

**TRIPLE PHASE SPIRAL C.T. IN THE EVALUATION OF HEPATIC MASSES**G. V. Prasad<sup>1</sup>, Kondal Rao<sup>2</sup>, Rajendra<sup>3</sup>**HOW TO CITE THIS ARTICLE:**

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**ABSTRACT: BACKGROUND AND OBJECTIVE:** The goal of the study is to determine the value of various phases of Triple, Helical CT, Hepatic arterial Phase (HAP), Portal venous phase (PVP) and Equilibrium Phase (EP), is the detection and characterization of Hepatic Lesions and to evaluate whether unenhanced and hepatic arterial phases when used in conjunction with porto venous phase would lead to detection of greater number of lesions or better characterization of lesion. **METHODOLOGY:** The study population consists of 50 Patients aged between 30 Years and 80 Years were examined with multiphase (plain, hepatic arterial, portal venous and equilibrium phases). Spiral CT of liver. Patients were referred for CT scan when liver diseases were suspected clinically, if ultrasound and other previous investigations revealed lesions which had to be further evaluated by spiral CT and to detect liver metastases in known cases of primary extra hepatic malignancy. **CT TECHNIQUE:** Helical scanning of liver with Toshiba astein s4, continuous spiral run and the images were reconstructed at 5mm intervals. Contrast material 100ml was injected through 18 or 20G catheter at the rate of 3ml per second using automatic medrad power injector. Non-ionic contrast [IOHEXOI – 300mg perml was used in all the patients]. After obtained unenhanced CT scan HAP scanning was initiated 25 seconds after initiation of contrast injection. Portal venous phase scanning was initiated 60-65 seconds after start of contrast injection. Equilibrium phase scanning was initiated after 180 seconds after the start of contrast injection. **IMAGE EVALUATION:** All the images of 4 phases were reviewed. **First Step:** The presence, appearance and enhancement of each Lesion were noted in all phases and lesion were described Isodense, Hypodense Hyperdense based on their attenuation relative to liver parenchyma during that phase of scanning. Based on enhancement pattern of the lesion during various phases they were classified broadly in to; 1. Blobular enhancement seen in cases of hemangiomas. 2. Homogeneous hypodense (attenuation value less than 25 H.U). 3. Homogeneous hypodense (solid). 4. Heterogeneous hypodense. 5. Homogeneous hyperdense. 6. Heterogeneous hyperdense in cases of metastases. **RESULTS:** The relative enhancement of liver during hepatic arterial phase (HAP) portal venous phase (PVP) and equilibrium phase (EP) was obtained satisfactorily in all patients included in the study. Arterial phase images showed intensely opacified hepatic arterial system. In some cases portal veins showed enhancement when the imaging extended into late arterial phase period, however the liver parenchymal enhancement was well below the enhancement achieved in portal venous phases. Average parenchymal attenuation was baseline (NECT) attenuation + 10-20H.U. Portal venous phase image showed peak enhancement of liver parenchyma. The portal vein enhancement at portahepatis was more intense compared to arterial system in this phase. Liver parenchyma attained peak attenuation during portal venous phase which was approximately 40-50 H.U above

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baseline (NECT) lives attenuation. During equilibrium phase, the vascular spaces and parenchyma could be distinguished, but with very less conspicuity compared to hepatic arterial phase and portal venous phase images. Average liver attenuation fell back to 25 – 30 H.U above baseline value, during this phase. Total of 572 lesions were detected is 50patients of these 531 lesions in 36 patients were malignant and 41 lesions is 14 patients were beings. **INTERPRETATION AND CONCLUSION:** Based on our study and on reviewing the literature. Hepatic arterial phase and portal venous phase are the most useful phases among triple phase spiral CT. Hepatic arterial phase and portal venous phase together can confidently characterize and differentiate hypervascular malignant lesions (HCC or hypervascular metastases) from most common benign lesions, with 3 specific patterns of enhancement showing high positive predictive value for hemangiomas, HCC, metastases respectively. HAP is the best phase for detecting hypervascular HCC or metastases and it should always be included for detecting hypervascular lesions. When tumors are more than 2cms is size both hepatic arterial phase and portal venous phase are equally good for detection of such lesions. Portal venous phase is the best phase for hypovascular lesions and detecting metastases as most of the metastases are hypovascular lesions. Equilibrium phase is not useful is characterization or detection of additional lesions. We conclude that, hepatic arterial phase and portal venous phase have to be included for scanning of suspected liver lesion for characterization and better detection of lesion. Equilibrium phase is best avoided as it is not effective except for those cases where hemangioma forums a differential diagnosis. Unenhanced scans are useful in detecting hemorrhage and calcification with in lesions.

**KEYWORDS:** Hepatic Lesions Triple Phase CT.

**INTRODUCTION:** The importance of CT in characterization of Hepatic diseases and in the detection of hepatic lesions is well established. Strategies for optimizing CT detection of liver abnormalities have been evaluated since early 1980's. Despite technological advances increased understanding of how to optimize the CT techniques, conventional CT has been reported to detect only 50-80% of primary and secondary malignant liver lesions.

High quality CT scanning can definitely increase the rate of liver lesion detection and characterization. In general, high quality CT scanning of liver requires,

1. Rapid bolus infusion of iodinated contrast followed by rapid image acquisition.
2. Minimum respiratory misregistration artifacts.
3. Ability to construct images at overlapping intervals.

All the above said can be achieved by spiral (or helical) scanning techniques. Multiphase helical CT, such as dual phase which includes hepatic arterial (HAP) and portal venous phase (PVP), triple phase (HAP, PVP and EQUILIBRIUM PHASES), could be achieved solely due to the advent of rapid scanning. These various phases of liver enhancement can be possible only if entire liver can be scanned in a short interval of 15-20 seconds. This was not possible with conventional CT technology. Spiral CT with Dual phase technology has become a popular technique for detection of liver tumors and to a lesser extent for characterization of liver lesions. Role of non-enhanced CT and equilibrium phase CT for detection or characterizing liver lesions are still being studied. Multiphase techniques are effective for evaluating the liver, in part because of the unique dual. Blood supply to the liver and inherent differences in blood supply to liver tumors & liver parenchyma.

