Diffusion-weighted MR Imaging for Non-neoplastic Conditions in the Hepatobiliopancreatic Region: Pearls and Potential Pitfalls in Imaging Interpretation

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Authors: T. U. Kim¹, S. Kim², N. K. Lee², J. Roh¹, H. I. Seo²; ¹Yangsan-Si/KR, ²Pusan/KR
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Learning objectives

1. List diffusion-restricted non-neoplastic conditions in the hepatobiliopancreatic region
2. Recognize conventional MR and DWI features of various non-neoplastic conditions in the hepatobiliopancreatic region
3. Differentiate diffusion-restricted neoplastic from non-neoplastic conditions in the hepatobiliopancreatic region at MR with DWI

Background

Diffusion-weighted MR imaging (DWI) is an appealing technique because it is noninvasive, can be performed relatively quickly, and does not require any exogenous contrast agents or ionizing radiation. The apparent diffusion coefficient (ADC) calculated from DWI enables quantitative information regarding tissue water mobility, tumor characterization between benign and malignant lesion, and tumor response to treatment.

Recently, DWI in the hepatobiliary and pancreatic regions has the potential in the detection of malignant lesions and their differentiation from benign lesions in conjunction with findings obtained with conventional MR imaging. However, some benign tumor-like lesions in the hepatobiliary and pancreas regions may also exhibit restricted diffusion on DWI, as a result of pus, active inflammation or high cellularity within the lesions.

In this article, we illustrate a variety of diffusion-restricted non-neoplastic conditions in the liver, gallbladder, bile duct and pancreas. We also review MR imaging findings that may assist in narrowing the differential diagnosis of diffusion-restricted non-neoplastic conditions from neoplasms in the hepatobiliary and pancreas regions.

Findings and procedure details

Basic concepts

DWI can detect thermally-induced motion of water molecules within living tissue, called Brownian motion. In biological tissue, water diffusion consists of motion of water molecules in intracellular, extracellular and intravascular space. In contrast to the free diffusion, diffusion in biological tissue is impeded by the interaction of water with cell membranes and macromolecules as well as microcirculation because tissue has structures.
The exact biologic mechanisms are unclear; however, any increase in cellularity leads to greater overall restriction of diffusion and crowding of the extracellular spaces, making the spaces between cells more convoluted and tortuous and further restricting the diffusion of water. Restricted diffusion is seen in tissues with high cellularity such as tumors, abscesses, cytotoxic edema, whereas free diffusion is seen in tissue with low cellularity and disrupted cell membranes.

DW, which was first described by Stejskal and Tanner, is based on a spin echo T2-weighted imaging sequence with the application of a pair of symmetric bipolar gradients on the opposite sides of the 180° refocusing pulse. Static water molecules develop additional phase shift from the application of the dephasing gradient (diffusion sensitizing gradient), but these phase shift are cancelled by the application of the rephasing gradient, resulting in no additional net loss of signal (aside from normal T2 decay). However, moving water molecules are not completely rephased by the second gradient due to positional change between gradients, so that a subsequent reduction in signal intensity is observed. As a result, the more restricted the movement of molecules, the higher the resultant signal intensity at diffusion-weighted imaging.

DWI is performed with at least 2 b-values and the sensitivity of the diffusion sequence to water motion can be altered by changing "b-value", which is proportional to the gradient amplitude, the duration of the sensitizing gradients, and the time between the gradient pair. To obtain a higher b-value, the gradient amplitude is maximized and the gradient duration and interval changed to control the b-value in most applications.

Water molecules with a large diffusion distances per unit time (e.g., blood flow) will show signal attenuation with small b values (e.g., b < 100-150 sec/mm²). By comparison, when large b values (e.g., > 500 sec/mm²) are used, there is usually less signal attenuation from cellular tumors containing slow-moving water molecules. The signal loss in water molecules at different b values can be used for lesion detection or characterization.

Quantitative analysis is performed by calculating the ADC values. ADC value is derived from linear regression analysis of the logarithm of relative signal intensity (y-axis) against b-value (x-axis). ADC value is calculated for each pixel of the image and is displayed as a parametric map. By drawing regions of interests on these maps, the ADCs of different tissues can be derived.

Liver

Hepatic abscess

Hepatic abscess is a localized intrahepatic accumulation of pus surrounded by a capsule with destruction of the liver parenchyma. Typically, hepatic abscess is depicted as a single or multiloculated hypodense mass with capsular enhancement on CT. However,
certain hepatic malignant tumor may develop central necrosis, which results to mimic the imaging appearance of hepatic abscess.

