Japanese Journal of Gastroenterology and Hepatology

Review Article

ISSN: 2435-1210 | Volume 10

Magnetic Resonance Cholangiopancreatography (MRCP): Innovations in Non-Invasive Visualization of the Hepatobiliary and Pancreatic Systems

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Received: 12 Aug 2024

Accepted: 25 Sep 2024

Published: 30 Sep 2024

J Short Name: JJGH

Keywords:

MR cholangiopancreatography; Bile duct calculi; Bile duct neoplasms; Bile duct abnormalities; Pancreatic ducts

Citation:

Khan HU., Afef Ali Al Yafei FA. Magnetic Resonance Cholangiopancreatography (MRCP): Innovations in Non-Invasive Visualization of the Hepatobiliary and Pancreatic Systems. J Gastro Hepato. 2024; V10(12): 1-13

1. Abstract

Over the past two decades, magnetic resonance cholangiopancreatography (MRCP) has become more sophisticated. It contious to play a crucial part in the non-invasive study of numerous pancreaticobiliary diseases. The following review aims to provide readers with an overview of the fundamental concepts behind MRCP, the various methods now in use such as functional and secretin-stimulated MRCP), the pitfalls, and the primary clinical indications for its application.

2. Introduction

Magnetic resonance cholangiopancreatography (MRCP) is a unique method of magnetic resonance imaging (MRI) (Figure 1.1) exam that offers detailed images of the hepatobiliary and pancreatic systems. It is noninvasive procedure as it does not work on ionizing radiation but it is very important that the patient inform the doctor about any health problems, recent surgeries or allergies and if there is any chance of being pregnant as the high magnetic field might cause malfunctioning of some medical devices and cause thermal reaction of the body (Edwards, et al., 2012). There are several MRI compatible implants usually used but it is a must to inform the technologist as some might cause serious outcomes. Many MRI procedures have certain guidelines depending on procedure or patient condition (Baccarani, et al., 2013). It is very crucial to be aware of patients comfort and ask about their fear as some patients have claustrophobia and anxiety, and if the patients have such fears a mild sedative can be given on doctor's prescription. MRI produces a detailed picture of internal body structures as it uses powerful magnetic field, radio waves and a computer to evaluate the liver, gallbladder, bile ducts, pancreas and pancreatic duct for diseases as seen in Figure 1.2 (Al-Dhuhli, 2009). MRCP results images with high temporal and spatial resolution leading to successful application in various clinical environments. Furthermore, MRCP has gained approval as most consistent alternative to direct cholangiography in depicting the biliary system.

Figure 1.1 MRCP/Open MRI.

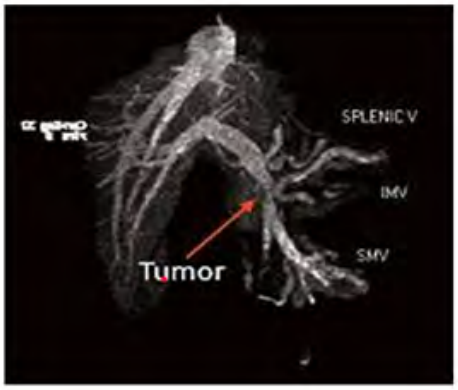


Figure 1.2 Arrow shows a pancreatic tumor on MRCP scan

3. Liver MRCP: Anatomy and Physiology

Imaging of the bile duct system is also known as cholangiography. The bile ducts are located inside and outside of the liver. The bile is produces by the liver, stored in the gallbladder, and carried by the bile duct and it is carried through the pancreas to the duodenum, which is a small part of the small intestine. Bile is secreted in repose to digest the fats and it is a dark green or yellowish-brown fluid, furthermore, the gallbladder releases bile to help in digestion and fat absorption as shown in Figure 2.1. Bile is a dark-green or yellowish-brown fluid secreted by the liver to digest fats. Live also function as the route of excretion for bilirubin, recycle or produce the byproduct of the old red blood cells and remove the waste products (Al-Dhuhli, 2009).

