A New and Simple Practical Plane Dividing Hepatic Segment 2 and 3 of the Liver: Evaluation of Its Validity

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Objective: The conventional method of dividing hepatic segment 2 (S2) and 3 (S3) is subjective and CT interpretation is unclear. The purpose of our study was to test the validity of our hypothesis that the actual plane dividing S2 and S3 is a vertical plane of equal distance from the S2 and S3 portal veins in clinical situations.

Materials and Methods: We prospectively performed thin-section iodized-oil CT immediately after segmental chemoembolization of S2 or S3 in 27 consecutive patients and measured the angle of intersegmental plane on sagittal multiplanar reformation (MPR) images to verify its vertical nature. Our hypothetical plane dividing S2 and S3 is vertical and equidistant from the S2 and S3 portal veins (vertical method). To clinically validate this, we retrospectively collected 102 patients with small solitary hepatocellular carcinomas (HCC) on S2 or S3 the segmental location of which was confirmed angiographically. Two reviewers predicted the segmental location of each tumor at CT using the vertical method independently in blind trials. The agreement between CT interpretation and angiographic results was analyzed with Kappa values. We also compared the vertical method with the horizontal one.

Results: In MPR images, the average angle of the intersegmental plane was slanted 15 degrees anteriorly from the vertical plane. In predicting the segmental location of small HCC with the vertical method, the Kappa value between CT interpretation and angiographic result was 0.838 for reviewer 1 and 0.756 for reviewer 2. Inter-observer agreement was 0.918. The vertical method was superior to the horizontal method for localization of HCC in the left lobe ($p < 0.0001$ for reviewers 1 and 2).

Conclusion: The proposed vertical plane equidistant from S2 and S3 portal vein is simple to use and useful for dividing S2 and S3 of the liver.

Index terms:
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The segmental anatomy of the human liver has become increasingly important to the radiologist. It is important for communication between radiologists and clinicians to have accurate preoperative targeting of focal hepatic lesions. Moreover, knowing the location of a tumor is important for effective segmental transcatheter arterial chemoembolization (TACE) of hepatocellular carcinomas (HCC). Inaccurate segmentation in CT interpretation can lead to prolonged procedure times and erroneous embolization of uninvolved hepatic segments.

Contemporary hepatic surgeons and radiologists use a nomenclature based essentially on the internal vascular and biliary architecture of the organ. Couinaud's system with Bismuth modification (Fig. 1) (1, 2) is used worldwide (1, 3 –7). According to Couinaud, the liver can be divided into five sectors. The left liver is on the left side of the main portal fissure. It consists of two sectors, the left paramedian sector and the left lateral sector. The two sectors are separated by the left portal fissure (the plane of the left hepatic vein), which slants anteriorly and inferiorly as it courses caudally. However, this is not a surgically useful distinction and the anatomical landmark for this plane is difficult to demonstrate. More constant landmarks are the left portal segmental branches. As the left portal vein is traced from the bifurcation to the left, it curves medially and anteriorly. After it passes the horizontal fissure of ligament venosum, it gives off a branch to the left lateral sector or segment 2 (S2). It then courses anteriorly and sometimes caudally in the umbilical fissure to branch into segment 3 (S3) and segment 4 (S4), the paramedian sector. Although convenient for daily radiologic practice, use of this concept is highly questionable from an anatomical point of view (4, 8, 9). Clinical and extraclinical studies have demonstrated that the shape and localization of the hepatic segments based on this conventional method do not always match real situations (10 –12).

Until now, conventional consideration was that S2 was the superior-posterior part and S3 was the inferior-anterior part of the lateral segment of the left hepatic lobe (to the left of the falciform ligament, containing S2 and S3, which will be abbreviated as left lateral segment). However, this concept is subjective, unclear, and impractical for CT interpretation in clinical situations. Therefore, it is necessary to investigate the actual orientation of S2 and S3 in clinical cases and to develop a simpler and more objective method of dividing S2 and S3 with improved accuracy. The purpose of our study was to test the validity of our hypothesis that the actual plane dividing S2 and S3 is a vertical plane of equal distance from S2 and S3 portal veins in clinical situations.