Recent studies have reported a marked difference of signal intensity on DWI between hepatic abscess and cystic or necrotic tumor. On DWI, center of hepatic abscess shows marked hyperintensity with low ADC values, whereas necrotic portion of tumor shows hypointensity with high ADC values. This is explained by the difference in the biochemical components of the necrotic components: abscess cavity is filled with pus, containing inflammatory cells, bacteria, necrotic tissue, and proteinaceous exudates with high viscosity and cellularity. In contrast, necrotic portion of tumor has low viscosity. The peripheral rim of hepatic abscess also reveals different signal intensity compared with that of malignant tumor on DWI. The rim of hepatic abscess demonstrates hyperintensity on DWI with high ADC values ("T2-shine through" effect), due to decreased cellularity and increased extracellular fluid in the periphery secondary to inflammation. Whereas, the rim of necrotic tumors shows hyperintensity on DWI with low ADC values due to the rich tumoral cellularity at the periphery.

However, the signal intensity of hepatic abscess on DWI can vary depending on the degree of abscess maturation. Early abscess shows histopathologic alterations like inflammatory cell infiltrations and granulation tissue with less developed liquefaction and necrosis. Thus, DWI in the early abscess formation often overlaps that of malignant solid tumor, which may lead to misinterpretation.

**Focal eosinophilic liver disease**

Focal eosinophilic liver disease (FELD) is associated with variable conditions including parasitic infestation, allergy, internal malignancy, drug hypersensitivity and hypereosinophilic syndrome. These hepatic lesions are often confused with hepatic metastasis in patients with underlying malignancy.

Several studies have described imaging features of FELD to differentiate this disease from hepatic metastasis. The morphologic characteristics and enhancement pattern of FELD might be influenced by the stage of disease. FELD generally divided into two histologic subtypes (eosinophilic infiltration, and eosinophilic abscess) according to the presence or abscess of central necrosis.

The characteristic features of eosinophilic infiltration are nonspherical shape with fuzzy margin, iso-intensity on T1-weighted image, slight hyperintensity on T2-weighted image, homogeneous enhancement on portal and equilibrium phase, mixed iso-or hypo-intensity on hepatobiliary phase, and reduction in size and different shape on hepatobiliary phase compared with T2-weighted image. In contrast to eosinophilic infiltration, metastasis have hypo-intensity on T1-weighted image, rim-enhancement on dynamic images, target appearance on hepatobiliary phase, and no observed change in size and shape on hepatobiliary phase compared with T2-weighted image.
Eosinophilic abscess is more likely to have similar appearance to liver metastasis than eosinophilic infiltration. Eosinophilic abscess oftentimes takes on a globular shape, discrete margin, and homogeneous or rim enhancement, which make it difficult to differentiate them from metastasis.

FELD sometimes shows hyperintensity on DWI with low ADC values, which favors malignant features. Accumulation of eosinophils, distortion of normal histologic architecture, and consequent recruitment of activated inflammatory cells may cause diffusion restriction. Thus, DWI alone are not likely to be helpful in differentiating FELD from other malignant lesions, but suggestive conventional imaging findings, and peripheral eosinophilia may lead to a correct diagnosis of FELD.

**Inflammatory myofibroblastic tumor**

Inflammatory myofibroblastic tumor (IMT), previously known as inflammatory pseudotumor is an unusual benign tumor consisting of chronic inflammatory cell infiltration with predominant plasma cells and a fibrous stroma. MR findings of IMT are nonspecific, and vary depending on the relative quantity of fibrous tissue, inflammatory cell infiltration, and necrosis in the mass: solitary or multiple nodular lesions with hypointensity on T1-weighted image, isointensity or slight hyperintensity on T2-weighted image, and variable enhancement. Although the enhancement pattern including peripheral enhancement or multiple septa and nodular enhancement may help differentiate it from hepatocellular carcinoma, there may be no specific MR imaging characteristics to aid in the differential diagnosis of IMT from other hepatic malignancies. On DWI, IMT appears hyperintense due to its inflammatory cell infiltrations, although wide range of ADC values may exist due to varied composition of this lesion. Thus, it is difficult to the correct diagnosis of IMT even using DWI.

**Granulomatous disease**

Granulomatous disease of the liver defined as inflammatory liver disease associated with granuloma formation of the liver. It can be incited by various entities including those that infectious such as tuberculosis, fugal, or parasite, and those that are noninfectious, such as sarcoidosis.