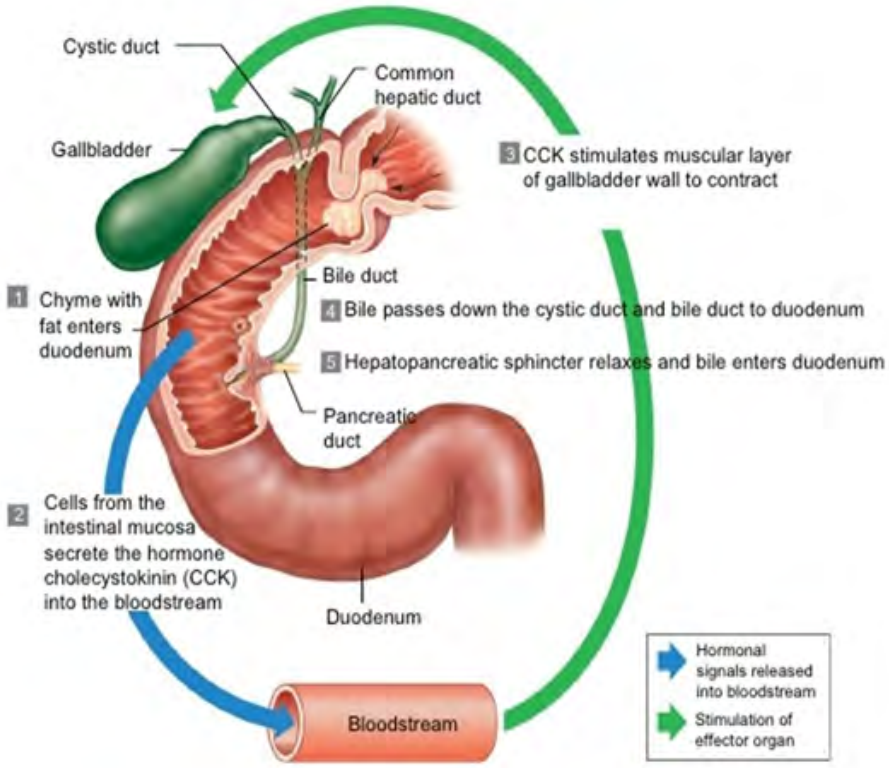


Figure 2.1: illustration of the regulation and production of bile.

MRCP is usually used when the patients tackle pathological conditions such as Obstruction of the bile duct or Pancreatic duct, which leads to narrowing of the ducts. It has been almost two decades since MRCP was applied in practice field (Edwards, et al., 2012). As mentioned, MRCP is the alternative method to cholangiography, as it uses strong magnetic radio waves, it is a repeatable and reproducible procedure, and has been approved highly accurate in identifying biliary abnormalities noninvasively. Tumor, jaundice, pancreatitis (inflammation of the pancreas), liver disease and upper abdominal pain are some common pathologies leading to MRCP (Baccarani, et al., 2013).

4. Equipment and Patient Care

Patient presenting to the MRI department for liver imaging often require special attention. To ensure patient's safety, patient's history such as: previous surgery, and metal implants or other metals in their body, should be taken into consideration as during the procedure the strong magnetism from the MRI machine could affect any metal including.

- Pacemakers, Wires and Defibrillators,
- Surgical Clips,
- Pins, Plates and Screws,
- Cochlear Implants,
- Dental Fillings, or
- An injury that caused metal fragment in anywhere in the patient's body.

However, in some cases, patients with metallic implants will not be prohibited from doing scan and that depends on the doctor and radiographer to take the decision whether it is safe for the patient or not.

Moreover, any foreign bodies with the eyes and in rare cases, tattoos, which may contain small amounts of metals in the ink, could be affected by the temperature of the MRI machines during the scan and can lead to severe consequences such as blindness due to wearing lenses.

For an MRCP of children, movement maybe frequent and therefore, during the procedure they might be sedated. In such cases, and for any unconscious patient, a pulse oximetry will be attached to the patient's fingertip to monitor the oxygen saturation.

Claustrophobic patients, who are afraid of confined places, must contact the department before the time of test so that the required steps will be taken. The doctor can give a medicine to help the patient to relax at the time of procedure.

In addition, MRI is considered typically safe during pregnancy; however it is contraindicated during the first three months of gestation.

5. Patient Preparation

- Patient preparation for an MRCP include:
- The patient must present for an MRCP examination fasting, not eating nor drinking, for four to six hours prior the examination.
- Before going into the scan room, the patient will sign a satisfactory written consent form, and the technologist will explain the procedure and answer any patient's questions.
- Then, the patient will be asked to get unchanged and wear a hospital gown.
- The patient's weight will be weighted down.
- The patient will also be asked to remove all metallic items including his/her keys, coins, cards with magnetic strips, wallet, coins, jewelries such (such as: necklace, earrings, etc.), hairpins, and hearing aids if present.
- After positioning the patient, the MRI technologist will practice with the patient the breathing techniques two to three times before beginning the scan. Then he/she will instruct the patient to hold their breath for the breath hold scans and breathe gently for the gated scans.
- A member of the staff or a relative maybe allowed entering the scanner room if the patient was Claustrophobic.
- Before leaving the room, the technologist will provide the patient with headphones for communication purposes as well as ear protection.

6. Patient Positioning

- After making sure that the patient is prepared well, the patient will be positioned, on a movable exam table, supine over the spine coil with the head resting on pillow and pointing toward the magnet and will be secured with straps and bolster to maintain the position.
- The body coil will be placed over the upper abdomen as shown in Figure 3.2.1, and exactly it'll be positioned from the top at the nipple and the iliac crest at the bottom. To prevent motion artifacts from breathing, the coil will be tightened well using straps.
- The patient's leg will be resting on cushions to make the patient as comfortable as possible.
- Finally, the laser beam localizer will be centered over the xiphoid process of the sternum.

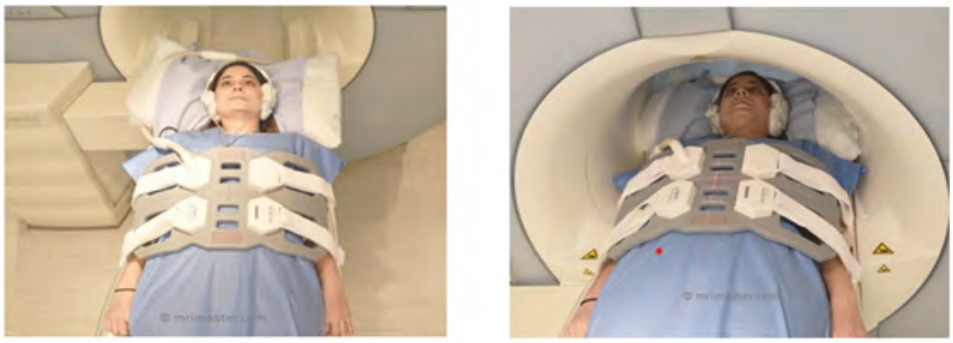


Figure 3.2.1: illustration of the placement of body coil over the upper abdomen.