MATERIALS AND METHODS

Part I: Prospective Preliminary Study about the Orientation of the Plane Dividing S2 and S3

Examinations were performed in accordance with the standards of the institutional review board. Informed consent was not required by the review board. At first, we performed thin-section iodized-oil CT immediately after segmental chemoembolization of S2 and S3 in 27 consecutive patients with small (≤ 3 cm) solitary nodular HCC at the left lateral segment (LLS) from June 2003 to March 2005. There were 20 men and seven women ranging in age from 52 –75 years, with a median age of 62-years-old. Multidetector row helical CT was performed on a Sensation 16 (Siemens Medical Solutions, Forchheim, Germany) or LightSpeed (GE Medical Systems, Milwaukee, WI) with 1-mm thick sections. The axial images were transferred to a PC equipped with dedicated three-dimensional (3D) reconstruction software (Rapidia®; Infinitt, Seoul, Korea), and sagittal multiplanar reformation (MPR) images of the LLS were generated. We measured the angle ('+' was defined as the anterior direction and ' –' as the posterior direction) of the plane dividing S2 and S3 on the basis of a vertical plane at three different parts and calculated the average (Fig. 2). These three parts were the medial and lateral ends of the plane (as divided by lipiodol uptake) and the center of the plane.

Part II: Retrospective Study Comparing the Vertical Method with the Horizontal One in Segmental Localization of Hepatocellular Carcinomas in S2 or S3

Patient Selection

In this retrospective study, a computerized search of the TACE registry database of our department during a five-year period from March 1998 to June 2003 revealed triple-phase helical CT of 106 patients with small (≤ 3 cm) solitary nodular HCC specifically within the LLS. Segmental location was confirmed by selective angiography of segmental arteries and segmental TACE followed by iodized-oil CT. Homogeneous iodized-oil accumulation in the entire tumor nodule without a defect was the inclusion criteria.

Four patients were excluded from the analysis for any of the following reasons: (a) variations in S2 and S3 portal vein comprised of common trunk (n = 2), (b) nonvisualization of the left portal vein or its branches on CT scan (n =

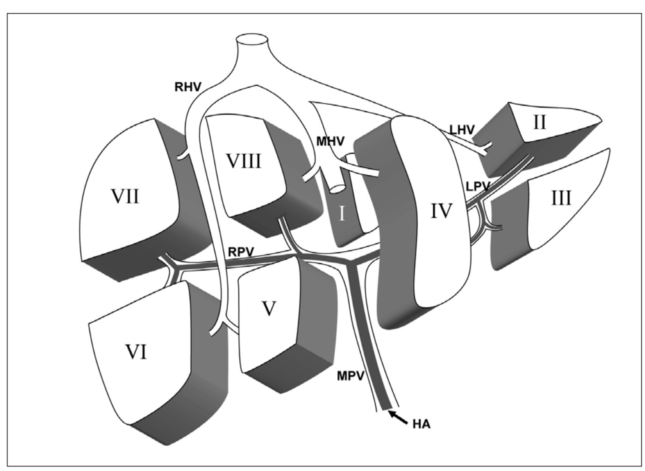


Fig. 1. Diagram of the hepatic segments (I –VIII) with their portal venous branches, separated by the hepatic veins and the transverse fissure. Anterior view of the liver. Segments are numbered in a counterclockwise direction (RHV = right hepatic vein, MHV = middle hepatic vein, LHV = left hepatic vein, RPV = right portal vein, LPV = left portal vein, MPV = main portal vein, HA = hepatic artery).