Tuberculosis involving hepatic parenchyma is either miliary or macronodular. Miliary hepatic tuberculosis is commonly found in patients with disseminated disease. It is depicted as innumerable micronodules, which may not be detected at imaging. Macronodular tuberculosis is uncommon, and MR signal intensity varies depending on its stage of maturation. Early stage of tuberculoma usually appears slightly hypointense on T1-weighted image and hyperintense on T2-weighted image. Solid caseating tuberculosis appears relatively iso- to hypointense on both T1-weighted and T2-weighted images with
peripheral rim enhancement. These imaging features are nonspecific and are similar to those of metastasis, and abscess. Although studies about DWI of hepatic tuberculosis are not reported yet, central area of caseating tuberculomamay appear hyperintense on DWI with low ADC values, because its core contains caseous necrosis, inflammatory cells, and cell debris. This DWI finding can be distinguished from necrotic tumor, but may overlap with pyogenic abscess. Early stage of tuberculomawith less caseation also frequently reveals diffusion restriction, but may overlap other hepatic focal lesions. Thus, tissue confirmation by biopsy would be necessary, depending on a different clinical setting.

Sarcoidosis is a systemic inflammatory disease of unknown origin characterized by the formation of noncaseating granulomas. Although sarcoidosis mostly affects lung and mediastinal lymph nodes, every other organ can be involved such as the liver and spleen. The common imaging finding of hepatic sarcoidosis is hepatomegaly and nodular infiltrations. On MRI, hepatic nodules are slightly hypointense on both T1- and T2-weighted images with minimal and delayed enhancement. In our clinical experience, diffusion restriction was also seen, due to the coalescence of small granulomas. These seen lesions can mimic more serious neoplastic or infectious diseases of the liver. Thus, sarcoidosis should be included in the abdominal differential diagnosis in the appropriate clinical setting.

**Biloma**

Biloma is an encapsulated intrahepatic or extrahepatic bile accumulation outside the biliary tree that arises due to a bile leak. Differentiation of infected biloma from noninfected biloma is crucial to therapeutic decision making. Infected or symptomatic biloma may require treatment with percutaneous drainage.

On CT, biloma appears as a well-defined intrahepatic or perihepatic collection with the low-attenuation value, similar to that of the water. Peripheral enhancement is often noted when infection is accompanied. Biloma can appear as heterogeneous intensity on T1-weighted image, and homogeneous hyperintensity on T2-weighted image, according to the presence or abscess of infection. MR cholangiography using hepatocyte-specific agents can confirm the presence of bile leakage by demonstrating delayed contrast filling into biloma. DWI itself cannot help diagnose biloma. However, DWI may be useful in differentiating between sterile and infected biloma, because peripheral rim of infected biloma may have diffusion restriction.

**Pylephlebitis**

Pylephlebitis is defined as septic thrombophlebitis of the portal venous system, secondary to an infection in the region drained by the portal system or in the structures contiguous to
the portal vein. Common sources of infection are colonic diverticulitis, acute appendicitis, urinary infections, pelvic infections, and biliary diseases.

Pylephlebitis depicted as non-enhancing intravascular thrombosis in the portal vein and its branches on CT. Transient hepatic attenuation differences is also seen due to portal vein thrombosis. However, these imaging features are not specific for pylephlebitis, which must be distinguished from bland thrombosis in the portal vein.

Although identification primary source of infection is necessary for the differential diagnosis of pylephlebitis, DWI may be used to differentiate pylephlebitis from bland thrombosis; pylephlebitis appears hyperintense on DWI with low ADC values due to inflammatory cell infiltrations in the thrombus, whereas bland thrombosis has no diffusion restriction.

**Biliary tract**

**Acute cholecystitis**

Acute cholecystitis is the most frequent acute inflammatory condition of the gallbladder. US is generally the preferred initial imaging technique when acute cholecystitis is clinically suspected. However, US has varying sensitivity and specificity (40%-90%) and specificity (40%-95%). CT and MRI usually provide morphological information similar to that provided by US, and can be performed if the clinical presentation is atypical. Diffuse gallbladder wall thickening, mural or mucosal enhancement, gallbladder distention, and increased pericholecystic hepatic parenchymal enhancement are frequent as well as specific CT and MR imaging findings of acute cholecystitis.