7. MRCP Sequences and Planning

7.1. Localizer

According to Mohamed Gause, a senior radiographer and trainer in ADNEC, three planes true FISP localizer must be taken initially and plan sequences as shown in Figure 4.1.1. These are fast single shot localizers with under 25s acquisition time which are excellent for localizing abdominal structures.

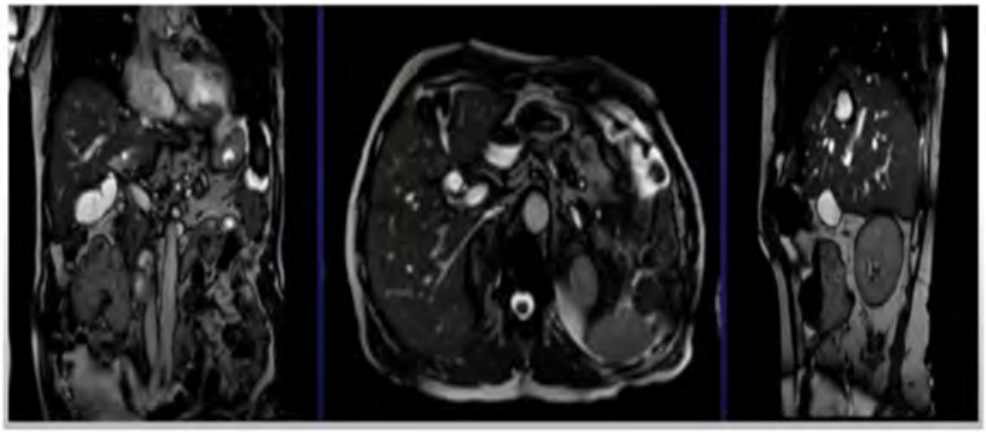


Figure 4.1.1: Figure illustrates the planning of true FISP localizer

7.2. T2 TRUEFISP FAT SAT (or haste) 4mm breath hold coronal

Radiographer then will plan the Coronal slices on the axial localizer by positioning the block across the liver as shown in Figure 4.2.1 Mainly to cover the whole liver from the anterior abdominal wall to the posterior abdominal wall. To avoid artefact patient should be instructed with proper breathing technique in addition the use of phase oversampling.

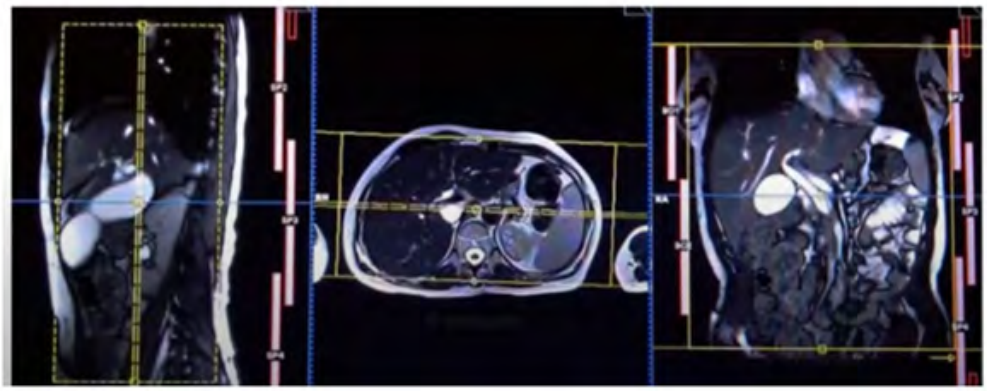


Figure 4.2.1: The images show locating of the block across the liver.

7.3. T2 HASTE FATSAT AXIAL (4 mm on CBD)

Radiographer will plane the axil slices on the coronal TRUFI image and position the block across the liver as shown in Figure 4.3.1. Biliary system from the diaphragm down to the C loop (Figure 4.3.2) of the duodenum with proper breath hold technique keeping 2mm thick slice in axial plane.