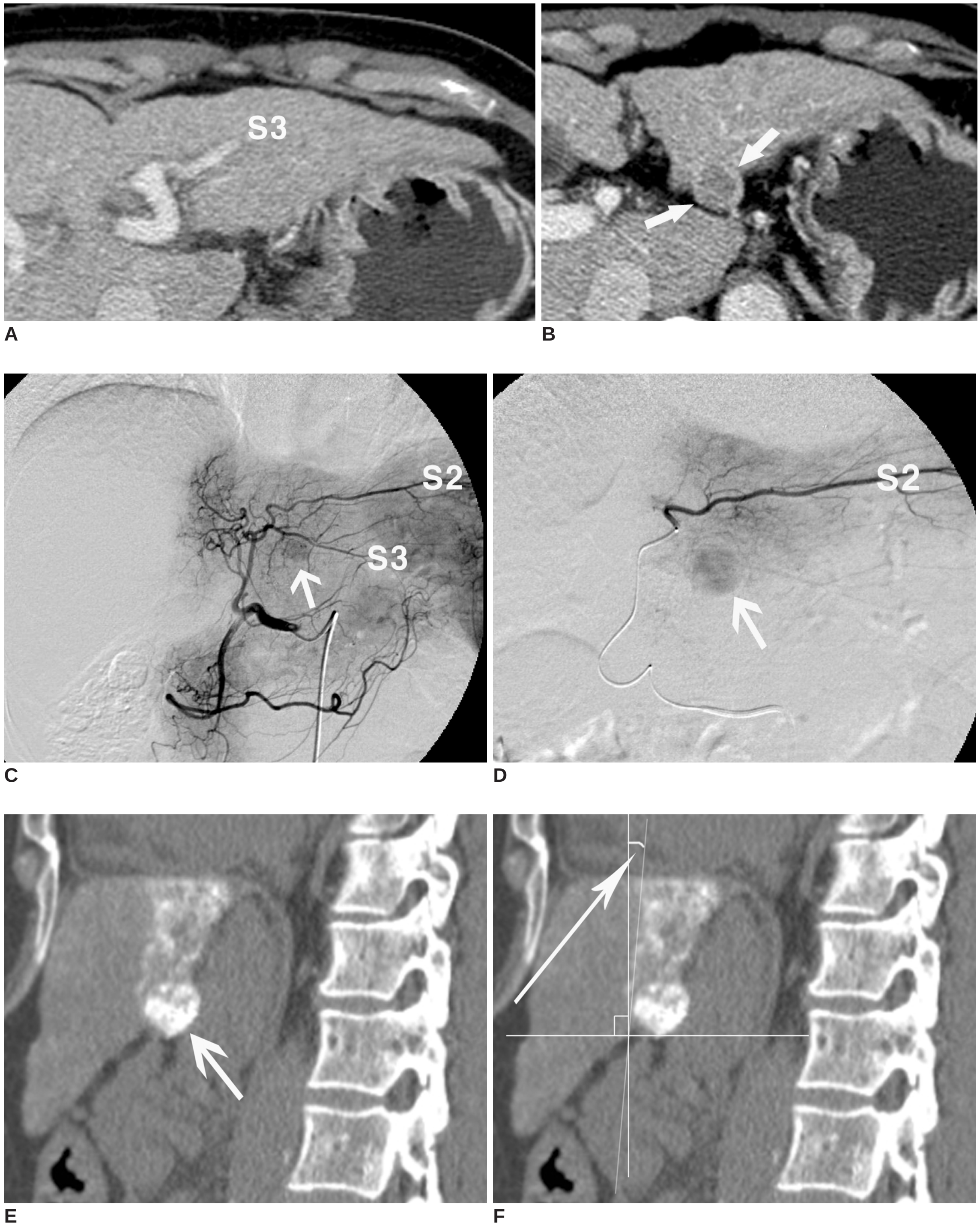


Fig. 2. Intersegmental plane depicted on iodized-oil CT in a 61-year-old female with hepatocellular carcinoma in the left lateral segment.
A. Portal venous phase CT image shows the umbilical portion of the left portal vein.
B. Small peripheral rim-enhancing tumor nodule with central low attenuation (arrows) is noted in the section below the umbilical portion.
C. Proper hepatic arteriogram shows the small tumor staining below the S3 hepatic artery. However, selective S3 hepatic arteriogram (no figure shown) shows no tumor staining.
D. Selective S2 hepatic arteriogram shows the tumor staining. Segmental chemoembolization of S2 was performed.
E. Sagittal multiplanar reformation image of thin-section iodized-oil CT performed immediately after segmental chemoembolization shows the segmental distribution of the iodized oil in S2 and dense iodized oil uptake to the tumor without any defect (arrow).
F. The intersegmental plane between S2 and S3 (thin continuous line) was almost vertical (angle: -2 degree). '+' was defined as the anterior direction and '–' as the posterior direction.

1), and (c) an undersized S3 portal vein branch (n = 1).

Our study group was comprised of the remaining 102 patients . The mean age of the patients was 65 years (age range, 38–81 years). Seventy-eight patients were men, and 24 patients were women. The mean diameter of the solitary nodules was 2.1 cm (size range, 1.0–3.0 cm). The average time interval between CT and TACE was 3.1 weeks. An institutional review board approved this retrospective review. Informed consent was not required by the review board.

CT Technique

All patients underwent triple-phase CT imaging consisting of pre-contrast, arterial dominant, and portal dominant phases before embolization. A single detector helical CT (Somatom plus: Siemens, Erlangen, Germany) was used for six patients and a multidetector helical CT (LightSpeed: GE Medical Systems, Milwaukee, WI; MX8000: Marconi Medical Systems, Cleveland, OH) was used for 96 patients. For pre-contrast images, 5 mm section thickness was acquired for 95 patients; for the remaining seven patients, section thickness was 8 mm. After the administration of 120 ml of Ultravist 370 iopromide, a nonionic contrast material (Schering AG, Berlin, Germany) at a rate of 3 mL/sec using a power injector, arterial and venous phase helical CT scans were obtained. The scanning parameters for the single detector helical CT scanners were 5 mm slice thickness, pitch of 1.5, 3 mm reconstruction interval for the arterial phase and 5 mm interval for the portal venous phase, 150 mAs, 120 kVp, and a 512 × 512 matrix. Scanning parameters for multidetector helical CT scanners included gantry rotation time of 0.5–0.8 sec with 4 × 1.25 mm or 8 × 1.25 mm detector configuration, 2.5 mm slice thickness, pitch of 1–1.5, 3 mm reconstruction interval for both phases, 150 mAs, 120 kVp, and a 512 × 512 matrix. Arterial phase scans were initiated 11 seconds (for single detector helical CT) or 13 (for multi-detector helical CT) seconds after the aortic attenuation reached 100 HU using bolus tracking. After completion of arterial phase scanning, a 15-second delay (for single detector helical CT) or 30-second delay (for multidetector helical CT) was used for the portal venous phase. Unenhanced follow-up CT examination was performed during the second or third weeks after embolization.