In our experience, some cases of acute cholecystitis appear hyperintense on DWI due to severe inflammation, and their ADC values overlap those of gallbladder cancer. However, diffuse and smooth hyperintense wall thickening is more common in acute cholecystitis than in cancer in which, focal, irregular and asymmetric hyperintense wall thickening is common that may help to differentiate acute cholecystitis from wall-thickening type gallbladder cancer. Moreover, DWI may be helpful to assess the severity of acute inflammation by the degree of signal intensity of DWI and ADC values.

Pus in the gallbladder, known as empyema, occurs in approximately 2-3% of patients with acute cholecystitis. Urgent treatment such as drainage of cholecystectomy is required, because empyema has a high risk of sepsis and perforation. MR imaging finding indicative of empyema is a fluid-fluid level with hypointensity in the dependent portion of the gallbladder on T2-weighted images. However, a fluid-fluid level of the bile in the gallbladder is also seen in other conditions. On DWI, the pus in the dependent portion appears hyperintense with low ADC values due to its high viscosity, whereas
concentrated bile or sludge has no diffusion restriction. Thus, DWI can be helpful to differentiate pus from other conditions showing a fluid-fluid level of the bile on MR images.

**Xanthogranulomatous cholecystitis**

Xanthogranulomatous cholecystitis (XGC), an unusual variant of chronic cholecystitis, is characterized by a lipid-laden inflammatory process. On MR imaging, XGC closely resembles gallbladder cancer with diffuse or focal wall thickening, heterogeneous wall enhancement, and multiple intramural lesions with markedly elevated T2 signal intensity. Multiple hyperintense intramural lesions on T2WI correspond to accumulation of foamy histiocytes, a finding that is suggestive of XGC rather than carcinoma. However, this characteristic MR feature is not always able to differentiate XGC from gallbladder cancer. Focal and irregular high signal intensities in the gallbladder wall on DWI favors the diagnosis of gallbladder cancer over benign inflammatory conditions of the gallbladder. However, these DWI findings are also seen in XGC. In XGC, severe inflammatory fibrosis can cause diffusion restriction, and foamy histiocytes also restrict the motion of water protons. Thus, differentiating XGC from gallbladder cancer is difficult even using DWI, and histological examination of the resected specimen may be needed for the final diagnosis.

**Hemobilia**

Biliary tract blood, known as hemobilia is a rare condition, which is usually caused by either trauma or underlying medical disorders such as hemophilia, vascular anomalies, cholecystitis, cholelithiasis, and malignant tumors.

MR imaging findings indicative of hemobilia are clot which appear as defects in the gallbladder and bile duct at MRCP, and hemorrhagic bile which has hyperintensity on fat-suppressed T1-weighted images and mixed signal intensity on T2-weighted images. On DWI, hematoma may be hyperintense, and ADC values may be in the wide range according to blood products in various stages of breakdown: decreased ADC values in hemorrhage with intact red blood cell membranes (i.e., hyperacute, acute, and early subacute hematoma) and increased ADCs after lysis of red blood cell membranes (i.e., “free” methemoglobin in subacute-to-chronic hematoma). This may be mistaken formalignant lesions on DWI or the ADC map, causing erroneous characterization of lesions.

**Inflammation in the ampulla of vater**

Papillitis is an acute inflammatory disorder involving the mucosa overlying the major duodenal papilla. Papillitis is commonly associated with clinically acute inflammatory
condition such as acute cholangitis, or acute pancreatitis, which is usually caused by the passage of biliary stones, periampullary diverticulum, parasites, and other infection. Symmetric wall thickening and increased enhancement in the papilla may help distinguish benign papillitis from hypovascular ampullary carcinoma with irregular contours along the surface of the papilla. On DWI using high b values, ampullary carcinoma displays hyperintensity with low ADC values due to high cellularity of tumors, whereas benign ampullary lesions usually show iso-intensity. However, papillitis with severe active inflammation infrequently remains at hyperintensity, similar to ampullary carcinoma. Thus, it is not always easy to distinguish between malignant and benign ampullary lesions on MR imaging with DWI.

Pancreas

Acute pancreatitis

Dynamic CT is well established for differentiating acute interstitial edematous pancreatitis from necrotizing pancreatitis. However, CT is not necessary in depicting acute interstitial pancreatitis. MR imaging is superior to CT in detecting mild pancreatic and peripancreatic inflammation. Recently, DWI has been applied in the evaluation of inflammation of pancreas. In previous studies, acute pancreatitis appeared as hyperintense on DWI with decreased ADC values, which could be differentiated from normal pancreas. Acute pancreatitis is characterized at the cellular level by acinar cell death, invasion of acinar spaces by leukocytes, deposition of fibrin in intercellular space, and microthrombi in blood vessels. Diffusion restriction in acute pancreatitis may be due to any of these factors.

