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Leading Innovation >>>

Liver Perfusion Analysis  
New Frontiers in Dynamic Volume Imaging

**ONE**  
*Aquilion*  
dynamic volume CT

Case Study Brochure  
Chang Gung Memorial Hospital



**TOSHIBA MEDICAL SYSTEMS CORPORATION**

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**ONE**  
*Aquilion*

# Liver Perfusion Analysis

New Frontiers in Dynamic Volume Imaging

## Introduction

Chang Gung Memorial Hospital in Linkou, Taiwan, is a 3715 bed hospital that has been providing care to the community for over 35 years.

The 43 physicians and 91 radiographers in the Radiology Department perform a wide range of radiologic examinations and treatments for the entire patient spectrum from neonates to geriatric patients. In September 2009, an Aquilion ONE™ scanner was installed in our department.

The Aquilion ONE at our hospital has inspired an enormous amount of enthusiasm for the exploration of advanced dynamic volume imaging.

The Aquilion ONE, with its 16 cm coverage, makes it possible to acquire an entire lesion or organ at the same instant in time, and the system is therefore ideal for CT perfusion studies.

The liver perfusion analysis software gives us a new method not only for diagnosing liver tumors but also for assessing the effectiveness of tumor treatment. It is especially helpful in patients with a large amount of retained Lipiodol from previous treatments. In such patients, viable HCC nodules in close relation to the Lipiodol can easily be identified. Liver perfusion analysis also gives us greater insight into liver hemodynamics, which is valuable for assessing liver cirrhosis. We have recently begun to perform selective internal radiation therapy (SIRT) with yttrium-90. CT liver perfusion follow-up in these patients allows us to evaluate the formation of necrosis and thus assess the effectiveness of the SIRT procedure.

This brochure presents a number of clinical cases in which liver perfusion analysis was of great value in diagnosis, treatment, and follow-up.



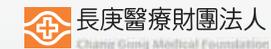
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WARNING: Any reference to x-ray exposure, intravenous contrast dosage, and other medication is intended as a reference guideline only. The guidelines in this document do not substitute for the judgment of a healthcare provider. Each scan requires medical judgment by the healthcare provider about exposing the patient to ionizing radiation. Use the As Low As Reasonably Achievable radiation dose principle to balance factors such as the patient's condition, size and age; region to be imaged; and diagnostic task.

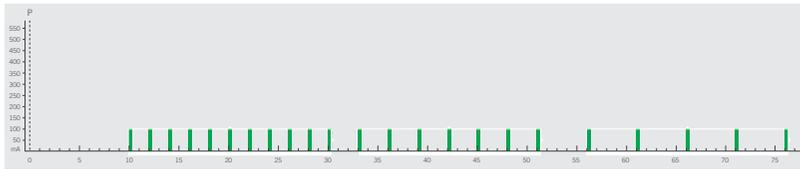
# Liver Perfusion Analysis

Aquilion ONE is the world's first dynamic volume CT system. Volumetric scans of up to 16 cm in length permit the entire liver to be scanned in a single gantry rotation. Sequentially acquired volumetric scans allow dynamic volume imaging, making it possible to perform time-based functional studies.

The liver perfusion protocol is designed specifically for assessment of the entire liver in a single 76 s scan sequence with a small contrast medium volume and a low exposure dose.

## Scan Protocol

The scan protocol acquires volumetric scans of the entire liver during quiet respiration. The quiet respiration should be shallow, even and as slow as possible. The first two volumes are used as a baseline for analysis. A series of low-dose intermittent scans are initially performed every 2 s to capture arterial flow, then spaced out to every 3 s to capture portal flow, and then every 5 s to capture the slower liver maximum enhancement phase. The entire protocol is performed at 100 kV and 50 mAs, corresponding to an exposure dose of approximately 15.1 mSv ( $k=0.015$ ), with the administration of 30-80 mL of intravenous contrast medium.



A CT perfusion study requires the use of contrast medium with an iodine concentration of at least 350 mgI/mL. The following contrast injection protocol has been optimized for CT liver perfusion analysis. Due to the high injection rates, an 18G or larger IV cannula must be placed in a right antecubital vein. The saline flush is needed to ensure that all of the contrast medium arrives at the heart promptly.

Weight (kg)	Injection rate (mL/s)	Contrast volume (mL)	Saline flush (mL)
<50	6.0	30	30
50-69	7.0	35	30
70-89	8.0	40	30
≥90	10	50-80	40

## Workflow

Following data acquisition, postprocessing is performed in two steps.

### Step 1 - Registration

Because the liver perfusion scans are acquired over multiple breath-holds, the volumes are not perfectly aligned. In order to perform accurate perfusion analysis, registration is necessary to align the volumes and minimize the effects of respiratory movement between volumes. Toshiba has developed an advanced deformable registration algorithm that accurately aligns the anatomy throughout the entire scan.