Methods for Segmental Localization of Tumors

Horizontal Method

The horizontal method divides S2 and S3 by a horizontal plane at the level of the umbilical portion of the left portal vein. The nodule above the umbilical portion of the left portal vein is considered to be S2 and the nodule below the umbilical portion is considered to be S3.

Vertical Method

We established a hypothesis that a plane, which is vertical and of equal distance from the S2 and S3 portal veins, can divide S2 and S3 more accurately than the transverse plane. In the cases of liver cirrhosis, the vertical plane becomes the curved plane when the left lateral segment is hypertrophied. According to the vertical method, all the nodules anterior to the plane are considered to be in S3, whereas the nodules posterior to the plane are considered to be S2. How to create the vertical plane in each case is illustrated in Figure 3. The procedure was performed on a PACS viewer using the cine mode.

CT Interpretation and Analysis

We applied two different segmentation methods (vertical method proposed by the authors versus horizontal method) in each patient. Two board certified radiologists independently interpreted triple-phase helical CT examination of the 102 patients and predicted the segmental location of the tumor using the vertical method independently. To prevent bias, the reviewers were uninformed as to the results of angiography, other reviewer's opinions, and other segmental methods.

After six months or more, the same reviewers applied the horizontal method to predict segmental location of tumors without knowing the results of angiography and the previous segmentation method.

When a tumor was intersected by a dividing plane during the process of segmental localization, it was classified as being in a "borderline location," abbreviated as S23, and the possibility of blood supply from both segmental hepatic arteries was suggested.

Using the S2 portal vein and S3 portal vein as a standard, the LLS of the liver can be divided into three parts, both in the anterior-posterior direction (anterior, middle, and posterior) and superior-inferior directions (superior, middle, and inferior). The LLS of the liver is thus divided into nine zones: superior-anterior (SA), superior-middle (SM), superior-posterior (SP), middle-anterior (MA), middle-middle (MM), middle-posterior (MP), inferior-anterior (IA), inferior-middle (IM), and inferior-posterior (IP).

According to this concept, the distribution of 102 nodules among the nine zones was accordingly assessed (Fig. 4).

Angiography and Segmental Transcatheter Arterial Chemoembolization

A 5-Fr RH catheter (Cook, Frankfurt, Germany) was used to perform celiac arteriography via the right femoral