In Shinya et al., there was no difference in the ability to detect acute pancreatitis between DWI and contrast-enhanced CT. However, the large dose of iodinated contrast medium might worsen or prolong attacks of acute pancreatitis, and it is hard to perform enhanced CT in patients with renal failure due to severe acute pancreatitis. In these conditions, DWI can detect acute pancreatitis more clearly than nonenhanced CT.

DWI can be useful for characterizing peripancreatic fluid collection, which usually has no restricted diffusion on high-b-value DWI, but infected fluid may have restricted diffusion. Moreover, DWI can be useful for evaluating activity of acute pancreatitis. After treatment, signal intensity in acute pancreatitis on DWI gradually decrease and finally disappear, and ADC values return to normal levels.

Mass-forming pancreatitis

Mass-forming focal pancreatitis, which is defined as a focal inflammatory process in the pancreas, remains difficult to distinguish from pancreatic carcinoma on MR imaging, because both appear as a hypointense mass or mass-like lesion in the
pancreas on T1-weighted images and are associated with ductal obstruction. Irregularity of the pancreatic duct, intraductal or parenchymal calcifications, and unobstructed main pancreatic duct coursing through the mass ("duct penetrating sign"), favor the diagnosis of focal pancreatitis over pancreatic carcinoma. However, overlap between two diseases still exists.

In several previous studies, ADC values for both focal pancreatitis and pancreatic carcinoma significantly differed from ADC values of normal pancreas; however, there is an overlap in ADC values of focal pancreatitis and pancreatic carcinoma, with the consequent problem of their correct differentiation. Comparing ADC values of both focal pancreatitis and pancreatic carcinoma to the remaining pancreas may be helpful in differentiating two diseases. Most of masses in focal pancreatitis had indistinguishable ADC values as compared with the remaining pancreas, which might reflect that the same inflammatory process may be present both in focal pancreatitis and the remain pancreas. Whereas, ADC values of pancreatic carcinomas was invariably lower than those of the remaining pancreas.

In a study using intravoxel incoherent motion DWI, perfusion fraction may be a helpful parameter for differentiating focal pancreatitis from pancreatic carcinoma. The perfusion fraction was significantly higher in focal pancreatitis compared with that in pancreatic carcinoma, whereas true diffusion constant were not significantly different between two diseases. This was explained by increasing perfusion effects at lower b values, which was correlated with high vascularity in focal pancreatitis.

However, DWI alone is suboptimal for differentiating between focal pancreatitis and pancreatic carcinoma, and should be interpreted in conjunction with conventional MR imaging.

**Autoimmune pancreatitis**

Autoimmune pancreatitis (AIP) is a rare form of chronic pancreatitis and can be classified into two subtypes. "Classic" AIP (type 1 AIP) is also known as lymphoplasmacytic sclerosing pancreatitis (LPSP) is encountered most commonly in elderly patients and is more commonly associated with extrapancreatic manifestations as part of an IgG4-related sclerosing disease. In contrast, idiopathic duct-centric chronic pancreatitis (type 2 AIP) is seen in a younger population in comparison with patients with type 1 AIP, tends to have normal IgG4 levels, and can only be diagnosed by histologic findings including neutrophilic infiltration in the ductal epithelium with duct destruction, paucity of IgG4 cells, and characteristic ductal granulocyte epithelial lesions.

An accurate differential diagnosis between LPSP and pancreatic carcinoma is important to avoid unnecessary surgery, as LPSP responds dramatically to steroid therapy. The diagnostic criteria for LPSP included imaging findings (focal or diffuse enlargement of the pancreas and irregular narrowing of the main pancreatic duct), laboratory
findings (elevated serum IgG4 levels and autoantibodies), and histopathologic findings (lymphoplasmacytic infiltration with fibrosis around the pancreatic ducts). Among these criteria, imaging finding is the most important; the laboratory and pathology findings are sometimes nonspecific in cases of LPSP. However, type 1 AIP and type 2 AIP, especially in focal form is sometimes difficult to differentiate from pancreatic cancer, even with CT, MRI, and FDG-PET.