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The drive to develop & optimize techniques for scanning by helical CT stemmed from the known inability of conventional CT to depict hyper vascular tumors, such as HCC and metastases from carcinoid, melanoma, and pancreatic islet cell tumors. The vascular nature of these tumors results in their rapid enhancement in hepatic arterial phase, and latter achieving the same degree of enhancement and attenuation as background liver parenchyma. Therefore they are not visualized during the portal venous phase of hepatic, enhancement. Because of the window of time to image liver during hepatic arterial phase is short; it was not possible to scan entire liver during that short interval with convention CT, unlike with spiral scanner.

### **The important advantages of spiral CT over conventional CT are:**

1. The ability to completely scan liver during various phases because of the short scanning time (12-16 sec, for entire liver) required by spiral scanners.
2. Absence of respiratory misregistration, which occurs in conventional CT, when patients take different, sized breaths, between each slice. This totally eliminates the problem of small areas of liver being not imaged.
3. Ability to reconstruct images at overlapping intervals and at very small intervals as small as 1 mm. Though the additional slice reconstructions remain the same thickness, the ability to shift the center of the slice can affect lesion conspicuity by placing the lesion directly within a reconstructed image, rather than being volume averaged between two contiguous slices.

We took up this study as we have the unique opportunity of having state of Art Spiral CT Scanner with sub second (0.75 s) scan duration facility, and automatic pressure injector which injects contrast at a predetermined rate.

### **AIMS AND OBJECTIVES:**

1. Purpose of the study is to determine the value of various phases of triple helical CT, hepatic arterial phase (HAP), Portal venous phase (PVP) & equilibrium phase (EP), in the detection and characterization of hepatic lesions.
2. To evaluate, whether unenhanced and hepatic arterial phases, when used in conjunction with portal venous phase, would lead to detection of greater number of lesions. or better characterization of lesions.
3. Whether, equilibrium phase scanning would contribute, in any way, to detection or characterization of lesions.
4. Whether unenhanced scans are routinely necessary in the evaluation of hepatic neoplasm's.
5. To evaluate a protocol, if possible, which would indicate, the necessary phases, to be included in scanning of liver for suspected hepatic lesions.

**METHODOLOGY: MATERIAL AND METHODS:** Fifty patients with age range from 30 years to 80 years were examined with multiphase (Plain, hepatic arterial, portal venous and equilibrium phases) spiral CT of liver. Of the 50 patients, 31 were males, 19 were females. Patients were referred for CT scans when,

1. Liver disease was suspected clinically,
2. If ultrasound and other previous investigations revealed lesions which had to be further evaluated or characterized by spiral CT.

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3. To detect liver metastases in a known case of primary extra hepatic malignancy, this could alter the patient's management.
  - Patients were referred with a suspicion of primary HCC based on clinical findings and symptoms.
  - 8 patients with a known primary malignancy underwent CT for detection of liver metastases or to know the extent of spread of primary malignancy.
  - 10 patients were referred to CT when a predominantly hyperechoic lesion was seen on ultrasonography, with a suspicion of either hemangioma or HCC or metastases.
  - 1 patient underwent CT when ultrasound revealed hypoechoic lesion in GB fossa and right lobe of liver, which was thought to be carcinoma GB or HCC.
  - CT was done in 12 patients for evaluation of palpable mass in right hypochondrium.
  - 8 patients had cirrhosis of liver and underwent CT for detection of clinically suspected HCC.

**CT TECHNIQUE:** Helical scanning of liver was performed with "TOSHIBA ASTEION 54" helical sub second (0.75 Sec) scanner capable of 50 sees, continuous spiral run, Images were reconstructed with 1800 linear interpolation reconstruction algorithm.

### Scan Parameters & Technique:

Slice Collimation	7 mm.
Table Speed	7 mm/sec.
Pitch	1:1.
KV	120.
MA	280.

Images were reconstructed at 5 mm intervals using standard reconstruction kernel and 180 degrees linear interpolation.

**Contrast Material:** 100 ml of contrast material was injected through 18 or 20G catheters at the rate of 3.0 ml/second using automatic Medrad Power Injector.

- Non-ionic contrast (Iohexol - 300 mg/ml) was used in all patients.
- After obtaining scout view - unenhanced (NECT) scan of liver was done in spiral mode.
- Hepatic arterial phase scanning was initiated 25 seconds after initiation of contrast injection in craniocaudal direction. In all cases this could be completed within 12-18 seconds.
- Portal venous phase scanning was initiated, with same image acquisition parameters, 60-65 seconds after start of contrast injection. Hence there was a time gap of at least 10 seconds between the completion of arterial phase and start of portal venous phase which could cool the X-ray tube. Table position was readjusted to the initial position between these times. Portal phase scanning was done again in crania-caudal direction again.
- Scanning of rest of abdomen & pelvis continued after portal phase scanning.
- Equilibrium phase scanning was initiated, after 180- 300 seconds, after contrast injection with similar parameters.

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**Image Evaluation:** All images of 4 phases were reviewed on console and on hardcopy.

**First Step:** The presence, appearance and enhancement of each lesion were noted in all phases.

Lesions were described as Isodense, hypodense or hyperdense based on their attenuation relative to liver parenchyma during that phase of scanning. Based on enhancement pattern of the lesion during various phases, they were classified broadly into 6 groups or categories of enhancement patterns as described below.

**Category I: GLOBULAR ENHANCEMENT:** Include lesions which are showing small nodular enhancing areas almost Isodense to aorta. This globular enhancement starts in the periphery of the lesion and progresses centripetally.

E.g.: Hemangiomas.