### Step 2 - Analysis

Liver perfusion maps are calculated using the Dual Input Maximum Slope analysis method. ROIs are simply placed in the aorta, portal vein, normal liver tissue, and spleen. The following maps are generated.

Perfusion parameter	Units
Portal flow (PF)	mL/min/100 mL
Arterial flow (AF)	mL/min/100 mL
Hepatic perfusion index (PI)	AF/(AF+PF) [percentage]

## Interpretation

Initial interpretation of perfusion maps should include the qualitative comparison of relative perfusion results in various regions of the liver. The patient's clinical presentation should also be considered when evaluating perfusion maps. Early results for quantitative measurements in liver perfusion analysis suggest the following guidelines for normal values.

Perfusion parameter	Normal range (mL/min/100 mL)
Portal flow (PF)	100-200
Arterial flow (AF)	10-45
Hepatic perfusion index (PI)	Threshold 40%

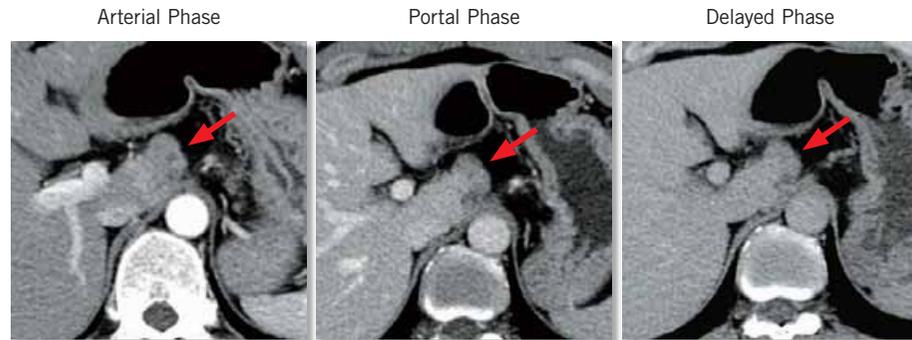
The above values are based on early results. Further studies involving larger numbers of patients are needed to confirm these values.

## Caudate lobe mass workup

### Patient History

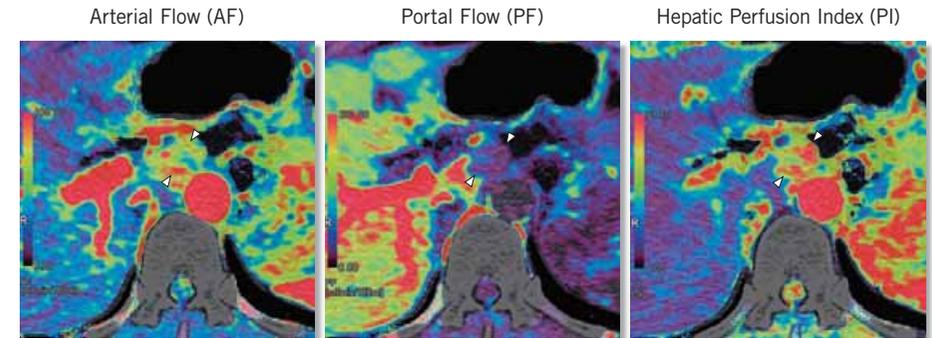
This is a 50-year-old man with a clinical history of hepatitis B virus (HBV) infection who presented with an elevated alpha-fetoprotein (AFP) value of 191 ng/mL. Ultrasound examination did not show a definite liver mass. In view of the elevated AFP value and history of HBV infection, the patient was referred for a triphasic liver CT study.

### Initial CT Study

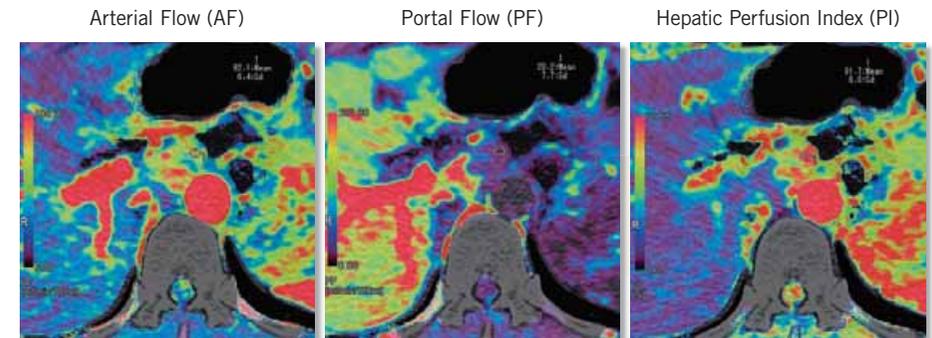


The triphasic CT study showed a 23 mm hypoattenuating nodule over segment 1 (arrows). Liver perfusion CT was performed for further assessment of the S1 lesion.