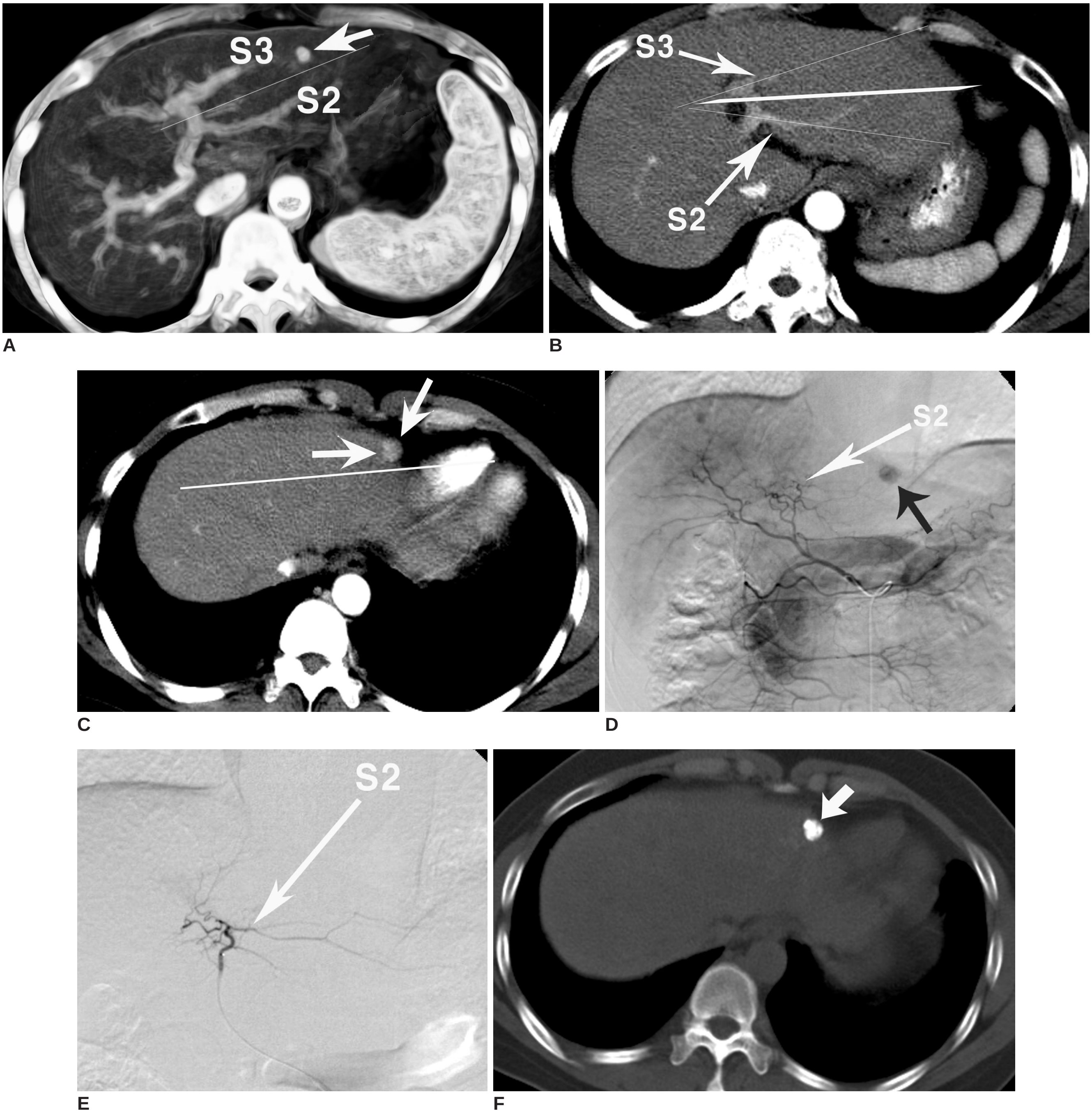


Fig. 3. How to create a hypothetical vertical plane equidistant from S2 and S3 portal veins in a 52-year-old female with hepatocellular carcinoma in the left lateral segment.
A. Axial maximum intensity projection image shows S2 and S3 portal vein branching from the umbilical portion and the location of the hypothetical vertical plane (line), which is vertical and of equal distance from S2 and S3 portal veins. Small hepatocellular carcinoma nodule (arrow) is noted between S2 and S3 portal vein and anterior to the plane.
B. The first step in creating the plane is to draw a line along S2 and S3 portal veins on the axial portal phase helical CT (thin lines). It is a prerequisite to use the cine mode in PACS viewer. Then, we can easily create a line (thick line) in equal distance from the two lines, which is the hypothetical vertical plane tested in this study.
C. By scrolling images, we can reach the axial plane containing the tumor. Small enhancing nodule (arrows) is noted at the peripheral area of the left lateral segment above the umbilical portion. By applying the hypothetical plane in this image, we can predict the nodule is located in S3 because it is anterior to the plane.
D. A proper hepatic arterial angiogram shows a hypervascular tumor (black arrow) just below the diaphragm above S2 hepatic artery (white arrow with S2).
E. However, a selective S2 hepatic arteriogram shows no tumor staining. Tumor staining was detected at the selective S3 hepatic arteriogram (not shown) and segmental chemoembolization of S3 was performed.
F. Follow-up iodized-oil CT after segmental transcatheter atterial chemoembolization shows homogenous deposition of iodized oil in the tumor.

artery. After selective placement of a microcatheter (Microferret-18, Cook, Canada) in the S2 or S3 hepatic arteries, the segmental arterial blood supply to the individual tumor nodule was evaluated with digital subtraction angiography. After identifying tumor-feeding segmental hepatic arteries, segmental TACE with an emulsion of doxorubicin hydrochloride and iodized-oil (Lipiodol Ultrafluid; Laboratoire Andre Guerbet) was performed. Two weeks later, unenhanced iodized-oil CT was performed and homogeneous iodized-oil accumulation in the entire tumor nodule without a defect was confirmed. The angiographic results of tumor feeding arteries were used as a standard reference for the comparison (Fig. 3).

Statistical Analysis

One radiologist validated and compared the results of segmentation by two different methods based on the results of angiography and segmental TACE.