**Category II: HOMOGENEOUS HYPODENSE (CYSTIC):** Include hypodense lesions which are cystic (less than 25 H.U.) and show either no enhancement, or only peripheral rim enhancement on Hepatic arterial, Portal venous and Equilibrium phases.

E.g.: Abscesses.

**Category III: HOMOGENEOUS HYPODENSE (SOLID):** Include lesions which are solid and hypodense on Hepatic arterial, Portal venous and Equilibrium phases. These lesions show very minimal or no enhancement at all. Lesions showing only faint marginal or peripheral enhancement are also included under this category.

E.g.: Metastases.

**Category IV: HETEROGENEOUS HYPODENSE:** Include lesions which are hypodense or Isodense on non-enhanced CT. On portal venous phase, these lesions show areas of enhancement, but they constitute less than 50% of the lesion. Lesions may show peripheral ring enhancement. These lesions may show enhancing tumor vessels around the lesion during hepatic arterial phase, but the lesion does not show any significant enhancing areas within it.

E.g.: Metastases.

**Category V: HOMOGENEOUS HYPERDENSE:** Include lesions which may be Isodense or hypodense on non-enhanced CT and show significant homogenous enhancement on Hepatic arterial phase. In portal venous phase, these lesions may still be hyperdense or may become Isodense or hypodense, compared to liver parenchyma.

E.g.: HCC

**Category VI HETEROGENEOUS HYPERDENSE:** Include lesions which show heterogeneously enhancing areas constituting nearly 50% or more of the lesion in Hepatic arterial phase. On portal venous phase these lesions may remain hyperdense or become iso or hypodense to liver parenchyma.

E.g.: HCC

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Presences of hemorrhage or calcification in plain scans are also noted. Differential enhancement of liver (THAD) is noted which could suggest vascular occlusion.

**Second Step:** Number of lesions visualized in each phase is counted and lesions which are less than 2cms were noted.

**OBSERVATION AND RESULTS:** The relative enhancement of liver during hepatic arterial phase (HAP) portal venous phase (PVP) and equilibrium phase (EP) was obtained satisfactorily in all the patients included in the study.

Arterial phase images snowed intensely opacified. Hepatic arterial system. In some cases portal veins showed enhancement when the imaging extended into late arterial phase period, however the liver parenchymal enhancement was well below the enhancement achieved In portal venous phases. Average parenchymal attenuation was baseline (NECT) attenuation + 10-20 H.U

Portal venous phase images showed peak enhancement of liver parenchyma. The portal vein enhancement at porta hepatis was more intense compared to arterial system in this phase. Liver parenchyma attained peak attenuation during Portal venous phase which was approx. 40-50 H.U above baseline (NECT) liver attenuation. During equilibrium phase, the vascular spaces and parenchyma could be distinguished, but with very less conspicuity compared to Hepatic arterial phase and Portal venous phase images. Average liver attenuation fell back to 25-30 H.U. above the baseline value, during this phase.

Total of 572 lesions were detected in 50 patients. Of these 531 lesions in 36 patients were malignant and 41 lesions in 14 patients were benign.

Sl. No	Diagnosis	No. of Patients	No. of Lesions
1.	Hepatoma	22	306
2.	Metastases	11	222
3.	Carcinoma of Gall Bladder	1	1
4.	Cholangiocarcinoma	2	2
5.	Hemangioma	7	24
6.	Abscess	3	11
7.	Hepatic cyst	1	3
8.	Biliary Cyst Adenoma	1	1
9.	Hydatid cyst	2	2
<b>Total</b>		<b>50</b>	<b>572</b>

Table 1: Classification of Various Liver Lesions Detected' By Triple Phase Spiral CT

Type of Lesions	No. of Lesions	Hypervascular	Hypovascular
Malignant (36 Patients)	531	143	388
Benign (14 Patients)	41	24	17
<b>Total</b>	<b>572</b>	<b>167</b>	<b>405</b>

Table 2: Classification of Liver Lesions As Hyper Vascular

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**MALIGNANT LESIONS:** Out of 531 (36 patients) lesions, 388 (24 pts) were hypovascular and 143 (12pts) were hypervascular.

**a) Hypovascular malignant lesions: out of 388 lesions,**

- 222 (11pts) were metastases,
- 052 from Breast carcinoma,
- 055 from Bronchogenic carcinoma,
- 003 from Carcinoma Cervix,
- 030 from Testicular carcinoma,
- 002 from Colonic carcinoma,
- 080 from Stomach carcinoma.
- 163. Iesions (in 10 patients) were hepatomas.
- 001 lesion was G.B Carcinoma infiltrating liver.
- 002 Cholangiocarcinoma.

**b) Hypervascular Malignant lesions: out of 143 lesions,**

- 143 (12 Pts) were hepatomas.

Diagnosis/No. of Patients	No. of lesions	No. of Hypervascular lesions	No. of Hypovascular lesions
Hepatoma/(22)	306	143	163
Metastases/(11)	222	-	222
Carcinoma Gall Bladder/(1)	1	-	1
Cholangiocarcinoma/(2)	2	-	2
<b>Total (36)</b>	<b>531</b>	<b>143</b>	<b>388</b>

Table 3: Classification of Malignant Lesions

**BENIGN LESIONS:** Out of 41 lesions (14 patients), 24 lesions in 7 patients were hemangiomas, which showed characteristic globular enhancement. 11 lesions in 3 patients were hypovascular cystic lesions - abscesses, 3 lesions in 1 patient was benign hepatic cysts, 1 lesion in a patient of Biliary cystadenoma and 2 lesions of Hydatid cyst in 2 patients.

There were no other hypovascular benign lesions, such as adenoma or focal nodular hyperplasia in the study.