### Perfusion Findings

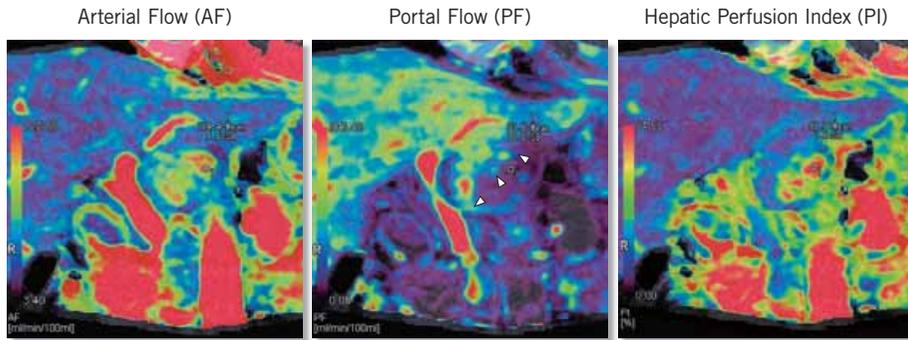


The perfusion maps clearly show the mass in the caudate lobe, best seen in the PF map. It is crescent-shaped medially and peripherally in segment 1 (arrowheads). No lesions are observed elsewhere in the liver.



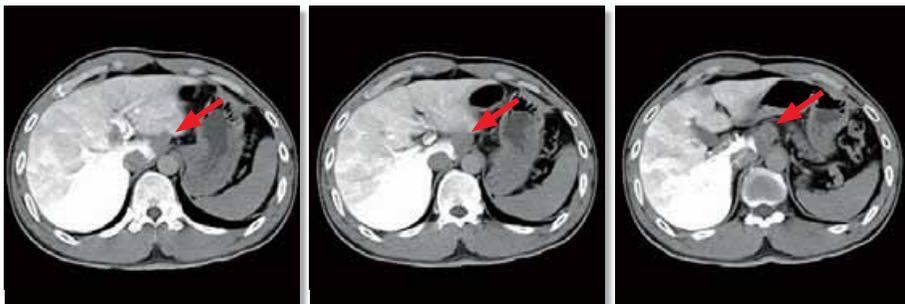
The quantitative perfusion parameters show an increased AF and a markedly reduced PF. AF = 82.1, PF = 20.2, and PI = 81.7. These values are characteristic of hepatocellular carcinoma (HCC).

## Caudate lobe mass workup (continued)



In the coronal plane maps, the margins of the lesion are again best seen in the PF map (arrowheads). The lesion encompasses the entire segment, with mixed, uneven perfusion indicating areas of rapid change. A very small amount of normally perfused liver remains in this segment.

### CTA Portogram

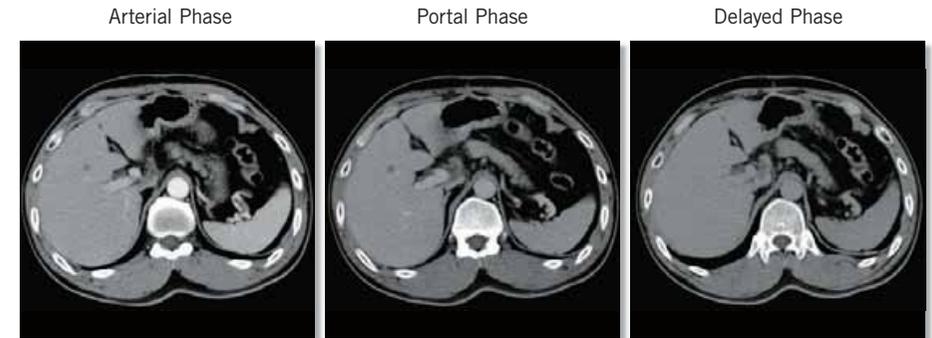


CTA portography was also performed. These contiguous axial images confirm that there is no portal circulation to the caudate lobe mass.

### Conclusion/Treatment

The patient underwent caudate lobectomy. Histological examination showed grade 3 HCC. Regular follow-up was arranged, with routine CT scans performed every 3 months over a 12 month period.

### Follow-up CT Scan



The caudate lobe has been completely excised. There are no lesions in other parts of the liver, indicating that there has been no tumor spread.

The use of liver perfusion analysis in the diagnostic workup of this patient made it possible to establish a definitive diagnosis of HCC, resulting in rapid surgical treatment with a good prognosis.