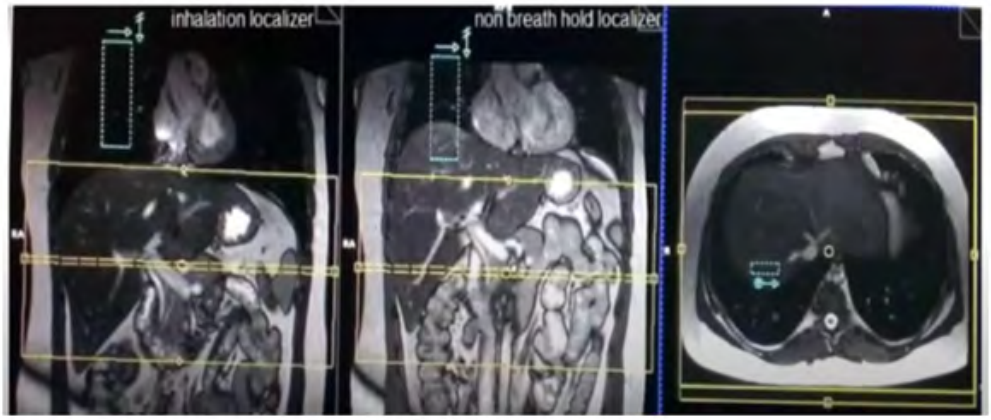
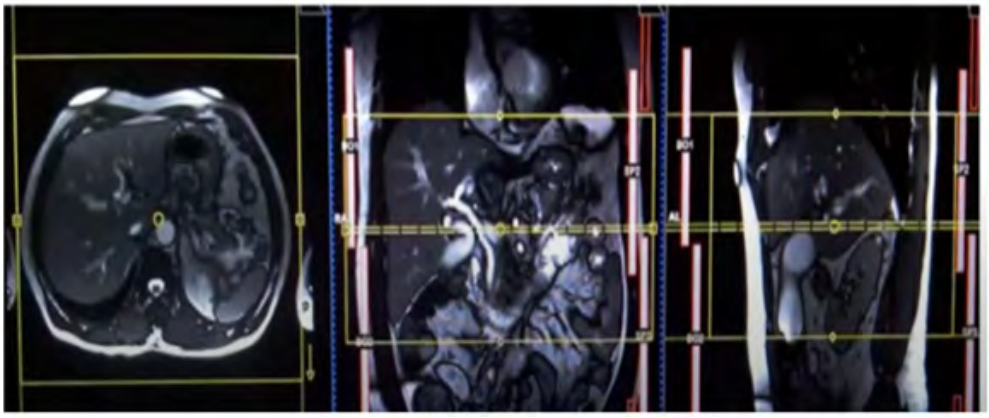


Figure 4.3.1: The image illustrates the block locating across the liver.

The liver will be pushed done while breathing, so it is important to plan the slice during the breath hold.



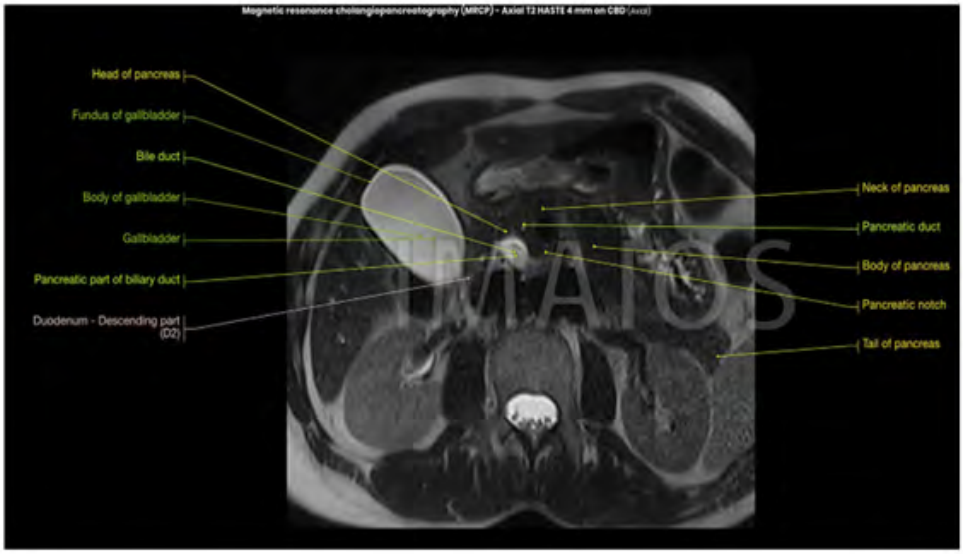


Figure 4.3.2: Magnetic resonance cholangiopancreatography (MRCP): Axial T2 HASTE 4 mm on CBD (Bile duct)

7.4. T2 TRUE FI AXIAL

This sequence requires long echo times to illustrate the fluid collection in the biliary ductal system, which will represent high signal intensity, however the background signals will be suppressed.

7.5. T2 HASTE 4O MM CORONAL OBLIQUES (Single slice)

Coronal oblique (LAO) is planned on axial TRUFP, a thick slab will be placed across the bile duct with 20-30 degree rotation to include the gall bladder. Phase oversampling must be used to avoid wrap around artefacts. Instruct the patient to hold their breath during image acquisition as shown in Figure 4.5.1.

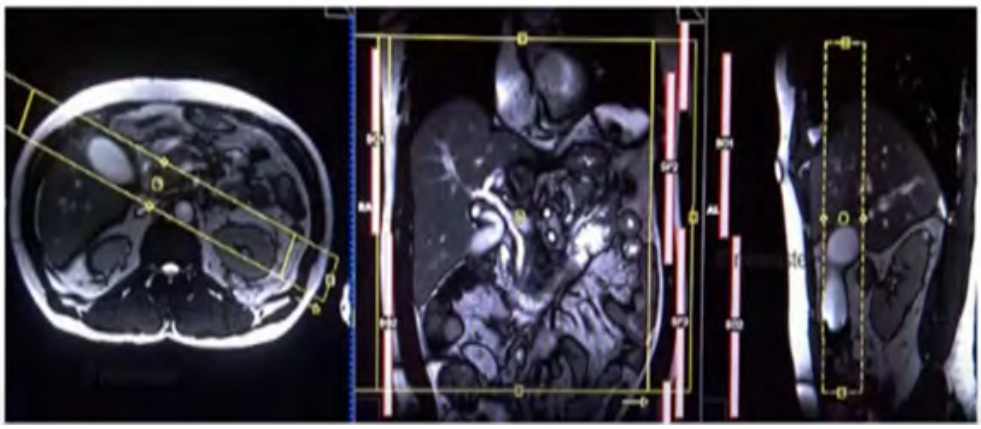


Figure 4.5.1: Image illustrate the planning of slices.

