

Iconic Communication Method for Liver Disease on Teleradiology

Sung-Hyuk Cha¹, Sang-Bok Cha, M.D.²

¹Information Technology R&D Center, Samsung SDS Co., Ltd.,

²Department of Internal Medicine, Catholic University, Medical College

= Abstract =

Teleradiology is the transmission of radiological information to remote locations for the purpose of interpretation, consultation, and education. Thanks to the Internet, radiological information, including patient demographic data, result, patient studies, as well as digital medical images, can be accessed by users around the globe. Our goal is to develop an informative and effective means by which users can share their ideas among distance clinical and research facilities.

The interaction with images is generally personal, subjective, and limited to some degree by geography (1). Furthermore, when transmitted on the World Wide Web, text information may need to be translated into other languages. We use the iconic communication method to mitigate these obstacles. We selected liver and its diseases as a framework and developed a database for liver diseases with their patterns. This method can provide an efficient diagnostic summary to wide audiences as well as the referring physician. With a little language processing, information represented by icons can be easily translated into many different languages since it can work as a meta-language.

Finally, we explore its potential role in a broader range, distance consulting and learning applications and provide the iconic liver disease vocabulary and their summary for various liver scans.

Key words : Teleradiology, Iconic reporting, Iconic Communication, Liver disease

1. Introduction

One of the most dramatic applications of the networking and radiologic technologies is that involving Teleradiology. Internet as a technological infrastructure for teleradiology promises many users around globe to access radiological information. Many radiologists and computer scientists have dedicated themselves to develop an efficient teleradiology system.

ACR-NEMA committee introduced a DICOM standard for interconnection of medical digital imaging devices and protocol for patient demographic data, result, patient studies, as well as digital medical

images (2). In this standard, reports on various examinations are not fully stated causing them to be personal and subjective. For this reason, we suggest the iconic reporting technique for computer-based teleradiology users to provide more informative and efficient diagnostic summary and a new protocol on liver disease from which radiologists and physicians send and receive iconic reports.

Kulikowski and Gong first introduced the iconic reporting technique (1, 5, 6). It is a graphical symbolic abstraction to represent objects in a simplified and unique fashion. It is useful to annotate sample-based images, or their abstract and canonical representations, such as in maps or atlases. They used specialized problems involving the knee with 100

MRI knee examinations as a framework and showed the great feasibility of using the iconic report to encode and communicate the findings for the radiologist to an orthopedic surgeon.

We updated the iconic reporting technique for liver disease. Iconic representation involving the liver poses more complex difficulties because the liver is the largest gland of the body and one of the most complex organs and there are numerous liver disorders. Although images are a vital and integral part of diagnosis, one cannot decisively tell what disease it is. For this reason, we derive a list of possible diseases from the image pattern. Liver diseases introduced in this paper are limited to those which can be found and defined by radiologists: Hepatocellular carcinoma(HCC), Hepatic metastasis(HM), hemangioma(HMG), focal nodular hyperplasia(FNH), pyogenic liver abscess(P-abs), amebic liver abscess(A-abs), Hematoma(HMT), Cholangiocellular carcinoma(CCC), Cystadenocarcinoma(CAC), Tuberculosis(TBC), etc. We develop a database for these diseases with patterns on images and provide electronic diagnostic reports with templates and icons for Isotope Liver Scan, Ultrasonography(US), Computed Tomography(CT), Magnetic Resonance Imaging(MRI), and Angiography(ANG) for the listed diseases (3, 4, 7, 8, 9). Diagnosis is made from various liver scan rather than a single examination. The simplified representation of medical images helps readers appreciably to understand more discretely.