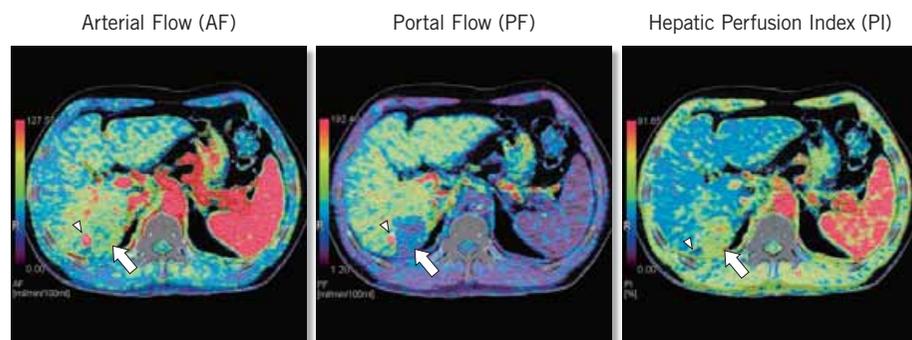


## HCC follow-up

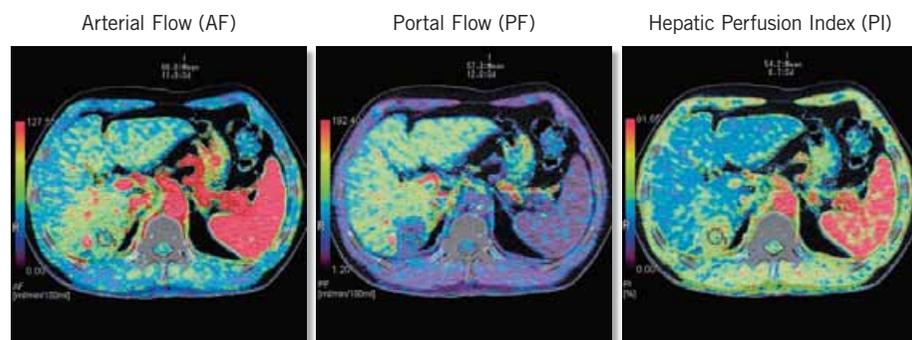
### Patient History

This 52-year-old man with a history of hepatitis B virus (HBV) infection and associated liver cirrhosis was being treated for a solitary hepatoma. He underwent a single radiofrequency ablation (RFA) treatment and five transarterial chemoembolization (TACE) treatments beginning in 2004. A follow-up liver perfusion CT study was performed to further assess the lesion's response to treatment.

### Findings



The lesion in segment 6 is best seen in the PF map (arrow). The AF is similar to that in the rest of the liver, and the PI is only slightly increased. The perfusion characteristics are homogeneous throughout the lesion. Retained Lipiodol from the previous TACE treatment is seen (arrowhead).

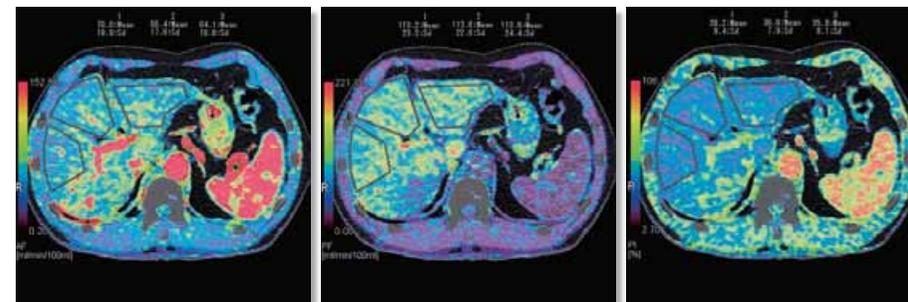


In the lesion, the perfusion results show a moderately increased AF and PI and a reduced PF. AF = 66.6, PF = 57.3, and PI = 54.2. The AF is still slightly increased, but is similar to that in the rest of the liver. This indicates that the tumor is not aggressively growing and that treatment has been partially effective. A completely treated tumor would show necrosis and very low total perfusion

Arterial Flow (AF)

Portal Flow (PF)

Hepatic Perfusion Index (PI)



Regional perfusion can be measured, as demonstrated in these axial maps. Segments 2 and 3: AF = 64.1, PF = 113.9, and PI = 35.9. Segment 4: AF = 66.4, PF = 113.6, and PI = 36.8. Segments 5 to 8: AF = 70.0, PF = 113.2, and PI = 38.2. The perfusion parameters consistently show a slightly increased AF and a similarly reduced PF. These findings are consistent with cirrhosis. No focal lesions are seen elsewhere in the liver.