Diagnosis/ No. of Patients	Hypervascular lesions	Hypovascular lesions
Hemangiomas/(7)	24	-
Abscess/ (3)	-	11

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Hepatic cyst/ (1)	-	3
Biliary cyst Adenoma/ (1)	-	1
Hydatid/ (2)	-	2
<b>Total (41)</b>	<b>24</b>	<b>17</b>

Table 4: Classification of Benign Lesions

**IMAGE ANALYSIS WITH REGARDS TO CHARACTERIZATION OF LESIONS:** Lesions were described as Isodense, hypodense or hyperdense based on their attenuation relative to liver parenchyma during that phase of scanning. Based on enhancement pattern of the lesion during various phases, they were classified broadly into 6 groups or categories of enhancement patterns as described below.

**Category I: GLOBULAR ENHANCEMENT:** Include lesions which are showing small nodular enhancing areas which are almost Isodense to aorta. This globular enhancement starts in the periphery of lesion and progresses centripetally.

**Category II: HOMOGENEOUS HYPODENSE (CYSTIC):** Include hypodense lesions which are cystic (less than 25 H.U.) and show either no enhancement, or only peripheral rim of, enhancement on Hepatic arterial phase, Portal venous phase or Equilibrium phase.

**Category III: HOMOGENEOUS HYPODENSE (SOLID):** Include lesions which are Solid and hypodense on Hepatic arterial phase, Portal venous phase or Equilibrium phase. These lesions show very minimal or no enhancement at all. Lesions showing only faint marginal enhancement or peripheral enhancement are also included under this category.

**Category IV: HETEROGENEOUS HYPODENSE:** Include lesions which are hypodense or Isodense on NECT. On portal venous phase, these lesions show areas of enhancement but they constitute less than 5% of lesion. Lesions may show peripheral ring enhancement. These lesions may show enhancing tumor vessels around the lesion during hepatic arterial phase, but the lesion does not show any significant enhancing areas within it during hepatic arterial phase.

**Category V: HOMOGENEOUS HYPERDENSE:** Includes lesions which may be Isodense or hypodense on NECT and show significant homogeneous enhancement in hepatic arterial phase. On portal venous phase, these lesions may, still be hyperdense or may become Isodense or hypodense compared to liver parenchyma.

**Category VI: HETEROGENEOUS HYPERDENSE:** Include lesions which show heterogeneously enhancing areas constituting nearly 50% or more of the lesion in hepatic arterial phase. On portal Venous Phase these lesions may remain hyperdense or become Iso or hypodense to liver parenchyma.

Category II, III, IV patterns are described as hypovascular lesions.

Category V, VI patterns are described as hypervascular lesions.

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Category	Enhancement Pattern	HCC	METS	Car G.B	Cholangio Carcinoma
1.	G.E.	-	-	-	-
2.	Homogeneous Hypodense (Cystic)	-	12	-	-
3.	Homogeneous Hypodense (Solid)	11	205	1	2
4.	Heterogeneous Hypodense	152	5	-	-
5.	Homogeneous Hyperdense	55	-	-	-
6.	Heterogeneous Hyperdense	88	-	-	-
<b>Total</b>	<b>No. of Lesions</b>	<b>306</b>	<b>222</b>	<b>1</b>	<b>2</b>

Table 5: Classification of Malignant Lesions into Various Enhancement Categories

Category	Enhancement Pattern	Hemangioma	Abscess	Hydatid Cyst	Biliary Cyst Adenoma	Hepatic Cyst
1.	Globular Enhancement	24	-	-	-	-
2.	Homogeneous Hypodense (Cystic)	-	11	1	-	3
3.	Homogeneous Hypodense (Solid)	-	-	1	1	-
4.	Heterogeneous Hypodense	-	-	-	-	-
5.	Homogeneous Hyperdense	-	-	-	-	-
6.	Heterogeneous Hyperdense	-	-	-	-	-
<b>Total (41)</b>		<b>24</b>	<b>11</b>	<b>2</b>	<b>1</b>	<b>3</b>

Table 6: Classification of Benign Lesions into Various Enhancement Categories

Sl. No	Enhancement pattern	Suggested Diagnosis	Sensitivity	Specificity	Positive predictive value	Accuracy
1.	Globular Enhancement during HAP and PVP	Hemangioma	100	100	100	100

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2.	Homogenous Hyperdense or Heterogeneous hyperdense components during HAP	HCC	74	96	89	89
3.	Homogeneous hypodense lesion with or without peripheral enhancement noted in HAP or PVP	Metastasis	73	93	93	82

Table 7: Specificity and Sensitivity of the Various Enhancement Patterns

### IMAGE ANALYSIS WITH REGARDS TO LESION DETECTABILITY AND CONSPICUITY:

The Following table shows number of lesions detected in various phases of scanning.

Diagnosis	Total	NECT	HAP	PVP	EQ
Hepatoma	306	134	258	282	197
Metastasis	222	144	183	222	167
Carcinoma Gall Bladder	1	1	1	1	1
Cholangio Carcinoma	2	2	2	2	2
Hemangioma	24	16	17	22	24
Abscess	11	11	11	11	11
Hepatic Cyst	3	3	3	3	3
Biliary Cyst Adenoma	1	1	1	1	1
Hydatid cyst	2	2	2	2	2
<b>Total</b>	<b>572</b>	<b>314</b>	<b>478</b>	<b>546</b>	<b>408</b>

Table 8

Diagnosis	Total	NECT	HAP	PVP	EQ
Hypervascular HCC	143	65	143	119	94
Hypovascular HCC	163	69	120	163	103
Hypovascular Metastasis	222	144	183	222	167

Table 9

**Hypervascular Lesions visualized only in Hepatic Arterial Phase:** Hepatic arterial phase revealed 22 small hypervascular hepatomas which were not visualized on portal venous phase. All these lesions which were seen in Hepatic arterial phase and not seen in portal venous phase were less than 2cms.

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There were no lesions from hypovascular hepatomas or metastases which were visualized in hepatic arterial phase and not visualized in portal venous phase.