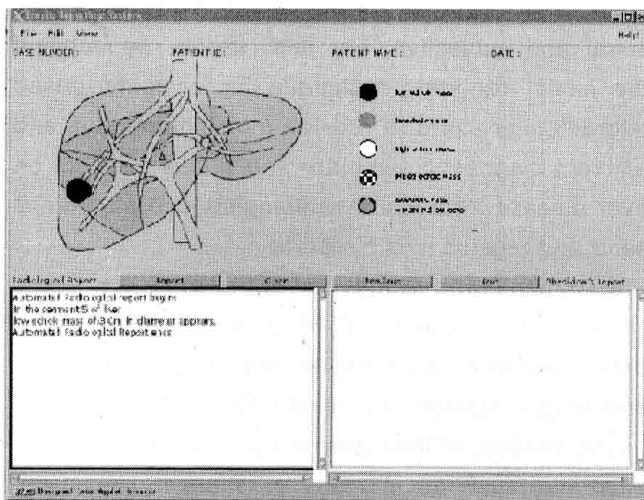


Fig. 1. A sample iconic report for US

2. Iconic Representation of liver disease

An iconic communication prototype system is built in the web-based teleradiology server: SUN Sparc E3000. Java, C, and HTML are used for the software development languages.

A sample iconic report is illustrated in Figure 1. Radiological liver examinations are taken in following order, but not necessarily always: Isotope Liver Scan, US, CT, MRI, and ANG.

In order to represent radiological findings iconically, one must define followings:

1. Visual context template selection
2. Classification by selecting an icon to represent a finding
3. Localization of the icon within the visual context template.

Selecting the templates and icons differs slightly by its modality; each modality may require different choices.

1) Segmentation of Liver and Branches of its vein

Liver is divided into 3 lobes: Caudate, Left and Right lobe. Left and right lobes are further divided into several segments as shown in Table 1. Portal vein, hepatic artery, and hepatic vein are also used to locate the findings. Portal veins are divided according to their segment to which the vein provides nutrition plus to an umbilical portion. There are right, middle, and left hepatic veins. Hepatic artery is divided into proper hepatic A., right hepatic A., cystic A., left hepatic A., medial branch, and lateral branch.

Table 1. Couinaud Hepatic Segment

| Name | Segment | Lobe |
|------|--------------------------|---------|
| S1 | Caudate lobe | Caudate |
| S2 | Left lateral superior | Left |
| S3 | Left lateral inferior | Left |
| S4 | Left medial | Left |
| S5 | Right anterior inferior | Right |
| S6 | Right posterior inferior | Right |
| S7 | Right posterior superior | Right |
| S8 | Right anterior superior | Right |

2) Isotope Liver Scan

This technique visualizes the size and shape of the liver, and is used often to locate space occupying lesion or simply SOL. The iconic reporting system superimposes icons representing the SOL onto a visual template of the liver in 4 views as illustrated in Figure 2.: anterior, posterior, right lateral, and left lateral. The icon needed for the liver scan is the SOL alone. Possible diseases are listed in the Figure 3. The icon may have different properties such as shape, size, etc. These properties are given in Figure 4. and they may be applied to some other icons defined in other modalities as well.

3) Ultrasonography

Ultrasonography, or simply sonography, is an imaging technique by recording the reflection of high-frequency sound waves. Template must show segmental division according to portal vein, hepatic vein and inferior vena cava to represent findings as shown in Figure 5. It is, however, very hard to locate masses by section in this scan. A list of icons and their diseases are given in Figure 6. These icons represent patterns of icons and are designed to look as similar as possible to real masses.

4) Computed Tomography and Magnetic Resonance Imaging

CT and MRI scans display the liver as a series of adjacent cross-sectioned slices and demonstrate detailed anatomy across the whole abdomen at the level of the slice. One scout template of the liver and 5 axial templates are needed to represent findings in both CT or MRI images as shown in Figure 7. We

use the same templates as there is little difference in diagnostic accuracy between MRI and CT for the detection of hepatic mass lesions. Segmental anatomy in transverse section is modified from Paganii's reference (9). We use the scout view template to choose different axial transverse cross section of liver. A list of icons and their diseases for CT and MRI are given in Figure 8. and Figure 9. respectively.