We used the weighted kappa coefficient of agreement (weighted Kappa) of GraphPad Prism, version 8.00 for Windows (GraphPad Software, San Diego, CA) to evaluate the agreement between the angiographic tumor location and CT interpretation and to evaluate the interobsever's agreement. A kappa value of 1 indicates complete agreement; on the other hand, a kappa value of 0 indicates only random agreement. We defined the segments as identical for values of > 0.75 (very good agreement), as coinciding acceptably by values between 0.45 and 0.75 (good agreement), and as coinciding poorly for values below 0.45 (poor agreement) (13).

Chi-square test (SPSS for Windows, release 10.0.7; SPSS, Chicago, IL) and the weighted kappa coefficient of agreement were used to compare two methods with respect to the segmental location of the tumor for each reviewer.

RESULTS

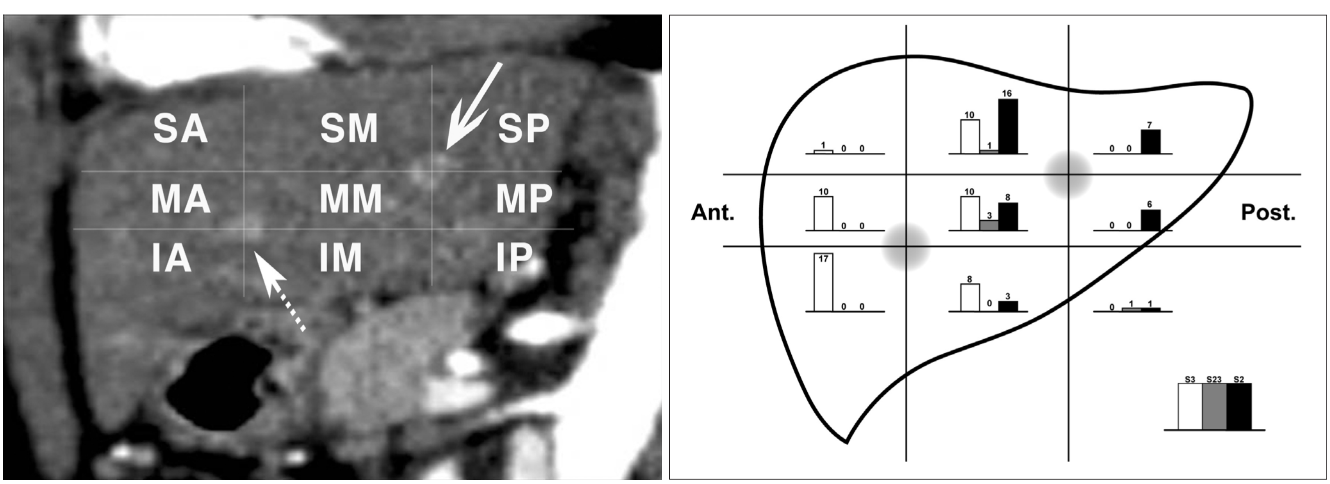
Part I: Prospective Study about the Orientation of the Plane Dividing S2 and S3

In the investigation with sagittal MPR images of the iodized-oil CT, the average angle of the plane dividing S2 and S3 was slanted 15 degrees anteriorly. The average angle from the vertical plane in the right-left direction was +12 degrees at the medial end of the plane, +17 degrees at the center of the plane, and +16 degrees at the lateral end of the plane (Fig. 2).

Part II: Retrospective Study Comparing the Vertical Method with the Horizontal One in Segmental Localization of Hepatocellular Carcinomas in S2 or S3

Distribution of Tumor Nodules Determined by Selective Angiography and Transcatheter Arterial Chemoembolization

Forty-one nodules were located in S2, 56 nodules were found in S3, and five nodules were in the borderline location with blood supply from both segmental hepatic arteries (which will be abbreviated as S23).



A B

Fig. 4. How to determine nine zones of the left lateral segment in the sagittal plane based on S2 and S3 portal veins and the distribution of their tumor-feeding arteries in each zone.

A. By the standard of S2 portal vein (continuous arrow) and S3 portal vein (dashed arrow), the left lateral segment of the liver was divided into nine zones: superior-anterior (SA), superior-middle (SM), superior-posterior (SP), middle-anterior (MA), middle-middle (MM), middle-posterior (MP), inferior-anterior (IA), inferior-middle (IM), and inferior-posterior (IP).

B. The distribution of tumor-feeding arteries of 102 hepatocellular carcinomas are illustrated in the schematic diagram of the nine zones.

Distributions of Tumor Nodules on the CT Scan

The left lateral segment was divided into nine zones. The distribution of 102 nodules among these nine zones, as well as the tumor-feeding arteries in each zone, are illustrated in Figure 4.