### Conclusion/Treatment

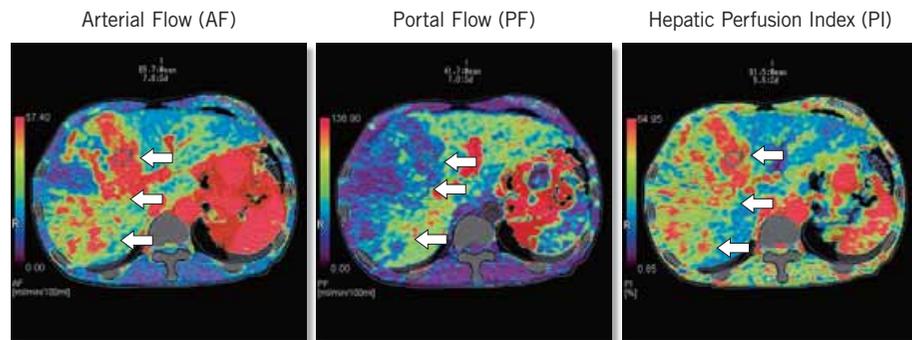
The hepatoma has been partially treated with TACE. However, since no changes in the remaining tumor are seen in follow-up scans, further treatment is not indicated. Regular follow-up CT scans will be performed to observe any changes in the tumor and to ensure that any new lesions are detected early.

## Liver disease status assessment

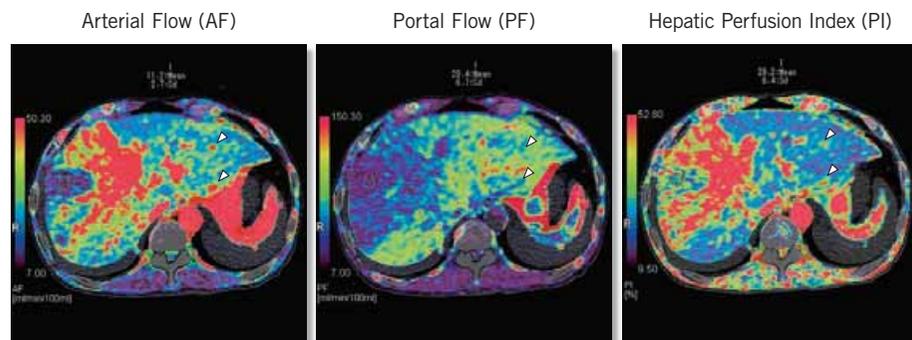
### Patient History

This 48-year-old man had a known primary malignant neoplasm of the liver. The patient complained of numbness and weakness of the left arm and leg. Liver perfusion CT and whole-body CT were performed to further assess the status of the patient's liver disease prior to brivanib therapy.

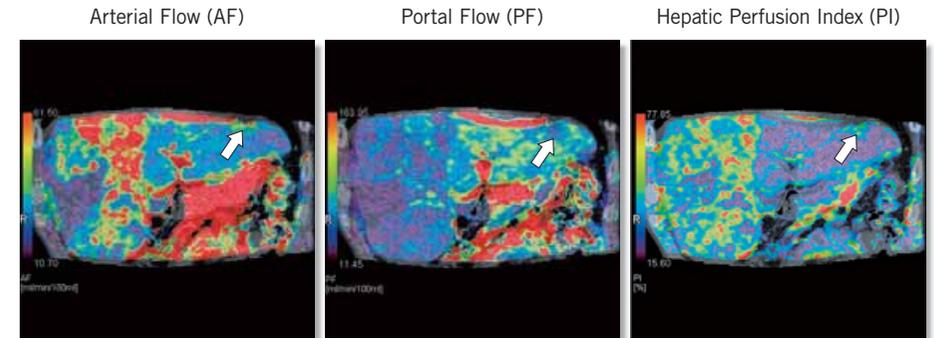
### Findings



The perfusion images show a very large tumor involving segments 4, 5, 6, 7, and 8 (arrows). There are also smaller lesions in segments 2 and 3. The periphery of the tumor shows the typical findings of an increased AF and a reduced PF, as seen in ROI 1, where AF = 65.7, PF = 41.7, and PI = 61.5.



There is an area of reduced perfusion in segments 5 to 8. The ROI values in this region indicate necrosis of the tumor (AF = 11.2, PF = 28.4, AF+PF = 29.6). Two smaller lesions are seen in segments 2 and 3 (arrowheads). These lesions are best seen in the AF and PI maps. There are multiple smaller lesions in segments 2 and 3.



In the coronal plane, another lesion in the superior portion of segment 3 is observed (arrows).