LPSP usually display hyperintensity on DWI with low ADC values due to dense infiltration of lymphoplasmacytes with inflammation, fibrosis, or edema. However, because both pancreatic carcinoma and AIP can cause focal or diffuse restriction, the value of DWI for differentiating these lesions is also limited. In a recent preliminary study, it was reported that LPSP could be useful for differentiating LPSP from pancreatic carcinoma. Diffuse or multiple high-intensity area or longitudinal high-intensity area might favor the suggestion of LPSP rather than pancreatic carcinoma, which usually showed solitary hyperintense area. Additionally, ADC values of LPSP were significantly lower than those of pancreatic carcinoma, which might reflect stronger diffusion restriction in LPSP with greater cellularity of lymphoplasmacytic infiltration in LPSP than that of pancreatic carcinoma. However, there was some degree of overlap of DWI finding for LPSP and pancreatic carcinomain our clinical experience. Thus, further studies in larger populations would be necessary to confirm these results.

DWI may also be useful for monitoring the effects of steroid treatment and for follow-up study. After steroid treatment, hyperintense areas on DWI were markedly decreased with improvement in pancreatic enlargement, and ADC values also returned to nearly that to normal pancreas.

Miscellaneous

Splenosis

Splenic tissue located outside Glisson's capsule usually represents splenosis afterautoimplantation of splenic tissue to exposed vascularized peritoneum after splenic rupture and splenectomy. Splenosis can be located anywhere in the abdominal cavity. Splenosis appears on conventional MR imaging as well demarcated ovoid or round nodules in the abdominal cavity, with signal intensity similar to that of the normal spleen. Spleen is the most restricted diffusion among upper abdominal solid organs. Therefore, splenosis appears hyperintense with low ADC values on DWI using high b values. Differential diagnosis between hepatic splenosis and hypervascular hepatic mass such as hepatocellular carcinoma or adenoma can be difficult on DWI. However, hepatic splenosis can be suspected in patients with history of splenic injuries or splenectomy, particularly in patients with splenic implants at the other sites and should undergo further investigations such as splenic scintigraphy in order to make a correct diagnosis.
**Intrapancreatic accessory spleen**

An accessory spleen is a congenital anomaly consisting of ectopic splenic tissue separated from the main body of the spleen; it occurs in approximately 10-30% of the population. The tail of the pancreas is the second most common site of an accessory spleen after the splenic hilum. The main clinical importance of intrapancreatic accessory spleen (IPAS) is to not IPAS for solid pancreatic tumor to obviate unnecessary biopsy or surgery and the associated increase in morbidity because it generally poses no clinical problem. Therefore, it is important to characterize IPAS and to differentiate these from solid pancreatic tumors as noninvasively as possible. On DWI, IPAS shows identical signal characteristics to those of the spleen in addition to conventional MR sequences, unlike the other solid pancreatic tumors.

**Pitfalls**

Normal hypercellular tissues sometimes exhibit restricted diffusion on DWI. Normal hypercellular tissues showing hyperintensity on DWI even with high b values are normal lymph node, small bowel mucosa, spleen, endometrium, and adnexa. Quantitative ADC measurement for differentiating between malignant and benign lymph node has been studied instead of visual DWI because normal lymph nodes may exhibit relatively restricted diffusion; malignant nodes have lower ADC values than benign lymph nodes. Nevertheless, its usability in routine clinical practice is limited as a result of significant overlap in ADCs.

Tiny hyperintense spots are sometimes detected on DWI that are difficult to correlate with structures on corresponding T1-weighted or T2-weighted images. Some of these foci may represent slow flow in small venules. Moreover, artifacts resulting from image ghosting, poor fat suppression, or susceptibility effects sometimes can be misinterpreted as disease.

Thus, radiologists must be aware of this potential pitfall, which may be partially solved using other conventional MRI sequences and clinical history.