7.6. T2 TSE 3D (or SPACE 3D) CORONAL GATED within 1.5 mm

Plan the coronal 3D on the axial TRUFI (or HASTE), then position the block over the bile duct. The slice should be planned to cover the entire common bile duct, pancreatic duct and gallbladder. Respiratory gating navigator should be used to cover the area between the dome of diaphragm and the right lobe of liver, moreover, the planning has to done while patient hold their breath as the liver will be pushed during inhalation and reduce the occurrence of artifact caused by swallowing. According to (Antoine, et al, 2020) for evaluating any focal pathology without any IV contrast Axial T1 VIBE FS: A 3D fat suppressed T1-weighted GRE sequence can be performed.

7.7. T2 thick slab 4 mm vibe FS AXIAL

A fat saturated HASTE sequence where a single slab of data 4 cm in thickness is acquired in a 1- to 2-s breath-hold in 3 different coronal planes. MIP images have also displayed.

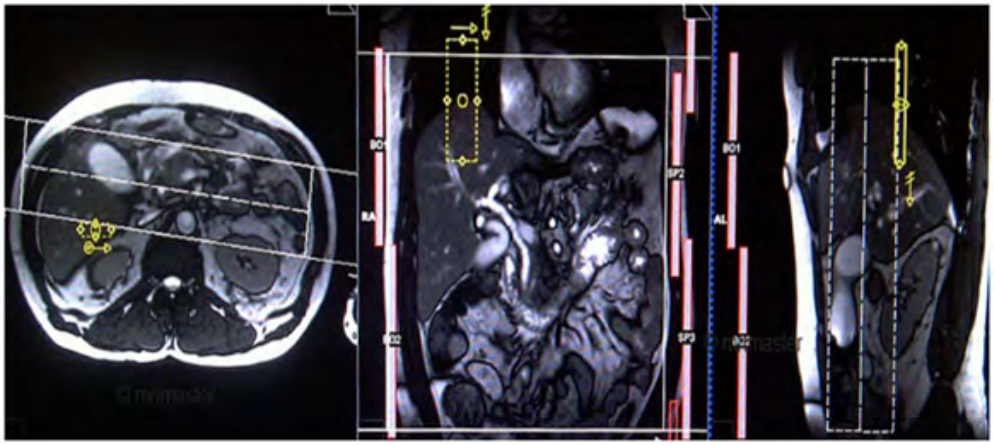
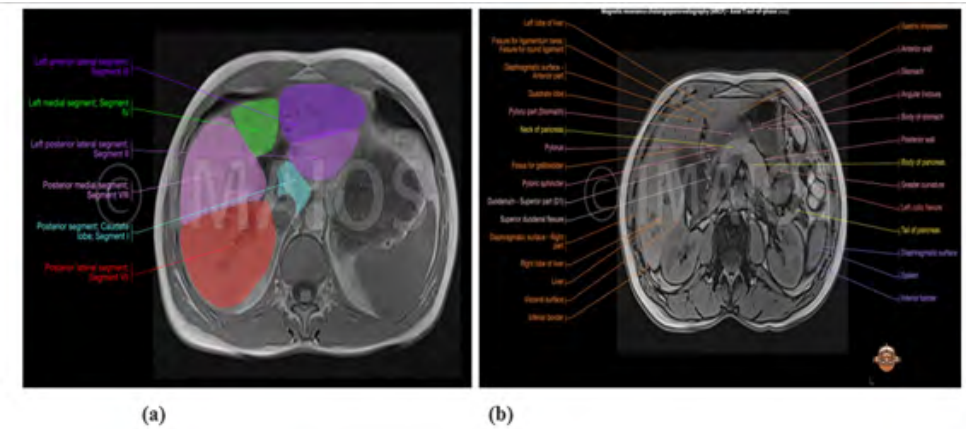


Figure 4.7.1: MRCP thick slab: Cystic duct, Bile duct, Pancreatic duct, Gallbladder. (Antoine, et al, 2020)

7.8. T1 Axial T1 in-phase and axial T1 out-of-phase (for Liver)

Conventional abdominal MRI imaging to study extra ductal structures (hepatic segments, pancreas, spleen, kidneys).



(a) (b)

Figure 4.8.1. a: Axial T1 in-phase: Hepatic segmentation.

Figure 4.8.1.b: Axial T1 out-of-phase: MRI - Liver – Pancreas (Antoine, et al, 2020)

7.9. T2 TSE axial

T2 Turbo Spin Echo is usually performed to cover the liver entirely and illustrate pathology.

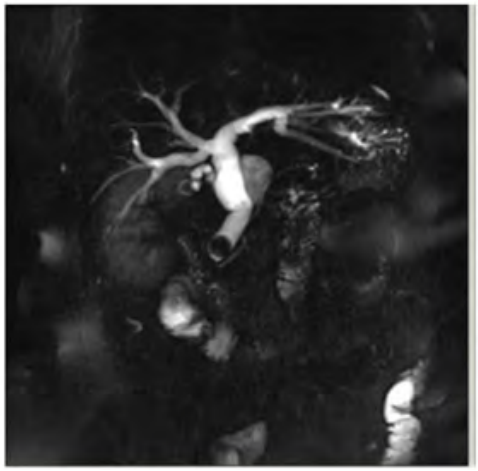


Figure 4.9: Image Illustrating stone at the bile duct

7.10. T2 GE axial

This sequence is Similar to the T2 TSE sequence as it will allow more information in regards to the potency of the bile ducts