Diagnosis	Total No. of Hypervascular lesion	Lesions visualized only on HAP and not visualized on NECT & PVP	
		Size < 2cms	Size > 2cms
HCC	143	22	2

**Table 10**

**HYPOVASCULAR LESIONS VISUALIZED ONLY IN PORTAL VENOUS PHASE IMAGES:** All the metastatic liver lesions were hypovascular (222 lesions in 11 patients). And all these lesions were seen in portal venous phase images. 45, lesions were seen only in portal venous phase images and not visualized on Hepatic arterial phase images. Off these, 22 lesions were less than 2cms.

Diagnosis	Total No. of Hypervascular lesion	Lesions visualized only on HAP and not visualized on NECT & PVP	
		Size < 2cms	Size > 2cms
HCC	163	28	16
Metastases	222	22	23

**Table 11**

**HEPATOCELLULAR CARCINOMA:** In 22 patients with HCC, 306 lesions were identified by all phases of imaging. 258 lesions (840/0) were visualized on hepatic arterial phase and 272 lesions (88%) were visualized on Portal venous phase images, 144(47%) were visualized on Non-enhanced CT and 197(640/0) were visualized on equilibrium phase images. Out of 306 HCC lesions 24(8%) lesions were seen on Hepatic arterial phase only. Out of which 22 lesions were less than 2cms and 2 lesions greater than 2 cms. None of these lesions were noted on Non-enhanced CT and equilibrium phase images. When lesions less than 2cms were considered, 168(1000/0) of the lesions were detected on portal venous phase images and 158(94%) were detected on HAP images.

Detectability of HCC sizes	Total	NECT	HAP	PVP	EQ
Lesions < 2cms	168	81	158	168	113
Lesions > 2cms	138	63	100	138	84

**Table 12: Detectability of HCC on 4 Phases Based On Size Criteria**

When lesions, whether hypovascular or hypervascular, were greater than 2cms in size, 100 lesions (72%) out of 138 were noted on Hepatic arterial phase, 138 (1000/0) on portal venous phase images, 63 (450/0) on Nonenhanced CT and 84 (60%) on Equilibrium phase images.

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**METASTASES:** 222 metastatic lesions were noted in 11 patients. All 222 lesions (100%) were visualized on portal venous phase, 183 (820/0). were seen on Equilibrium phase images and only 144 (65%) were seen on Non enhanced CT.

45 lesions (20%) were seen only on Portal venous phase images and not seen on Hepatic arterial phase images, off these 22 lesions were less than 2cms in size.

Therefore all lesions, irrespective of being hypervascular or hypovascular in nature, were visualized on Hepatic arterial phase, portal venous phase and Equilibrium phase. If they were larger than 2 to 3cms in size, however the conspicuity grading of lesion was higher, in Portal venous phase for hypovascular metastases, when compared to their conspicuity on Hepatic arterial phase images.

<b>Detectability of Metastases in 4 phases based on size criteria</b>	<b>Total</b>	<b>NECT</b>	<b>HAP</b>	<b>PVP</b>	<b>EQ</b>
Lesions < 2cms	77	39	55	78	55
Lesions > 2cms	145	105	128	144	112
<b>Total</b>	<b>222</b>	<b>144</b>	<b>183</b>	<b>222</b>	<b>167</b>

**Table 13: Detectability of metastases in 4 phases based on size criteria**

**HEMANGIOMAS:** Characteristic globular enhancement, Isodense to aorta, filling centripetally into the lesion, starting from periphery was noted in all 24 lesions (1000/0) in 7 patients.

17 lesions could be identified in Hepatic arterial phase and Portal venous phase images.

<b>HEMANGIOMAS DETECTED IN VARIOUS PHASES</b>	<b>Total</b>	<b>NECT</b>	<b>HAP</b>	<b>PVP</b>	<b>EQ</b>
Lesions < 2cms	8	3	4	6	8
Lesions > 2cms	16	13	13	16	16
<b>Total</b>	<b>24</b>	<b>16</b>	<b>17</b>	<b>24</b>	<b>24</b>

**Table 14: No. of Hemangiomas Detected in Various Phases**

**ABSCCESS:** 11 hypodense cystic lesions were noted in 3 patients. All of them were larger than 2 cms in size and visualized on all 4 phases. On PVP and EP images these lesions showed faint rim enhancement surrounded by thin hypodense rim giving the appearance of target. Faint rim enhancement was different in appearance compared to thicker rim enhancement noted in metastases.

	<b>Total</b>	<b>NECT</b>	<b>HAP</b>	<b>PVP</b>	<b>EQ</b>
Lesions < 2cms	-	-	-	-	-
Lesions > 2cms	11	11	11	11	11
<b>Total</b>	<b>11</b>	<b>11</b>	<b>11</b>	<b>11</b>	<b>11</b>

**Table 15: Abscess**

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**Calcifications:** They are noted in 5 cases. Case no. s: (1, 12, 21, 46).