**Images for this section:**
Fig. 1: Diffusion of water molecules. Highly cellular tissues with intact cell membrane restrict water molecule movement within intravascular, intracellular, and extracellular space. By contrast, less cellular tissues or damaged cells with defective cellular membrane increase extracellular space, which allow greater water molecule movement.
Fig. 2: Diagram of Diffusion-weighted imaging sequence
Fig. 3: Hepatic abscess in a 70-year-old women. (a) T2-weighted image shows a hepatic mass with a hyperintense cavity (arrow). (b) Contrast-enhanced T1-weighted image shows a hypointense mass with peripheral rim enhancement (arrow). (c, d) On DWI at b=1000 s/mm2 (c) and the ADC map (d), the center of the hepatic abscess reveals diffusion restriction (arrows).
Fig. 4: Eosinophilic infiltration of the liver in a 54-year-old woman. (a) T2-weighted image shows a focal, slightly hyperintense lesion with a fuzzy margin in the liver (arrow). (b) During the arterial phase of Gd-EOB-DTPA-enhanced T1-weighted image, the lesion shows homogeneous enhancement (arrow). (c) During the 20-min hepatocyte phase of Gd-EOB-DTPA-enhanced T1-weighted image, the lesion consists of a central isointense area with peripheral hypointensity (arrow). Size reduction in the hepatobiliary phase is noted compared with T2-weighted image. (d) On DWI at b=1000 s/mm², the lesion shows hyperintensity (arrow).
Fig. 5: Inflammatory myofibroblastic tumor of the liver in a 66-year-old man. (a) T2-weighted image shows a focal isointense mass with peripheral hyperintense rim in the liver (arrow). (b) During the equilibrium phase of Gd-EOB-DTPA-enhanced T1-weighted image, the lesion shows peripheral rim enhancement (arrow). (c) During 20-min hepatocyte phase of Gd-EOB-DTPA-enhanced T1-weighted image, the lesion shows mixed hypointensity (arrow). (d, e) On DWI at b=1000 s/mm2 (d) and the ADC map (e), the lesion shows diffusion restriction (arrows).
Fig. 6: Tuberculous granuloma of the liver in a 34-year-old man. (a) Heavily T2-weighted image shows a larger heterogeneous hyperintense mass (arrow) and a smaller homogenous hyperintense mass in the liver (arrowhead). (b) During 20-min hepatocyte phase of Gd-EOB-DTPA-enhanced T1-weighted image, the lesions show hypointensity (arrow and arrowhead). (c, d) On DWI at b=1000 s/mm² (c) and the ADC map (d), the periphery of the larger lesion shows diffusion restriction (arrows), and the smaller lesion shows homogeneous diffusion restriction (arrowheads).
**Fig. 7:** Hepatic sarcoidosis in a 31-year-old man. (a) Contrast-enhanced CT shows multiple tiny hypointense nodules in the liver (arrows). (b) On T2-weighted image, the lesions is not detected. (c) On DWI at b=500 s/mm², one of the lesions shows hyperintensity (arrow).

**Fig. 8:** Infected intrahepatic biloma after transcatheter arterial chemoembolization in a 58-year-old man. (a) Gd-EOB-DTPA-enhanced T1-weighted image shows a hypointense mass with peripheral enhancement (arrows). (b) On DWI at b=1000 s/mm², the periphery of the mass shows hyperintensity (arrows). (c) On cholangiography via the percutaneous transhepatic biliary drainage, communication between multiple intrahepatic bilomas and bile ducts is seen.
Fig. 9: Pylephlebitis in a 29-year-old woman with acute appendicitis. (a) Contrast-enhanced CT shows an enlarged appendix and appendiceal wall thickening with enhancement (arrow). (b) Contrast-enhanced CT shows hypodense foci of the intrahepatic portal vein (arrowheads). (c) On DWI at b=1000 s/mm², filling defects of the intrahepatic portal vein show hyperintensity (arrowheads).

Fig. 10: Acute cholecystitis with empyema in a 62-year-old man. (a) T2-weighted image shows diffuse gallbladder wall thickening, gallbladder distention (arrows), and increased pericholecystic fat strand. A fluid-fluid level with hypointensity in the dependent portion of the gallbladder (*) is noted. (b, c) The gallbladder wall (arrows) shows diffuse, symmetric hyperintensity on DWI at b=1000 s/mm² (b) with low ADC values (c). Pus in the dependent portion of the gallbladder (*) shows diffusion restriction.
Fig. 11: Xanthogranulomatous cholecystitis in a 55-year-old man. (a) T2-weighted image shows focal wall thickening with multiple hyperintense intramural lesions (arrows) in the fundal portion of the gallbladder. (b, c) This fundal portion of the gallbladder (arrows) shows hyperintensity on DWI at b=1000 s/mm² (b) with a low ADC value (c).