### Conclusion/Treatment

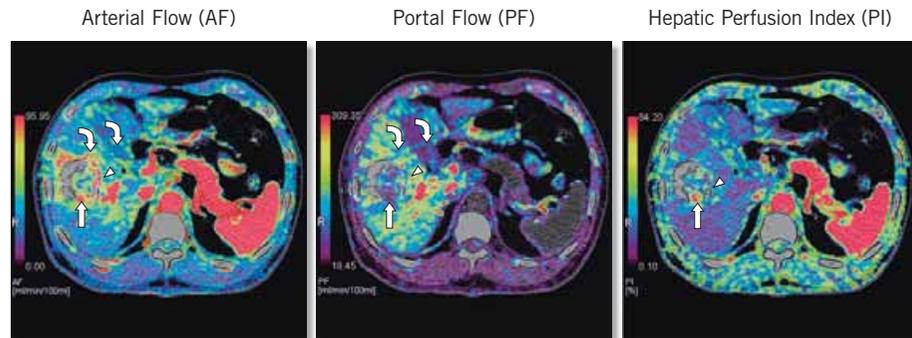
A large tumor involving multiple liver segments is demonstrated. The tumor shows high arterial flow, indicating that it is highly malignant and aggressive. Multiple smaller tumors in other segments of the liver indicate extensive local spread. Widespread metastases are also present in the lungs, indicating advanced disease. The ability to review the perfusion maps in multiple planes allows small lesions to be easily identified and their precise locations within the liver to be determined. Such information is extremely valuable when planning any surgical procedures for the treatment of liver disease.

## HCC treatment assessment

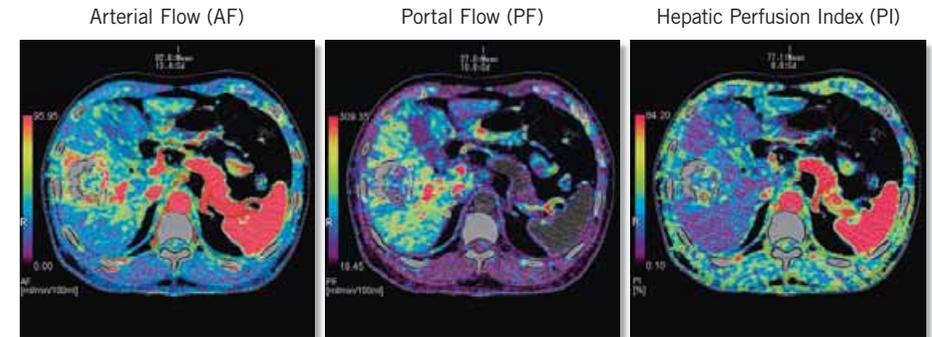
### Patient History

This 58-year-old man is a hepatitis B virus (HBV) carrier. The alpha-fetoprotein (AFP) value was 5748 ng/mL. A liver ultrasound examination showed a 5 cm hepatocellular carcinoma (HCC) in the right lobe. He underwent transarterial chemoembolization (TACE), and liver perfusion CT was performed to assess the effectiveness of TACE treatment.

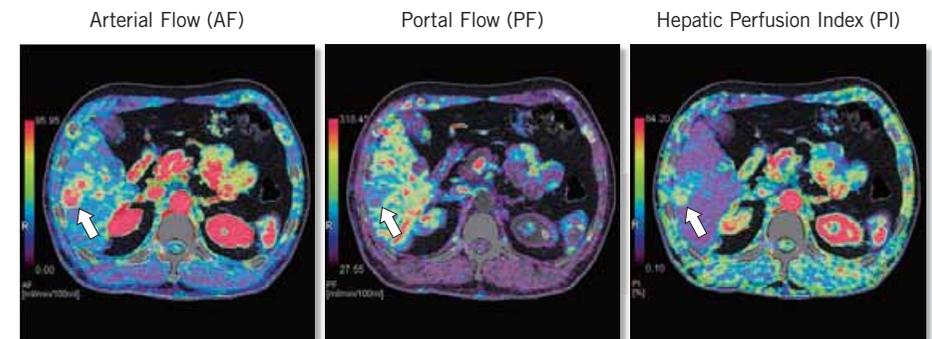
### Findings



The previously treated HCC mass is clearly visible in these axial maps. Dense retained Lipiodol from the previous TACE treatment is seen (gray area). There are areas of high arterial flow peripheral to the treated mass, but there is no corresponding decrease in PF or increase in PI. These are also caused by the retained Lipiodol (arrowheads). In this case, the dense Lipiodol has caused a linear streak artifact (curved arrows), most obvious in the PF map. There is a suspicious nodule in the inferior portion of the mass, best seen in the PI map (arrow).



The quantitative perfusion values in the suspicious nodule show an increased AF and PI and a reduced PF (AF = 82.6, PF = 27.0, and PI = 77.1). This perfusion pattern is characteristic of a viable HCC nodule.