**Hemorrhagic Lesions:** There are no cases of hemorrhage in our study.

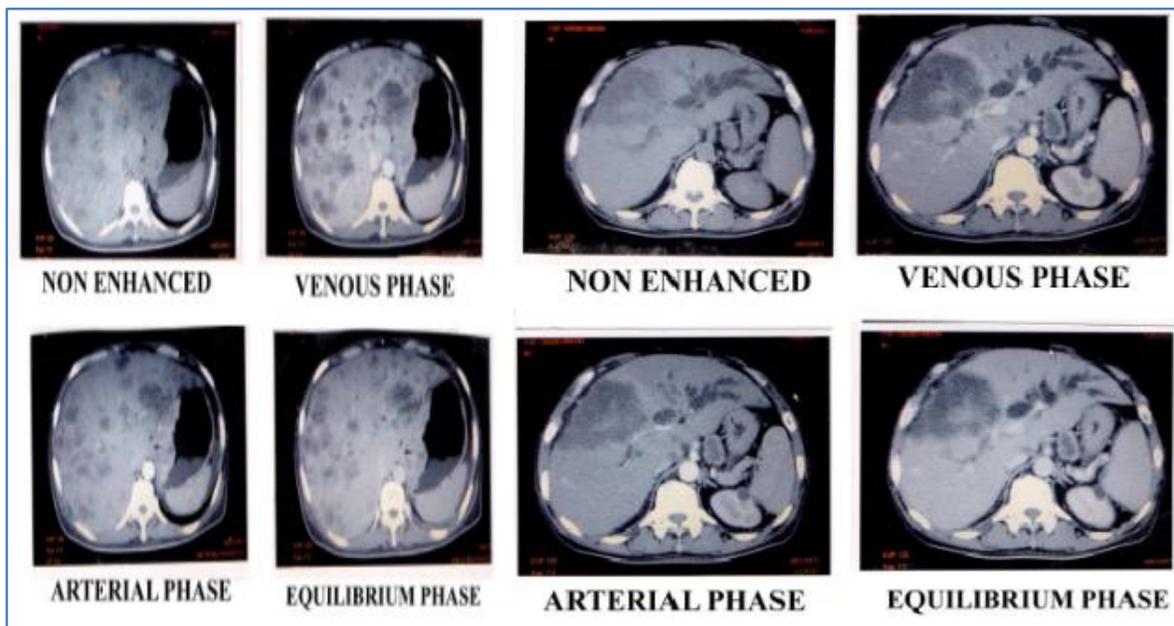
**Portal vein thrombosis:** was noted in 4 cases (case no. 1, 12, 21 & 46).

**I.V.C. Thrombosis:** noted in 8 cases. Case no. s: 7, 9, 15, 21, 34, 44, 47 and 50.

**Ascites:** noted in 16 cases: 1, 5, 6, 9, 12, 13, 17, 19, 21, 26~31, 40, 44, 45, 46 and 47.

**DISCUSSION:** Protocol for performing triple phase helical CT of liver decided after extensively reviewing the literature. Concept of performing multiphase helical CT and principles of enhancement of liver after contrast administration was well understood.

In this study, 100ml of iodinated contrast medium was injected intravenously at the rate of 3.0 ml/second. Hepatic arterial phase (HAP) scanning was initiated 25 seconds after start of contrast injection. Portal venous phase scanning was started 60-65 seconds after start of injection. Thus, a uniphasic contrast injection protocol was followed.



Dennis Foley et al<sup>1</sup> has shown in his study, about the contrast material injection protocol for hepatic helical CT, that uniphasic injection at 3ml/second and biphasic injection protocols (2ml/sec for 10 seconds and 2ml/sec for 65 seconds) were essentially equivalent. Hence monophasic injection technique is preferred for rapid hepatic helical scanning.

Pascal Garcia et al<sup>2</sup>, have shown that higher rates of injections shorten the time to peak liver enhancement but have no effect on maximum liver enhancement.

Increasing the rate of injection from 2.5 ml/sec to 4 or 6ml/sec does not lead to any significant increase in peak liver enhancement but only shortens time to attain that peak from 60-80 Seconds to 49 seconds These two studies formed the basis for our protocol.

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**Role of Multiphase CT in Characterization of Hepatic Lesions:** Because of high frequency of occurrence of benign and malignant liver lesions, such as hemangiomas, HCCS and Metastases, characterization of these lesions is essential.

Triple phase technique was used to image the entire liver in arterial, portal and equilibrium phases after obtaining NECT images of liver.

**Enhancement Patterns:** Numerous enhancement patterns of lesions were noted if the appearance of lesion in all 4 phases was considered. For example if a lesion is hypervascular it may appear hyperdense on hepatic arterial phase and portal venous phase images. Whereas another hypervascular lesion which is hyperdense on Hepatic arterial phase images may become hypodense on portal venous phase and equilibrium phase images.

Hence lesion 1 can be described as;

Iso/hyper/hyper/hypo,

Lesion 2 can be described as,

Iso/hyper/hypo/ hypo.

Therefore pattern of enhancement of lesions were broadly classified;

Into 6 categories (as described in the results).

Category II, III&IV- Hypovascular lesions.

Category V & VI - Hypervascular lesions.

Category I lesion showed a characteristic globular enhancement and is not included under hypo or hypervascular category

**Hypervascular Lesions (Hyperattenuating Enhancement Pattern):** Numbers of studies have been done recently which showed improved lesion detection of hypervascular tumors if Hepatic Arterial phase scanning is performed in addition to portal venous phase scanning, however characterization of lesions has received less attention.

143 lesions in 12 patients were hypervascular under category V&VI Pattern of enhancement. All 143 lesions (100%) were, malignant.

Therefore in our study category V&VI patterns, which include homogenous hyperdense or heterogeneous hyperdense with nonglobular hyperdense areas, during Hepatic arterial phase, were found only in malignant lesions.

All the 143 lesions were hypervascular HCC (100%). By putting together, category V & VI as nonglobular hyperattenuating pattern, this pattern was found to be 46% sensitive and 100% specific for HCC. Specificity is high because there were no hypervascular metastases and also no cases of hypervascular benign lesions such as FNH and Adenoma. Compared to specificity, sensitivity is low because there were 163 lesions of HCC which were hypovascular.

Among 41 benign lesions. 24 hemangiomas in this study were hypervascular. All 24 (100%) showed characteristic globular enhancement starting from the periphery. Therefore globular enhancement (Isodense to aorta) (category I) was 100% sensitive and 100% specific for hemangioma. There were no benign lesions in our study which showed hyperattenuating patterns. This may be due to extreme rarity of focal nodular hyperplasia and adenomas in our place.

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Van Hoe et al<sup>3</sup> reported 40 cases of FNH & 24 cases of adenomas in their study. 34 cases of FNH & 24 cases of adenomas showed homogenous hyperdense enhancement on Hepatic arterial phase and spoke wheel pattern of enhancement was noted in 6 cases of FNH.