All of the 28 nodules in front of the S3 portal vein were supplied by the S3 hepatic artery, and all of the 15 nodules posterior to S2 portal vein were supplied by the S2 hepatic artery. There was one exceptional case with partial S3 hepatic arterial supply to the IP zone. Among the 59 nodules between the S2 and S3 portal veins (in the SM, MM, IM zones), they were almost equally supplied by the S2 and S3 hepatic arteries: 28 nodules were solely supplied by the S3 hepatic artery, 27 nodules by the S2 hepatic artery, and the remaining four by both hepatic arteries. In the SM zone, nodules supplied by the S2 hepatic artery were dominant. On the other hand, IM zone nodules were more frequently supplied by the S3 hepatic artery.

Correlation between CT Interpretation by Vertical Method and Angiographic Results

The agreement rates between CT interpretation by vertical method and angiographic results were 88.2% (90 of 102) for Reviewer 1 and 84.3 % (86 of 102) for Reviewer 2 (Table 1). Weighted Kappa values were 0.838 for Reviewer 1 and 0.756 for Reviewer 2, which indicates 'very good' agreement between CT interpretation by vertical method and angiographic results.

Approximately 1/2 of all mismatches occurred in tumor nodules interpreted as S23 (that is, "borderline location") on CT interpretation (seven of 12 mismatches by Reviewer 1 and seven of 16 mismatches by Reviewer 2). In 11 cases with the tumors in the "borderline location" on CT interpretation either by Reviewer 1 or 2, five cases were angiographically confirmed as S2 lesions while the other two cases were S3 lesions. The remaining four cases were supplied by both the S2 and S3 hepatic arteries.

When the LLS of the liver was divided into nine zones by the standard of the S2 portal vein and S3 portal vein, mismatches by both Reviewer 1 and 2 occurred in SM, MM, and IP zones (two cases in SM, two cases in MM, and one case in IP zone).

Inter-observer agreement rate was 96.1% (98 of 102 cases) and weighted Kappa value was 0.918 with 'very good' degree in the strength of agreement (Table 2). Mismatches between reviewers were observed only in four cases.

Comparison between Vertical Method and Horizontal Method

The agreement rate between CT interpretation by the horizontal method and angiographic results was 78.4% (80 cases of 102 cases) from Reviewer 1 and 75.5% (77 cases of 102 cases) from Reviewer 2 with the weighted Kappa value of 0.611 for Reviewer 1 and 0.510 for Reviewer 2 (Table 3). Inter-observer agreement rate was 91.2% (93 of 102 cases) and weighted Kappa value was 0.813 with 'very good' degree of strength of agreement (Table 2).

The agreement rates in the vertical method were higher than those in the horizontal method from both reviewers (88.2% vs. 78.4% from Reviewer 1 and 84.3% vs. 75.5%

Table 1. Analysis of the Agreement Rates between CT Interpretation by the Vertical Method and Angiographic Results

		Angiographic Findings			Total
		S2	S23	S3	(n = 102)
First Reviewer	S2	34	1	2	37
	S23	5	4	2	11
	S3	2	0	52	54
Second Reviewer	S2	31	1	3	35
	S23	5	4	2	11
	S3	5	0	51	56

Note.— This data was derived from angiography and transcatheter arterial chemoembolization results.

Table 2. Analysis of Inter-observer Agreement Rate

	First Reviewer Analysis	Second Reviewer Analysis			Total (n = 102)
		S2	S23	S3	
Vertical Method	S2	34	0	3	37
	S23	0	11	0	11
	S3	1	0	53	54
Horizontal Method	S2	46	1	0	47
	S23	2	3	5	10
	S3	1	0	44	45

Table 3. Analysis of the Agreement Rates between CT Interpretation by the Horizontal Method and Angiographic Results

		Angiographic Findings			Total
		S2	S23	S3	(n = 102)
First Reviewer	S2	35	1	11	47
	S23	2	4	4	10
	S3	4	0	41	45
Second Reviewer	S2	35	1	13	49
	S23	3	0	1	4
	S3	3	4	42	49

from Reviewer 2). The difference was statistically significant (p-value > 0.0001 for Reviewer 1 and for Reviewer 2 by Chi-square test). Weighted Kappa value between two methods was 0.654 with Reviewer 1 and 0.543 with Reviewer 2.