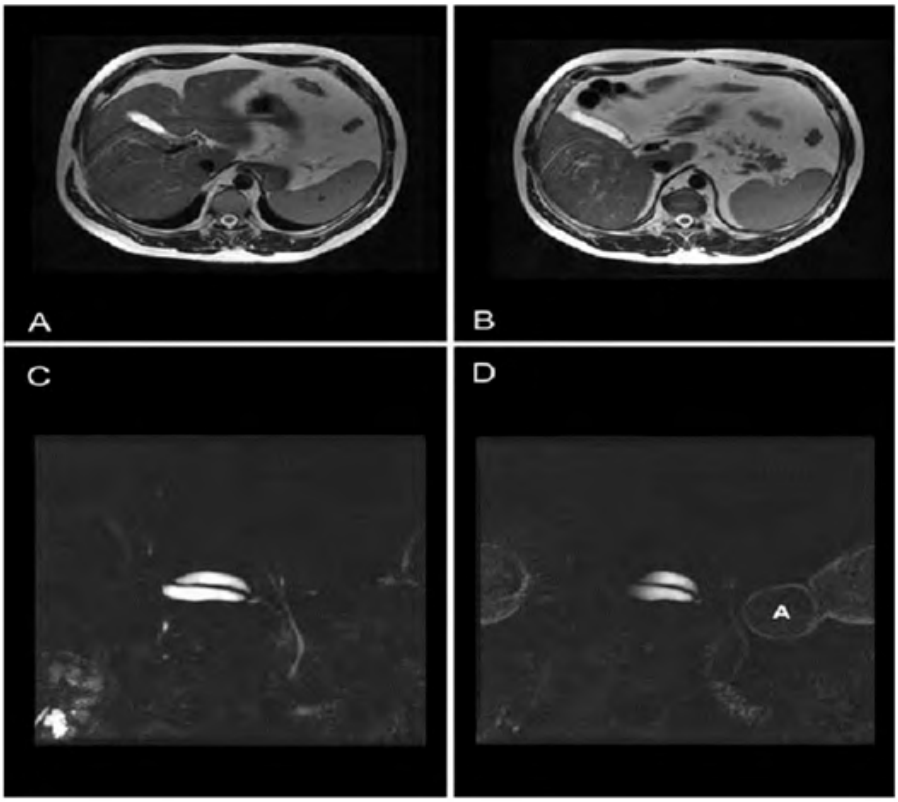


Figure 4.10: T2 weighted image illustrating the superior portion of the hepatic hilum

7.11. T1 axial 3D

In this sequence the imaging of the entire liver is made compulsory to demonstrate the anomy

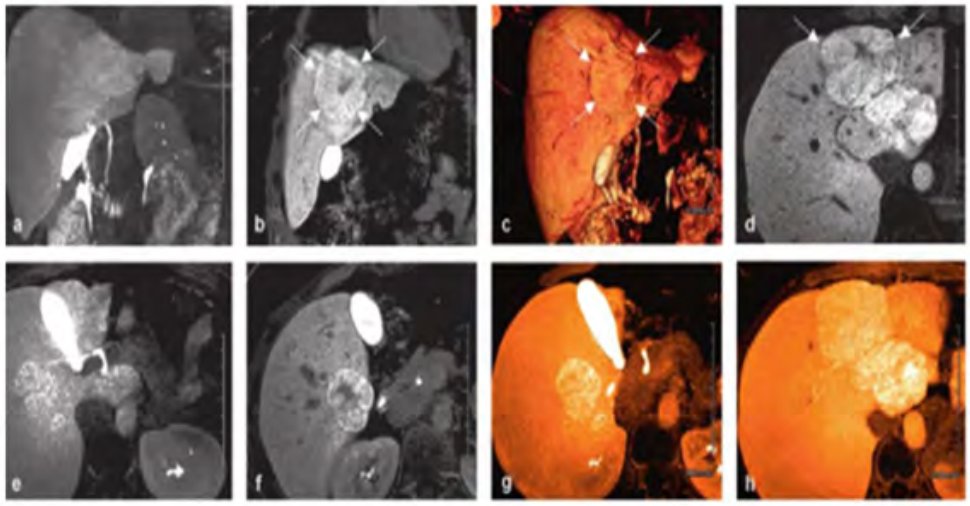


Figure 4.11: The image illustrates the 3D anatomical view of the whole liver

7.12. T2 GE coronal oblique

To cover the entire length of the bile duct these images are usually taken obliquely. These images should be heavily taken in T2 weighting as the duct will be imaged with high signal.