5) Angiography

Angiography is an x-ray examination of the inside of blood vessels by injecting a dye. A list of icons

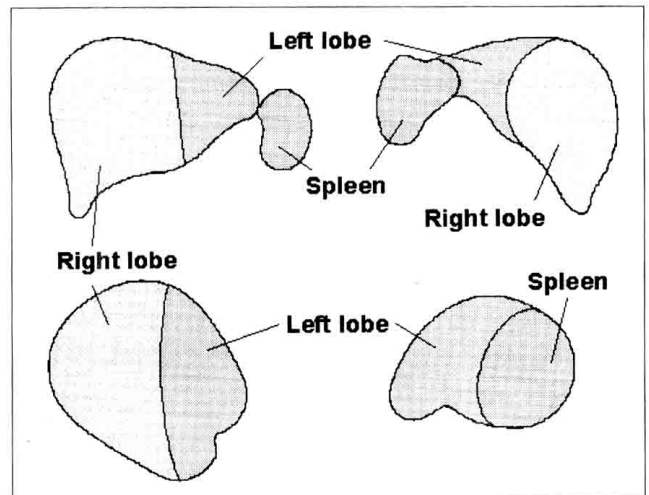


Fig. 2. Liver templates for isotope liver scan

| Isotope Scan (99m Technethium) | | |
|--------------------------------|---------------------------------|-------------------------------------------------|
| Pattern | Desc. | Disease |
| | SOL (Space Occupying Lesion) | HCC , HM , HMG, FNH, P-abs, A-abs, HMT, CCC,CAC |

Fig. 3. Findings from isotope liver scan

| Property of icons | | | | |
|------------------------------|------------------------------------------------------|------------|--------------|----------------|
| Size (diameter) | Shape | Number | Visibility | Location |
| < 3Cm | Round Lobulated | ▪ Solitary | Well defined | ▪ Segmentation |
| 3 < > 6 | Oval Capsuled | ▪ Dual | Ill defined | ▪ Lobe |
| > 6 Cm | Irregular Margin Single accompanied by small nodule | ▪ Multiple | | ▪ Vein |
| (x,y) (x),(x,y) real size | | ▪ Diffuse | | ▪ Artery |

Fig. 4. Properties of icons

and their diseases are given in Figure 10. The template is illustrated in Figure 11. Hepatic artery plays an important role here because tumour is supplied by the hepatic artery.

6) Language Processing

With a visually represented report, a computer generates an automated report containing the pattern description, location, shape, number, visibility, and size of the findings. The pattern description is known when one selects the icon, and location is achieved from the template. Templates used in the system are not simple background images but image maps. By dragging the mouse or clicking an icon on the template, one finds its location of the mouse or icon. The system tells its location according to lobes, Couinaud sections, portal vein, hepatic artery or hepatic vein depending on the type of scan. A computer obtains the size, shape, visibility, and number information from the property box of the icon.

3. Discussion

Teleradiology facilitates radiological services regardless of location and allows personnel in radi-