Fig. 12: Hemobilia in the gallbladder of a 77-year-old woman. (a) Non-contrast enhanced CT shows a hyperdense hematoma (arrow) in the gallbladder. (b, c) A hematoma in the gallbladder (arrows) shows hyperintensity on DWI at b=1000 s/mm² (b) with low ADC values (c) that is associated with intact red cell membranes in the hematoma.
Fig. 13: Clonorchis Sinensis infection in a 68-year-old man. (a) MRCP shows bile duct dilatation down to the level of the ampulla. (b) Contrast-enhanced T1-weighted image shows the bulging papilla with intense enhancement (arrow). (c) On DWI at b=800 s/mm², the papilla shows hyperintensity (arrow). (d) Photomicrograph (original magnification, ×100; hematoxylin-eosin stain) of the resected ampulla shows Clonorchis Sinensis (arrow) with inflammation in the ampulla (arrowheads).
**Fig. 14:** Acute pancreatitis in a 57-year-old man. (a) T2-weighted image shows diffuse enlargement of the pancreas (*) with peripancreatic fluid collection (arrowheads). (b) On DWI at 50 s/mm², the signal intensity of the pancreas is slightly hyperintense (*), compared with that of the liver. (c) On DWI at b=800 s/mm², the signal intensity of the pancreas is more hyperintense (*) than that of the pancreas on DWI at 50 s/mm² (* in b). (d) The ADC map reveals low ADC values in the pancreas (*).

**Fig. 15:** Mass-forming pancreatitis in a 56-year-old man (a) MRCP shows pancreatic duct dilatation, producing a beaded appearance (arrowheads). (b) T2-weighted image shows focal enlargement of the pancreas head (arrows). (c, d) On DWI at b = 800 s/mm², focal pancreatitis (c) shows hyperintensity (arrows). The remaining pancreas (d) is also slightly hyperintense (arrowhead). (e, f) On the ADC map, the ADC value of focal pancreatitis (arrows in e, 1.36± 0.16 s/mm²) is similar to that of the remaining pancreas (arrowhead in f, 1.48 ± 0.28 s/mm²).
**Fig. 16:** Autoimmune pancreatitis (type 2) in a 51-year-old man. (a) MRCP shows dilatation of the bile duct and main pancreatic duct. (b) T2-weighted image shows an ill-defined, mass-like lesion (arrows) in the pancreaticoduodenal groove and duodenum. (c) On DWI at b=800 s/mm², the lesion shows hyperintensity (arrows) in the pancreaticoduodenal groove and duodenum. (d) Photomicrograph (original magnification, ×400; hematoxylin-eosin stain) of the resected specimen shows granulocytic epithelial lesions, which are characteristic features in autoimmune pancreatitis type 2.
Fig. 17: Intrahepatic splenosis in a 56-year old man who had undergone splenectomy. (a, b) The arterial phase of the contrast-enhanced T1-weighted images shows a focal homogeneous enhancing hepatic mass (arrow in a). An enhancing mass in the splenic bed is noted, which is similar to the enhancement of the hepatic mass (arrow in b). (c, d) On DWI at b=800 s/mm², the hepatic mass (arrow in c) is hyperintense, which is a finding similar of that of the mass in the splenic bed (arrow in d).
**Fig. 18:** Intrapancratic accessory spleen in a 59-year-old woman. (a) Heavily T2-weighted image shows a focal mass in the pancreas tail (arrow) with similar signal intensity to that of spleen (*). (b) during the equilibrium phase of Gd-EOB-DTPA-enhanced T1-weighted image, the lesion shows homogeneous enhancement (arrow) similar to that of spleen (*). (c, d) On DWI at b=800 s/mm² (c) and the ADC map (d), the lesion shows diffusion restriction (arrow) similar to that of spleen (*).
Conclusion

Potentially, diffusion-restricted non-neoplastic conditions in the hepatobiliary and pancreatic regions are varied. False-positive DWI findings in benign lesions usually make it difficult to differentiate from malignant lesions. However, diffusion restriction in the benign lesions may provide additional information to the diagnosis. Diffusion restriction of hepatic abscess provides the additional clue to differentiate from malignant necrotic tumors. Diffusion restriction in the gallbladder lumen may aid to differentiate empyema from dense bile. Diffusion restriction in the portal vein may aid to differentiate pylephlebitis from bland thrombosis. In addition, DWI can monitor disease activity and treatment response of inflammatory or infectious disease in the hepatobiliary and pancreas regions.

In conclusion, knowledge of these DWI findings, combined with imaging characteristics that may be present on other conventional images, and correlation with the clinical history, will help narrow the differential diagnosis of malignant from benign lesions in the hepatobiliary and pancreatic regions to avoid misdiagnosis and potential unnecessary surgery.

Personal information

References

Inflammatory myofibroblastic tumor of the hepatobiliary system: report of MR imaging appearance in four patients.


