior superior, (2) posterior inferior, (3) anterior superior, (4) anterior inferior, (5) medial superior, (6) medial inferior, (7) lateral superior, (8) lateral inferior, (9) caudate (the caudate lobe and process form a separate subsegment on the basis of the pattern of their blood supply and biliary drainage). The sizes of the subsegments were very similar in 41 cases (48·23 %). In the others, some increase or decrease in the size of one or more subsegments at the expense of neighbouring subsegments was observed. These variations are illustrated.

Table 1. *The biliary drainage and blood supply of the caudate lobe*

Serial no.	Parts of the caudate lobe	Channels of 'portal triad'						
		Hepatic duct		Hepatic artery		Portal vein		
		Right ductal system	Left ductal system	Right arterial system	Left arterial system	Transverse portion of left branch of portal vein	Right branch of portal vein	Portal vein
1.	Right portion of the caudate lobe	47 cases (55·29%)	38 cases (44·71%)	51 cases (60·00%)	34 cases (40·00%)	58 cases (68·24%)	12 cases (14·12%)	15 cases (17·64%)
2.	Left portion of the caudate lobe	10 cases (11·77%)	75 cases (88·23%)	7 cases (8·24%)	78 cases (91·77%)	85 cases (100·00%)	Nil	Nil
3.	Caudate process	78 cases (91·76%)	7 cases (8·24%)	80 cases (94·12%)	5 cases (5·88%)	10 cases (11·76%)	61 cases (71·77%)	14 cases (16·47%)

Table 2. *Variations in the sizes of subsegments relative to the commonest pattern seen in the right lobe of the liver in the present series*

No. of cases	Percentage	Fig. no.	Posterior superior area		Posterior inferior area		Anterior superior area		Anterior inferior area	
			Visceral surface	Anterior surface	Visceral surface	Anterior surface	Visceral surface	Anterior surface	Visceral surface	Anterior surface
16	19·82	3	++	+	++	+	−	+++	++	+++
2	2·35	4	++	+++	++	+++	−	+	+++	+
1	1·18	5	++	−	+++	−	−	+++	−	+++
2	2·35	6	+	++	+	++	Present	++	+++	++
7	8·24	7	++	−	++	−	−	+++	++	+++
1	1·18	8	++	+	+	+	−	+++	+++	+++
1	1·18	9	+++	+++	+	++	−	+	++	++
1	1·18	11	++	−	+	+	−	+++	+++	+++
1	1·18	12	+++	+++	+	−	−	++	−	++
2	2·35	14	++	++	+	++	−	++	+++	++
1	1·18	15	++	+	++	+	−	+++	++	+++
1	1·18	16	+++	+	+	+	−	+++	+	+++
2	2·35	17	++	+++	++	+++	−	+	++	+

− = Absent.
++ = Size of hepatic areas in the commonest pattern.
+++ = Size of hepatic areas larger than the commonest pattern.
\+ = Size of hepatic areas smaller than the commonest pattern.
Note: Anterior superior area was usually confined to the anterior surface of the liver, but in two cases it extended on to the visceral surface (Fig. 6).

Table 3. *Variation in the sizes of subsegments relative to the commonest pattern seen in the left lobe of the liver in the present series*

No. of cases	Percentage	Fig. no.	Lateral superior area		Lateral inferior area		Medial superior area		Medial inferior area	
			Visceral surface	Anterior surface	Visceral surface	Anterior surface	Visceral surface	Anterior surface	Visceral surface	Anterior surface
4	4·70	10	+	+	+	+	+++	+++	+++	+++
			(Medial segment extends to the left of left segmental fissure)							
2	2·35	13	+	+	+++	+++	+	+	+	+
			(Lateral segment extends to the right of left segmental fissure)							
1	1·18	15	+++	+++	+	+	++	++	++	++
4	4·70	8, 16 and 17	+	+	+++	+++	++	++	++	++

++ = Size of hepatic areas in the commonest pattern.
+++ = Size of hepatic areas larger than the commonest pattern.
+ = Size of hepatic areas smaller than the commonest pattern.

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EXPLANATION OF NUMBERING USED IN FIGURES 2–17

1. Posterior superior
2. Posterior inferior
3. Anterior superior
4. Anterior inferior
5. Lateral superior
6. Lateral inferior
7. Medial superior
8. Medial inferior
9. Caudate