DISCUSSION

Radiologists have recently published observations that call into question the routine radiologic methods currently used for delineation of the segmental anatomy of the liver (14). These kinds of questions have been spurred by dramatic developments in medical imaging techniques. Nelson et al. (4) evaluated the preoperative subsegmental localization of focal hepatic lesions with the use of CT during arterial portography and concluded that the CT findings disagreed with the extent of spread observed at surgical resection in 11 of 36 (31%) lesions. Downey (15) called attention to the fact that the scissurae may curve, undulate, or even interdigitate within the liver. Soyer et al. (8) suggested that indirect landmarks are not reliable for correct delineation of portal venous segments with CT during arterial portography. Indeed, the radiologic-anatomic correlation of the subsegments was poor because the shape, size, and number of portal venous territories varied greatly. The territorial boundaries were not flat planes but were undulating (10, 16). Fasel et al. (10) suggested that radiological determinination of the segmental and subsegmental portal venous anatomy can be done by evaluation of the overlapping transverse slices in an interactive cine mode or by performing 3D rendering (17). However, reconstruction of the actual anatomy of the portal vein tree using these techniques is not easy . It requires acquisition of thin-section data and additional time and labor for reconstruction. A dedicated software program can shorten the time and improve the quality of 3D reconstruction (12). However, it is impractical to obtain volume CT in every patient for routine screening for liver tumors.

In the liver, the detailed segmental anatomy of the LLS has not yet been investigated on CT examination. It has been studied only according to the conventional concept of posterosuperior location of S2 and anteroinferior location of S3. Only recently, a study about the LLS by Fischer et al. (9) showed poor correlation for shape and position in segment 3 when Couinaud's method was compared to the portal-vein based method. Actually, the detailed segmental localization of tumors in the LLS is relatively less important to hepatic surgeons because the LLS is usually removed entirely except in cases of tumorectomy. Instead, it would be more important to have adequate communication between the diagnostic radiologists and interventional radiologists responsible for TACE.

In this study, we focused on the LLS. In the interventional radiologists' point of view, we used the segmental hepatic artery supplying a tumor nodule as the standard reference for its segmental localization. We demonstrated excellent correlation between CT interpretation based on segmental portal branches and angiographic results based on segmental hepatic arteries. This correlation between segmental portal branches and hepatic arteries is based on the anatomical fact that the hepatic artery and portal vein course together through the portal channel. This implies that accurate segmental localization of tumors on CT scan is quite useful for effective segmental TACE.

In contrast to the vague conventional concept of a posterosuperior-anteroinferior relationship between S2 and S3, we have proposed an anterior-posterior relationship for better applicability to clinical practice. On iodized-oil CT taken immediately after segmental TACE in part I, the average angle of the plane dividing S2 and S3 was much closer to the vertical plane than to the transverse plane (slanted 15 degrees anteriorly from the vertical plane in the right-left direction). This proved that the intersegmental plane had a more vertical nature. In part II, the agreement rates in the vertical method were 88.2% for Reviewer 1 and 84.3% for Reviewer 2 and these were significantly higher than those to both reviewers using the horizontal method (78.4% to Reviewer 1 and 75.5% to Reviewer 2).

We also retrospectively investigated tumor-feeding arteries in 102 HCC nodules (Fig. 4). These results imply that the intersegmental plane is almost vertical and that the distribution of S3 extends in a more superior direction than conventionally believed . However, in the SM zone, nodules supplied by the S2 hepatic artery were dominant. On the other hand, IM zone nodules were more frequently supplied by the S3 hepatic artery, which implies that the intersegmental plane is slanted slightly to the anterior from the vertical plane.

The inter-observer agreement rate with our method was 96.1% (98 cases of 102 cases) and this value of inter-observer agreement rate means that our method dividing S2 from S3 using a hypothetical vertical plane is highly objective. Among the four cases with interobserver disagreement on segmental localization of tumors, three cases had tortuous S2 or S3 portal branches. The remaining one had S2 portal veins with early dichotomization. We think that, in these anatomical variations, to draw a representative straight line for S2 or S3 portal veins becomes a subjective task, which can lead to interobserver disagreement.

Limitation

The model we propose has its limitations, however. This technique cannot be applied when the portal vein is not well delineated. This occasion may happen with liver cirrhosis, tumor invasion to the portal vein, or with inappropriate portal venous phase scans. Severe anatomical variation or tortuosities of S2 or S3 portal veins can cause incorrect segmental localization of tumors or give rise to considerable individual variations in interpretation. Fortunately, the LLS showed relatively constant portal anatomy (18, 19).

We compared the vertical plane for dividing the S2 and S3 segments, or vertical method, to the horizontal method. In our clinical experience of segmental angiography, the practical plane may be more oblique than horizontal, but we defined the actual conventional method as a purely horizontal plane simply because of individual variation and obscure definitions of the relationship between S2 and S3. According to the results of this study, the orientation of the intersegmental plane is slightly slanted anteriorly from the vertical plane. This was not only seen in the preliminary study using iodized-oil CT immediately after segmental chemoembolization, but was also observed in analysis of tumor-feeding arteries using small HCC in the LLS.

In conclusion, our proposed vertical method is simple and effective in accurately distinguishing the division between section 2 (S2) and section 3 (S3) of the liver.

Acknowledgments

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