Maarten et al<sup>4</sup> found 7 cases of FNH & 4 cases of Adenomas out of 131 cases included in his study. All the cases revealed hyperattenuating patterns on Hepatic arterial phase images.

### **HYPOVASCULAR ENHANCEMENT PATTERNS: INCLUDE CATEGORY II, III AND IV:**

Category II showing hypodense cystic lesion with no enhancement or a peripheral rim enhancement was noted in 27 lesions (6 patients). Benign lesions in 5 patients showed this pattern and one patient with secondaries from Lung.

Case no 39 underwent chemotherapy for Bronchogenic Carcinoma and presented with cough and loss of weight. Cystic lesions in liver were initially thought to be pyogenic abscesses; however FNAC from liver lesions proved them to be metastasis. Hypovascular homogenous hypodense solid lesions (category III pattern) were noted in 221 lesions, 205 of them were metastases. This pattern was 92% sensitive and 93% specific for metastases.

It is interesting to note that 163 HCC lesions out of 306 (53%) are hypovascular. Maarten et al<sup>4</sup> et al in their study of characterization of focal liver lesion with Triphasic spiral CT found all HCC Lesions (100%) to be hyperattenuating. However there were only 18 lesions (in 5 patients) out of 375 lesions included in his study, compared to 306 lesions (in 22 patients) in our study.

All the liver metastases were predominantly hypodense on Hepatic arterial phase and Portal venous phase images.

Some of the metastases showed ring enhancement in Hepatic arterial phase and Portal venous phase. This rim enhancement in hypovascular metastases is well described. Maarten et al<sup>4</sup> in his study found that all 29 lesions which are solid hypodense showing rim enhancement in HAP, were malignant lesions. He found that all these lesions showed a reverse pattern (hypodense rim) in equilibrium phase, which is known as 'wash out sign'. This was not noted in our study because equilibrium scanning was done after 3 to 5 mts unlike Maarten et al<sup>4</sup> who have done a delayed scanning after 8 to 10 minutes.

Category I type of globular enhancement was found to be pathognomonic for hemangiomas in our study. All the 24 lesions which showed globular enhancing areas, which are isodense to aorta, slowly filling centripetally into the lesion, were hemangiomas. No other lesion showed this pattern of enhancement.

Small areas of dense globular enhancement starting from the periphery were noted in HAP itself in all lesions. Some of the lesions were larger than 5cms. These large hemangiomas had central hypodense areas which did not become isodense on equilibrium phase. This may be due to time duration that is; these lesions would have become isodense on more delayed scans, or due to a central fibrotic area.

Maarten et al<sup>4</sup> found 51 hemangiomas which showed characteristic globular enhancement and 5 hemangiomas which were 1 to 2 cms in size which Remained hypodense in all phases. They were considered to be completely or partly fibrosed hemangiomas.

In our study, out of 306 HCC lesions in 22 patients, 143 lesions in 12 patients were hypervascular & 163 lesions in 10 patients were hypovascular. Compared to studies done by ALBERTL BOERT et al which had 15 HCC lesions out of 102 focal neoplasm's, and Maarten et al<sup>4</sup>

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which had 18 HCC (5 Patients) out of 375 lesions, the number of HCC lesions in our study are significantly high. This may be due to high incidence of HCC in south-east Asian countries, which is well documented in literature.

As the number of Hypervascular HCC were significantly high, arterial phase scanning was very useful in characterizing and detecting HCC. 143 out of 143 hypervascular lesions in our study were HCC indicating high positive predictive value of HCC for lesions enhancing in arterial phase.

Cases no. 1, 3, 4, 13, 24, 28, 34, 44, 45, 46, 47 & 50 showed hypervascular HCC. In case No. 34 there were 4 lesions which were homogeneously hyperdense on arterial phase and could be well visualized. Amongst the 4 lesions, 3 lesions are less than 2 cms in size were not visualized on Portal venous phase and Equilibrium phase images. The largest lesion >2cms showed heterogeneous enhancement and was visualized in all phases. But the hyperdense enhancing areas during HAP favored the diagnosis of HCC rather than metastases.

**Hypovascular HCC:** There are 10 cases of hypovascular HCC out of 22 HCCs in this study. Most of the lesions were heterogeneously hypodense in the hepatic arterial phase, showing minimal enhancing areas in Portal venous phase images. However there are some lesions which showed hypovascular solid lesions not showing any enhancement on Hepatic arterial phase and Portal venous- phase images. So, this type of hypovascular HCC were not described in the study done by Maarten et al,<sup>4</sup> in which there were 18 lesions. Lieven Van Hoc et al<sup>3</sup> in his study found same pattern of enhancement in all 15 HCCs during Hepatic arterial phase. Lim JH et al study shows hypoattenuating nodules on either portal or equilibrium phase images without arterial phase enhancement. In our study there were no lesions which remained hypodense on both Hepatic arterial phase and Portal venous phase images without any enhancement.

**Metastases:** Even though extensive studies done to evaluate the value of multiphase helical CT for detection of metastases, there are no significant numbers of studies, describing the pattern of enhancement of metastases. In this study, 222 out of 222 metastases were hypovascular. All these lesions are known to produce hypovascular metastasis.

As most of the metastases are hypovascular, Arterial phase scanning was not found to be much useful for characterization of liver metastases. Lieven van hoe et al<sup>3</sup> found peripheral enhancement of metastases during HAP or PVP images in 10 out of 28 lesions. But this was not specific for metastases as this type of peripheral enhancement was also noted in 2 cases of adenoma (out of 4 cases) and 7 out of 31 cases of hemangioma.

Maarten S.Venleenen et al<sup>4</sup> described hypervascular rim around metastases in 29 lesions, which became hypodense on delayed scans, described as 'wash out' sign. This "wash out' sign, was not found in our study, as delayed scan (8 to 10 mts delayed) were not done.