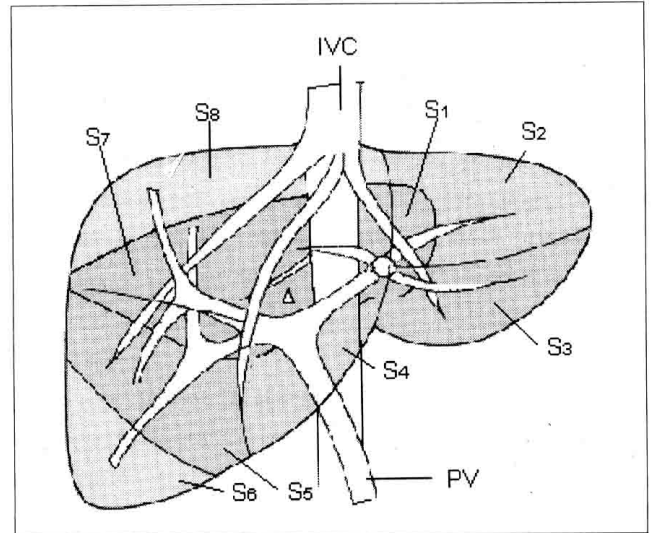


Fig. 5. Liver templates for Ultrasonography

| US (UltraSonography) | | | | | | | |
|----------------------|---------|----------------------------------------|---------------|----|---------|-------------------------------------------------------------|---------------|
| No | Pattern | Description | Disease | No | Pattern | Description | Disease |
| 1 | | low echoic mass | small HCC, HM | 15 | | tumor in tumor appearance | HCC, HM(rare) |
| 2 | | isoechoic mass | HCC | 16 | | low echo + central calcification + posterior enhancement | HM |
| 3 | | high echoic mass | HCC, HM, HMG | 17 | | low echo mass + posterior enhancement | cyst |
| 4 | | mixed echoic mass | HCC, FNH | 18 | | Marginal high echo + Central low echo + Internal high echo | HMG |
| 5 | | isoechoic mass + marginal low echo | HM | 19 | | Mixed echo + halo | HMG, HM |
| 6 | | high echoic mass + halo (ring type) | HCC, HMG | 20 | | Dotted high echo | P-abs. |
| 7 | | high echoic mass + low echoic fat | HCC | 21 | | low echo mass + internal high echo + high echo capsule | P-abs. |
| 8 | | high echoic nodule + lateral shadow | HCC | 22 | | mixed echo(dotted high echo) + posterior enhancement | A-abs. |
| 9 | | low echoic mass + lateral shadow | cyst, HCC, HM | 23 | | high echo mass + posterior shadow | HM, HCC(rare) |
| 10 | | Tumor thrombosis in portal vein branch | HCC | 24 | | mixed echo mass + lateral shadow + posterior enhancement | P-abs. |
| 11 | | Target sign (bull's eye) | HM | 25 | | low echo mass + internal isoechoic dotted + irregular shape | HMT |
| 12 | | Cluster sign (lobulated) | HM | 26 | | mixed echo mass + irregular low echo margin | CCC |
| 13 | | Central anecho + marginal high echo | HM | 27 | | low echoic mass + high echoic septum | CAC |
| 14 | | low echo mass + marginal high echo | HM | | | | |

Fig. 6. Findings from ultrasonography

ology department to work at home. Moreover, it helps students and researchers greatly due to the increased accessibility to radiology study collections. The iconic communication system provides not only the efficient summary of findings, but also even bet-

ter computer aided remote education such as case comparisons, liver sectioning study, and disease property study. Anyone who is even not an expert in radiology can practice the radiological diagnosis through the system. Readers of diagnostic reports are not limited to experts. It enables wide audiences to understand reports. Like an old saw, well defined picture is worth a thousand words.

Another advantage of the system is concerned with the amount of data on transmission. When transmitted between two systems, the data necessary to be transmitted are the name, properties of icon and template and modality names. These data are constant values which are only several bytes. We do not have to transmit the template and icon images; we assume that the receiving system also has the same system. The iconic communication method is an upcoming area of research in representing explicit content in image and multimedia database construction and utilization.

There are, however, some drawbacks of using the iconic reporting system over simple conventional dictated reports. One of its major disadvantages is that its flexibility (or degree to which nuances can be conveyed) is in direct proportion to the number of elements (icons) included in its vocabulary (6). Due