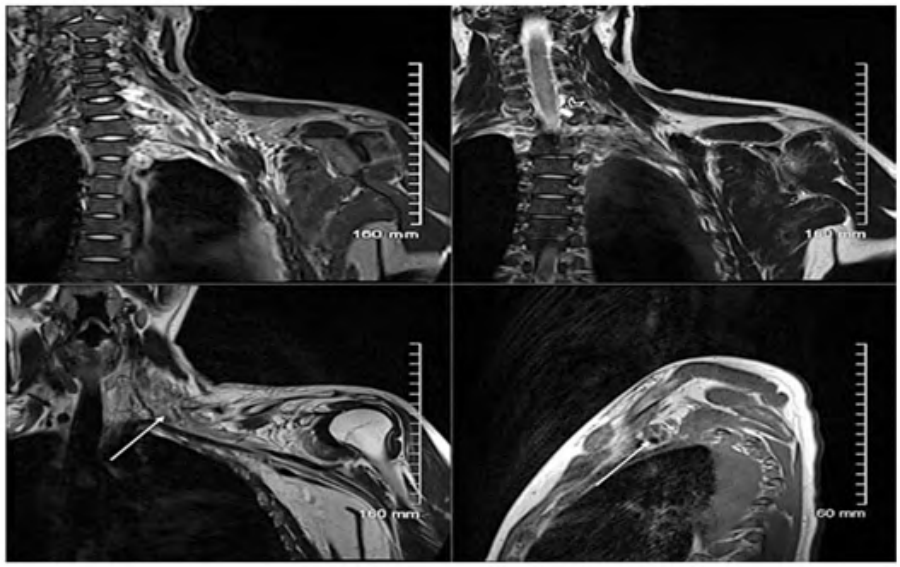


Figure 4.12: T2 GE coronal oblique view of a trauma patient

8. Techniques and Parameters:

	TR	TE	FLIP	NEX	SLICE	MATRIX	FOV	PHASE	OVERSAMPLE	TRIGGER
T2 FAT SAT (or haste) 4mm breath hold coronal.	4-5	2-3	10	1	3mm	256x256	350	R to L	50%	On
T2 HASTE FATSAT AXIAL.	1000-1500	100	150	1	4MM	320X320	400-450	A to P	50%	off
T2 HASTE 4O MM CORONAL OBLIQUES (Single slice).	1000-1500	100	150	1	4MM	320X320	400-450	R to L	50%	On
T2 TSE 3D (or SPACE 3D) CORONAL GATED.	2000-3000	200	12	1	1MM	320X320	350	R to L	50%	On

Table 5.1: Technical parameters for MRCP sequences (Antoine, et al, 2020)

Table 1.1 Magnetic resonance cholangiopancreatography: type of sequence and parameters employed

Sequence parameter	SS-FSE	Multislice T2-HASTE	3D-TSE
TR	∞	∞	Approximately 4 s (depending on patient's respiratory cycle)
TE (ms)	985	66–75	655
FOV (mm)	350	380	300
Slice thickness (mm)	60	6–8	1.3
Number of slices	1	36	40
Matrix	512×512	320×320	384×384
Time of acquisition	0.5 s	2 (18) s	3–5 min
Respiratory acquisition mode	Breath-hold	Breath-hold	Respiratory gating

FOV field of view, *HASTE* half-Fourier acquisition single-shot turbo-spin-echo, *SS-FSE* single-slice fast-spin-echo, TSE turbo-spin-echo

9. Clinical Indications of MRCP & Their Appearances on MRCP

9.1. Biliary Diseases

- Choledocholithiasis
- According to (Tangella, 2018), for any suspected gallstones being lodged in the biliary system, a CT scan and an Ultrasound Sonography Test will initially be performed.
- The appearance of the stones on MRCP are a signal void in a hyperintense bile. MRCP determines the size, number and exact location of the stones and with recent advances, stones as small as 2mm can be detected.

Figure 6.1.1: Magnetic resonance cholangiopancreatography (MRCP) image shows the presence of two gallstones (White arrow) on a heavily T2 - Weighted sequence of bile duct. (Tangella, 2018).

- Congenital Variants
- MRCP is a technique that well demonstrates any variations in the branching of the Intrahepatic Bile Ducts, which is an abnormality occurring in 37% of people.
- MRCP is also able to detect Cystic Duct anomalies. (Hussain, et al, 2004)MRCP is useful for visualizing accessory right and left hepatic ducts.

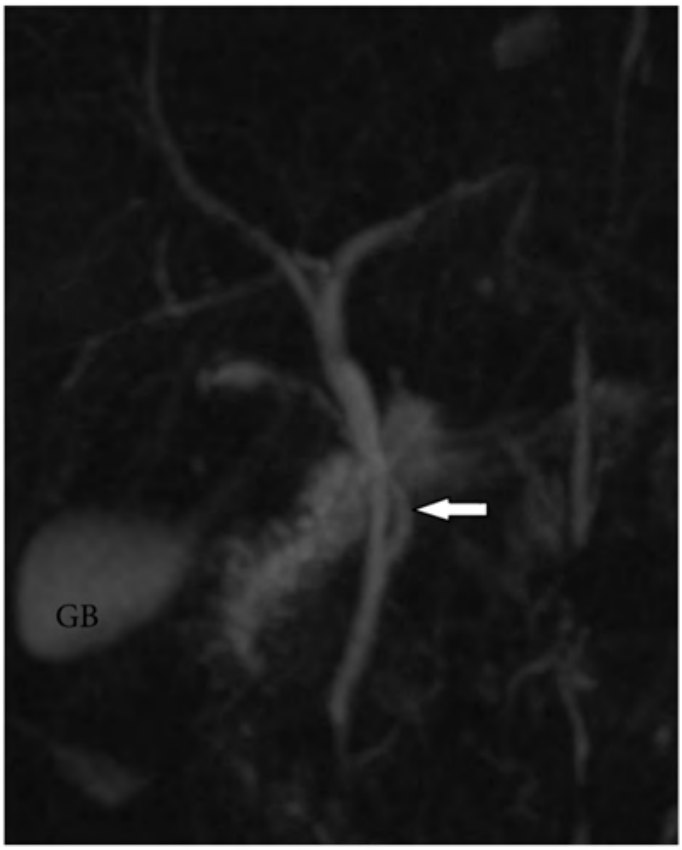


Figure 6.1.2: The white arrow on the MRCP 3D Coronal Oblique arrow demonstrates the cystic duct spiral course and its medial insertion with common hepatic duct. (Hussain, et al, 2004)

- Cholangiocarcinoma
- The presence and level of neoplastic obstruction of pancreatobiliary tract can be accurately identified on MRCP.