Another mass is demonstrated in segment 6, just inferior to the treated tumor. These axial maps show an increased AF, reduced PF, and increased PI (arrows), suggestive of another HCC nodule.

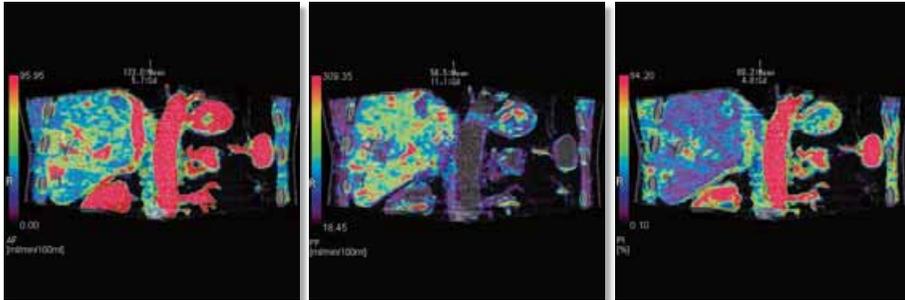


## HCC treatment assessment (continued)

Arterial Flow (AF)

Portal Flow (PF)

Hepatic Perfusion Index (PI)



In these coronal plane maps, the ROI is placed in the suspicious area in S6. AF is 123.0, PF is 56.5, and PI is 69.3. These perfusion parameters are characteristic of a viable HCC tumor.

### Conclusion/Treatment

The HCC tumor has been partially treated, but a viable tumor nodule located inferiorly and medially in the treated mass is observed. A second HCC focal mass in segment 6 is also demonstrated. The patient underwent two further TACE treatments. Follow-up with routine CT scanning in 3 months is planned.

The 16 cm z-axis coverage provided by Aquilion ONE allows almost the entire liver to be visualized. In this case, a second tumor in segment 6 was observed inferior to the treated tumor. A CT scanner without such wide z-axis coverage may have failed to detect this lesion.

## HCC treatment assessment

### Patient History

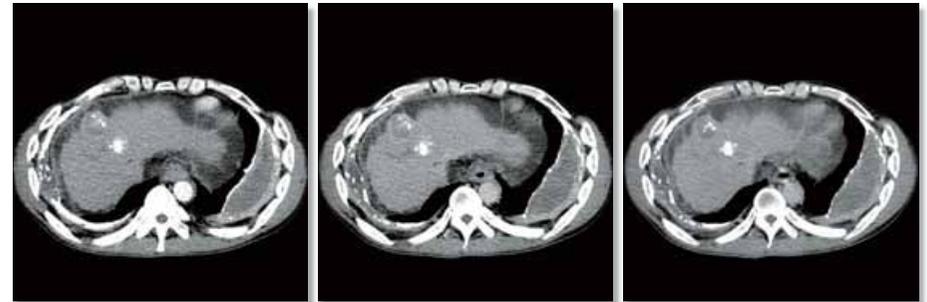
This 52-year-old man has a history of alcoholic liver damage and hepatocellular carcinoma (HCC) in segments 4 and 8 of the liver. The HCC was previously treated by transarterial chemoembolization (TACE) in July and September 2009. The patient has liver cirrhosis and portal hypertension. A liver perfusion CT study was performed to assess the patient's response to TACE and the advisability of further TACE treatment.