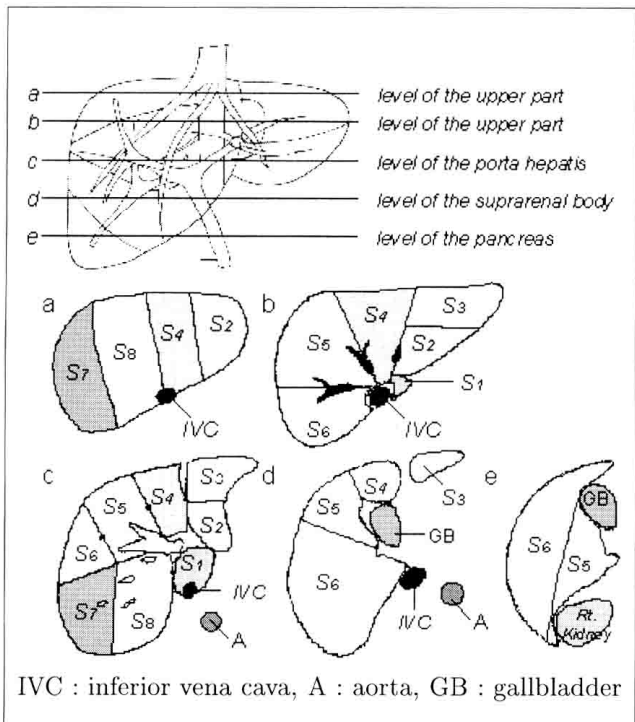


Fig. 7. Liver templates for CT and MRI

| CT (Computed Tomography) | | | | | | | |
|--------------------------|---------|--------------------------------------------|----------------------------------------------------|----|---------|--------------------------------------------|--------------------|
| No | Pattern | Desc. | Disease | No | Pattern | Desc. | Disease |
| 1 | | lowdense mass | HCC, HM, Cyst, CCC, TBC Lipoma, A-abs., Adenoma | 11 | | high dense mass + central septa (CECT) | FNH |
| 2 | | iso dense mass | HCC | 12 | | lobulated mass | TBC |
| 3 | | high dense mass | HCC, HM, HMG | 13 | | Cystic mass + protruded high echo | CAC |
| 4 | | mixed dense mass (low dense + high dense) | HCC, P-abs. | 14 | | Cystic mass + septae(high dense) | P-abs., Lymphoma |
| 5 | | mixed dense mass (high dense + lowdense) | HCC, P-abs. | 15 | | low dense lesion + air fluid level(P-scan) | P-abs., A-abs., HM |
| 6 | | high dense mass + centripetal enhancement | HMG | 16 | | P-scan -> CECT (low dense rim) | A-abs. |
| 7 | | central low dense mass + high dense wall | A-abs., HCC, CCC | 17 | | P-scan -> CECT | HM, CCC |
| 8 | | isodense center + calcified cyst | Cyst (Hyctid) | 18 | | P-scan -> CECT | A-abs. |
| 9 | | multi-septate cyst + pathycalcified wall | Cyst (Hyctid) | 19 | | P-scan -> CE(early) -> CE(late) | HCC |
| 10 | | multi-septate cyst + patchy calcified wall | Cyst (Hyctid) | 20 | | P-scan -> CE(early) -> CE(late) | HMG (Cavernous) |

Plain CT(P-CT),
Contrast Enhanced CT (CECT)
- early & late

Fig. 8. Findings from CT

| MRI (Magnetic Resonance Imaging) Scan | | | | | | | |
|---------------------------------------|---------|---------------------------------|----------|----|---------|----------------------------------------------------------------------|---------------------|
| No | Pattern | Desc. | Disease | No | Pattern | Desc. | Disease |
| 1 | | T1W low density mass | | 7 | | T2W high intense central scar | HCC |
| 2 | | T1W iso dense mass | | 8 | | T1W high intense mass + high intense rim T2W high intense capsule | HCC |
| 3 | | T2W low intense mass | HCC | 9 | | T1W mosaic like mass + high intense capsule | HCC |
| 4 | | T2W high intense mass | HCC, HMG | 10 | | T1W high intense rim | Cyst |
| 5 | | T2W high intense capsule | HCC | 11 | | T2W high intense tumor thrombus in portal vein | HCC |
| 6 | | T2W high intense central septae | HCC | 12 | | | HCC, HM, HMG FNH |