Miller et al<sup>5</sup> reported hypervascular metastasis from carcinoids, melanomas, pancreatic neuroendocrine tumors and sarcomas. There were no cases of metastases from unknown primary.

**Gall Bladder Carcinoma:** There is one case of Gall Bladder carcinoma (case37) which is infiltrating the liver. The lesion was hypovascular on Hepatic arterial phase showing peripheral ring enhancement around the tumor during portal venous phase indicating viable tumor tissue.

**Cholangiocarcinoma:** There are two cases of cholangiocarcinoma (no 3 and 27). Both these lesions are hypovascular on hepatic arterial phase and minimal peripheral enhancement was noted in the portal venous phase.

**Portal Vein Thrombosis:** 4 cases of portal vein thrombosis are noted in HCC (case no. 1, 12, 21 and 46). Peripheral enhancement of portal vein with central non enhancing defect, indicating thrombus, was well visualized in Portal venous phase images.

**Inferior Vena Cava Thrombosis:** 8 cases are noted. Case nos: 7, 9, 15, 21, 34, 44, 47, 50.

**Hemangiomas:** Globular enhancing nodules which are isodense to aorta, starting at the periphery and proceeding centrally into the lesion were found to be characteristic and specific for hemangiomas in our study. All 24 lesions showed this pattern and no other hypervascular lesions showed globular enhancement pattern. In our study, as 100% of hemangiomas showed globular enhancement there was no difficulty in differentiating them from other hypervascular lesions, mainly HCC.

Yasuyuki et al<sup>6</sup> in their dynamic CT study of hemangiomas found centripetally progressing peripheral enhancement in 11 tumors. But in 3 tumors (less than 3 cms in size) enhancement was more of diffuse type.

Dean F.leslie et al in their study also found globular enhancement, Isodense with aorta to be 100% specific but only 87% sensitive as 100/0 of hemangiomas showed non globular enhancement. They also found that none of the 25 patients with metastases in their study showed globular enhancement. There was no difficulty in differentiating homogeneously enhancing small HCCs from hemangiomas in our study due to 3 reasons.

Hyun – Jung et al<sup>7</sup> found small nodule with area of enhancement during Portal venous Phase with bright dot sign. In our study the enhancement was not homogeneous.

1. In all cases of small homogenous hypervascular HCC, there were also larger lesions which showed non globular enhancement suggestive of HCC.
2. Even in small hemangioma the enhancement was not as homogenous as observed in small hypervascular HCC.
3. Small Hypervascular HCC becomes almost isodense in PVP images however hemangiomas were brighter for longer duration.

### **Lesion Detectability and Conspicuity:**

**Value of hepatic arterial phase in hypervascular HCC & metastases:** Hepatocellular Carcinomas: Hepatic arterial phase images revealed 143 lesions, whereas Portal venous phase images showed 115 lesions. Addition of arterial phase imaging resulted in detection of 28 (19.5%) additional HCC tumor foci. All these 28 lesions are hypervascular lesions which became isodense on Portal venous phase images. All these 28 lesions were less than 2cms in size. Richard baron et al<sup>8</sup> in their study found tumor foci in 7 patients (11%) which were seen only on Hepatic arterial phase images. They also found that hepatic arterial phase revealed maximum no. of tumor foci. Hepatic arterial phase images showed 95% of tumor foci whereas Portal venous phase images showed 82% of lesions.

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Study	Arterial phase (%)	Portal venous phase (%)
OUR'S	100	80
RICHARD BARON ET AL <sup>8</sup>	95	82

Comparison of the detectability of hypervascular lesions in arterial and portal venous phases

Oliver et al<sup>8</sup> also showed findings similar to our study that addition of Hepatic arterial phase or non-enhanced CT or both revealed more number of tumor foci. They found additional 89 to 111 lesions on Hepatic arterial phase which were not seen on Portal venous phase images.

**Metastases:** Arterial phase scanning was not found to be useful in detecting metastases. All the lesions were visualized on portal venous phase images.

**Value of Equilibrium Phase:** Equilibrium phase was not found to be useful in detecting additional HCC or metastases. Only 197 out of 306 HCC (64%) and 167 out of 222 metastases (75%) were visualized on Equilibrium phase images. There were no HCC or metastases which were visualized- on Equilibrium phase images and not visualized on Portal venous phase images.

Equilibrium phase images did not add significantly to characterization of lesions.

**Value of NECT:** NECT images did not add to detection of additional lesions which were not seen in other phases.

- Calcifications are noted in 5 cases (case nos 20, 24, 32, 34, 43)
- No hemorrhagic lesions were noted in our study.
- Heiken MD, Brink JA, et al<sup>9</sup> showed findings in their study and concluded that unenhanced phase is not routinely necessary for detection of metastases or HCC.
- However studies showed it can be used detection of hemorrhage and calcification which could not be visualized in Hepatic arterial phase and Portal venous phase.

**CONCLUSION:** Hepatic Arterial phase and Portal venous phase are the most useful phases among triple phase spiral CT.

Hepatic arterial phase and Portal Venous phase, together can confidently characterize and differentiate hypervascular malignant lesions (HCC or hypervascular metastases) from most common benign lesions, with 3 specific patterns of enhancement showing high positive predictive value for Hemangiomas, HCC, metastases respectively.

HAP is the best phase for detecting hypervascular HCC or metastases and it should always be included for detecting hypervascular lesions. When tumors are more than 2cms in size both Hepatic arterial phase and Portal venous phase are equally good for detection of such lesions.

Portal venous phase is the best phase for hypovascular lesions and detecting metastases as most of the metastases are hypovascular lesions.

Equilibrium phase is not useful in characterization or detection of additional lesions.

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We conclude that, Hepatic arterial phase and portal venous phase have to be included for scanning of suspected liver lesion for characterization and better detection of lesion. Equilibrium phase is best avoided as it is not effective except for those cases where hemangioma forms a differential diagnosis. Unenhanced scans are useful in detecting hemorrhage and calcification with in lesions.

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