### Triphasic CT Findings

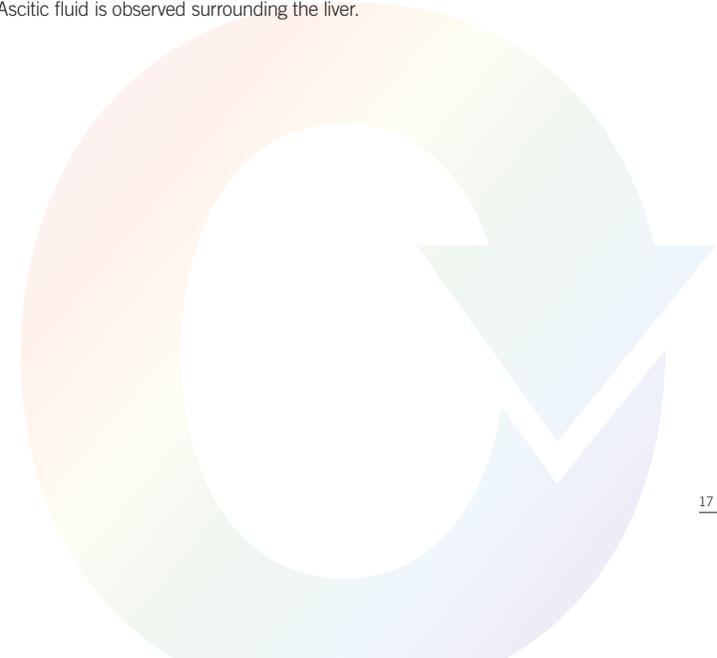
Arterial Phase

Portal Phase

Delayed Phase

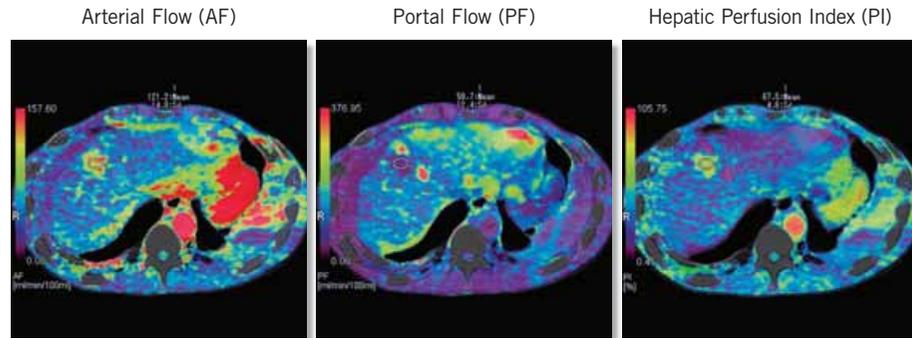


The CT images do not show any obvious enhancement of HCC lesions. Retained Lipiodol is seen as dense white regions in the liver. Ascitic fluid is observed surrounding the liver.

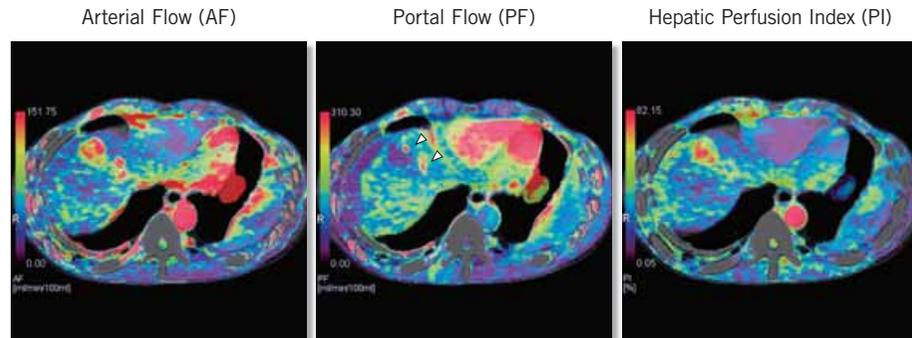


## HCC treatment assessment (continued)

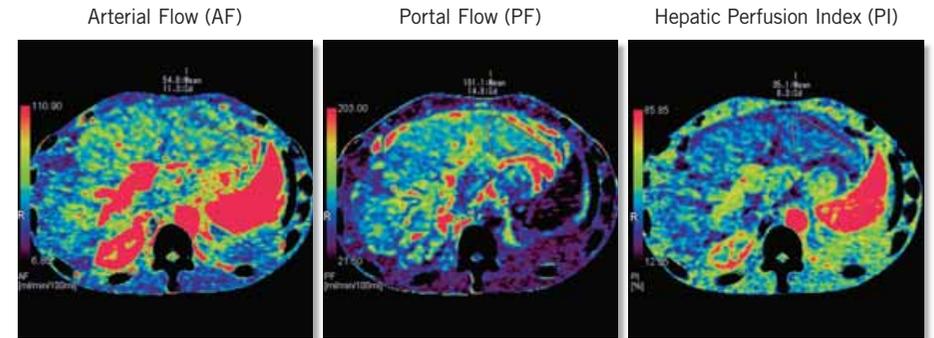
### Perfusion Findings



The perfusion maps clearly show an area of increased AF, reduced PF, and increased PI between the previously treated HCC lesions in segments 4 and 8. The perfusion values in the mass show an increased AF and PI and a reduced PF (AF = 121.2, PF = 59.7, and PI = 67.5). This perfusion profile is characteristic of HCC.



In these axial maps (at a level superior to that of the previous maps), the viable tumor is more clearly visualized in the AF and PI maps. The red spots in the PF map are retained Lipiodol (arrowheads).



The regional perfusion values in segments 2 and 3 are AF = 54.8, PF = 101.1, and PI = 35.1. The slightly increased AF and reduced PF are characteristic of liver cirrhosis. This perfusion pattern is consistent throughout the liver.

### Conclusion/Treatment

The perfusion maps demonstrated a viable HCC in segment 8, in close relation to the previously treated tumor. The patient underwent a further TACE treatment. Follow-up CT scanning will be performed in 3 months.