Fig. 9. Findings from MRI

| AG (Angiography) | | | | | | | |
|------------------|---------|-------------------------------------------------------------------------------------|-----------------------------|----|---------|-------------------------------------------|------------------------------|
| No | Pattern | Description | Disease | No | Pattern | Description | Disease |
| 1 | | Ap: dilated irregular tumor vessel | HCC, Adenoma | 10 | | Vp: dotted tumor stain or lakes in mass | HMG |
| 2 | | Ap: small tumor vessel | HCC, HM, CCC | 11 | | thread and streak sign | HCC |
| 3 | | Vp: ring-like staining of wall | HMG, HM | 12 | | Ap: tumor thrombus of portal vein or vein | HCC |
| 4 | | Vp: thin wall staining (radiolucent rim) | Cyst, HCC | 13 | | Ap: 1 + Cp: Septation of the mass | FNH |
| 5 | | Ap: round tumor stain | HCC, HM | 14 | | Ap + Vp | HM, CCC |
| 6 | | Vp: irregular tumor stain | HCC | 15 | | Ap + Vp | HM |
| 7 | | Ap: compression and stretching of the intrahepatic artery branch No tumor vessel | HM, CCC, Cyst, Abscess, HMG | 16 | | Ap + Vp | Cyst, Abscess, lymphoma, CAC |
| 8 | | Vp: swiss cheese appearance | HM | 17 | | Ap + Vp | A-abs |
| 9 | | Vp: doughnut-like tumor stain | HM | | | | |

Ap: Arterial phase Cp: Cappillary phase Vp: Venous phase

Fig. 10. Findings from Angiography

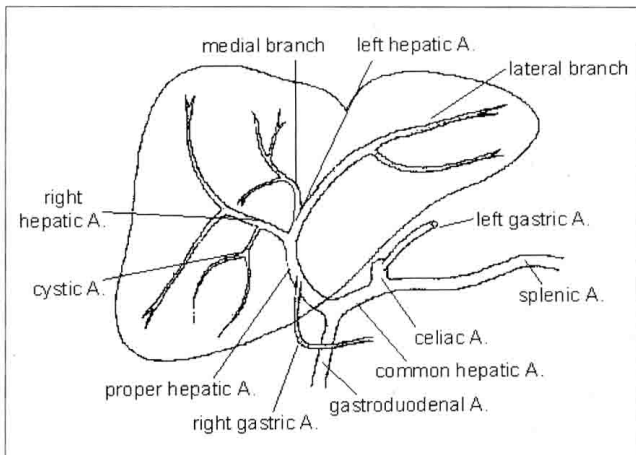


Fig. 11. Liver templates from Angiography


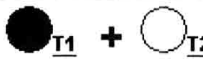



























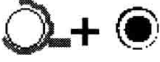


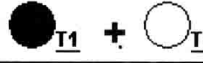



to the lack of flexibility in describing problems in details, we also provide a text area in which one can append his or her comments to the automatically generated report. Therefore, iconic reporting and conventional dictated reporting can be complementary to provide the more informative and effective report to the readers. Another inflexibility is handling deformation of liver. Because we use the fixed templates, it is hard to express badly deformed liver.

In the remaining space, we provide the summary of findings for liver diseases from various imaging scans. Table 12 helps users learn the system as well as liver diseases and verify iconic reports.

















Fig. 12. Summary of findings for liver diseases from various imaging scans

| Modality | Patterns & Description |
|------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 1. HCC (Hepatocellular carcinoma) | |
| US | low echoic mass isoechoic mass high echoic mass mixed echoic mass high echoic mass + halo (ring type) high echoic mass + low echoic fat high echoic nodule + lateral shadow low echoic mass + lateral shadow Tumor thrombosis in portal vein branch tumor in tumor appearance high echo mass + posterior shadow |
| CT | low dense mass iso dense mass high dense mass mixed dense mass (low dense + high dense) mixed dense mass (high dense + low dense) central low dense mass + high dense wall P-scan -> CE(early) -> CE(late) |
| MRI | T2W low intense mass T2W high intense mass T2W high intense capsule T2W high intense central septae T2W high intense central scar T1W high intense mass + high intense rim T1W mosaic like mass + high intense capsule T2W high intense tumor thrombus in portal vein T1W + T2W |
| AG | Ap: dilated irregular tumor vessel Ap: small tumor vessel Vp: thin wall staining (radiolucent rim) Ap: round tumor stain Vp: irregular tumor stain thread and streak sign Ap: tumor thrombus of portal vein or vein |
| 2. HM (Hepatic metastasis) | |
| US | low echoic mass high echoic mass isoechoic mass + marginal low echo low echoic mass + lateral shadow Target sign (bull's eye) Cluster sign (lobulated) Central anecho + marginal high echo low echo mass + marginal high echo tumor in tumor appearance low echo + central calcification + posterior enhancement high echo mass + posterior shadow Mixed echo + halo |
| CT | low dense mass high dense mass low dense lesion + air fluid level (P-scan) P-scan -> CECT |
| MRI | T1 + T2 |
| AG | Ap: small tumor vessel Vp: ring-like staining of wall Ap: round tumor stain Ap: compression and stretching of the intrahepatic artery branch No tumor vessel Vp: swiss cheese appearance Vp: doughnut-like tumor stain Ap + Vp Ap + Vp |
| 3. HMG (hemangioma) | |
| US | high echoic mass high echoic mass + halo (ring type) Marginal high echo + Central low echo + Internal high echo Mixed echo + halo |
| CT | high dense mass high dense mass + centripetal enhancement P-scan -> CE(early) -> CE(late) |

continued

| Modality | Patterns & Description |
|------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| MRI |  T2W high intense mass  |
| AG |  Vp: ring-like staining of wall  Ap: compression and stretching of the intrahepatic artery branch No tumor vessel  Vp: dotted tumor stain or lakes in mass |
| 4. Hepatic Cyst | |
| US |  low echoic mass + lateral shadow  low echo mass + posterior enhancement |
| CT |  low dense mass  isodense center + calcified cyst (Hydrid)  multi-septate cyst + pathycalcified wall (Hydrid)  multi-septate cyst + patchy calcified wall (Hydrid) |
| MRI |  T1W high intense rim |
| AG |  Vp: thin wall staining (radiolucent rim)  Ap: compression and stretching of the intrahepatic artery branch No tumor vessel  Ap + Vp |
| 5. Hepatic Abscess (pyogenic liver abscess : P-abs, Amebic liver abscess : A-abs) | |
| US |  Dotted high echo (P-abs.)  low echo mass + internal high echo + high echo capsule (P-abs.)  mixed echo mass + lateral shadow + posterior enhancement (P-abs.)  mixed echo (dotted high echo) + posterior enhancement (A-abs.) |
| CT |  mixed dense mass (low dense + high dense) (P-abs.)  mixed dense mass (high dense + low dense) (P-abs.)  Cystic mass + septae (high dense) (P-abs.)  low dense lesion + air fluid level (P-scan)  low dense mass (A-abs.)  central low dense mass + high dense wall (A-abs.)  P-scan -> CECT (low dense rim) (A-abs.)  P-scan -> CECT (A-abs.) |
| AG |  Ap: compression and stretching of the intrahepatic artery branch No tumor vessel  Ap + Vp  Ap + Vp (A-abs) |
| 6. FNH (focal nodular hyperplasia) | |
| US |  mixed echoic mass |
| CT |  high dense mass + central septa (CECT) |
| MRI |  T1 + T2 |
| AG |  Ap: 1 + Cp: Septation of the mass |
| 7. HMT (hepatic hematoma) | |
| US |  low echo mass + internal isoechoic dotted + irregular shape |
| 8. CCC (cholangiocellular carcinoma) | |
| US |  mixed echo mass + irregular low echo margin |

continued

| Modality | Patterns & Description | |
|------------------------------------|------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| CT |  low dense mass |  central low dense mass + high dense wall |
| AG |  Ap: small tumor vessel |  Ap: compression and stretching of the intrahepatic artery branch No tumor vessel |
| |  P-scan -> CECT |  Ap + Vp |
| 9. CAC (cystadenocarcinoma) | | |
| US |  low echoic mass + high echoic septum | |
| CT |  Cystic mass + protruded high echo | |
| AG |  Ap + Vp | |
| 10. Hepatic Adenoma | | |
| CT |  low dense mass | |
| AG |  Ap: dilated irregular tumor vessel | |
| 11. Malignant Lymphoma | | |
| CT |  low dense mass |  Cystic mass + septae (high dense) |
| AG |  Ap + Vp | |
| 12. TBC (Tuberculosis) | | |
| CT |  low dense mass |  lobulated mass |

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