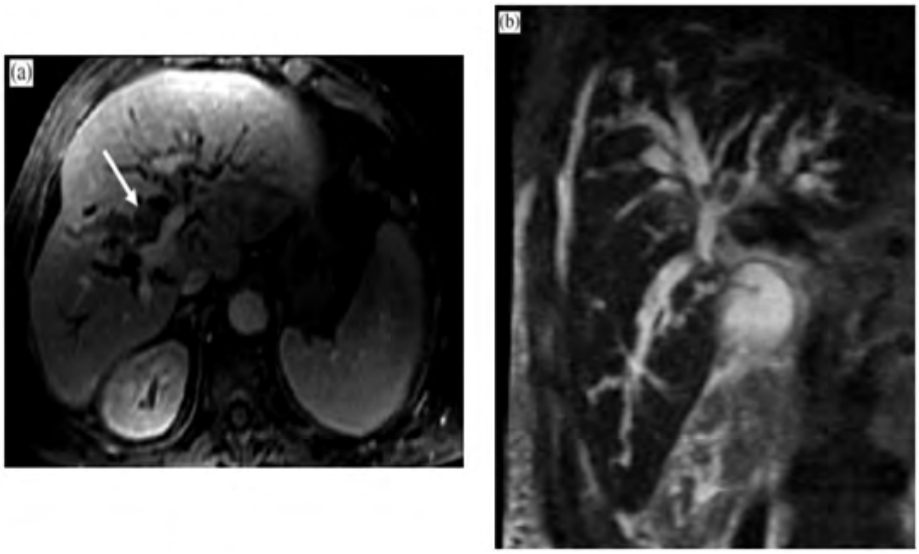


Figure 6.1.3 (a): reveals an Intraductal Cholangiocarcinoma (white arrow) which appears as a fiiling defect on **(b)** Coronal T2 - Weighted SSFSE MRCP. (Mukund, 2017)

- Post Operative Biliary Complications
- MRCP usefulness as discuused by (Radiol, 2013), has been demonstrated in the evaluation of surgical complications of the pancreatobiliary tract such as:
- Biliary - Enteric Anastomoses
- Pancreatoenteric Anastomoses
- Duct - to - Duct Anastomoses
- In addition to the alteration, it also reveals complications such as:
- Intradural Stone Formation
- Strictures
- Anatomical Leak

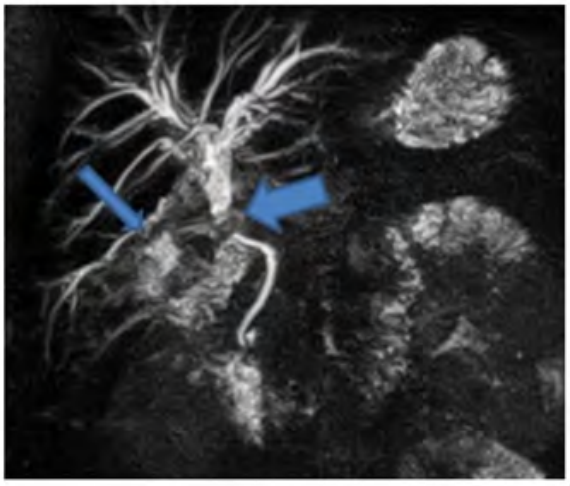


Figure 6.1.4: 3D MRCP image of transected segment of common bile duct along with biliary leakage (Thin blue arrow) in an oblique coronal plane. (Radiol, 2013)

9.2. Pancreatic Diseases

- Cancer of the Pancreas
- (Bridges, 2015) has mentioned that MRCP is useful in detecting if there is a mass obstructing the ducts and localizes the obstruction in relation to pancreas.
- In cases of mass in pancreatic head, "Double Duct Sign" will be observed. However it's worth mentioning that this sign is not only specific for this pathology as it may occur in chronic pancreatic.
- Chronic Pancreatitis

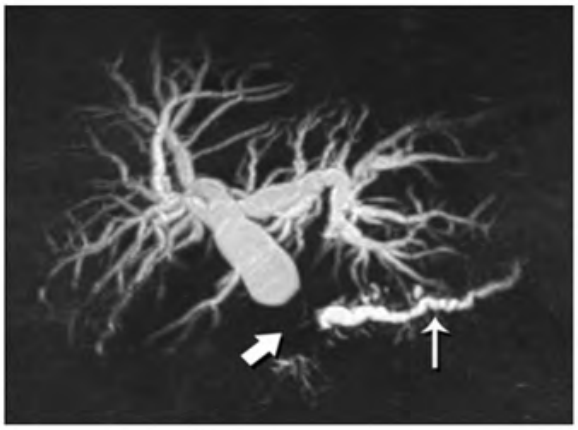


Figure 6.2.1: Maximum Intensity Reconstruction of 3D MRCP showing the "Double Duct Sign". Dilated bile and pancreatic ducts at pancreatic head demonstrated on MRCP with an abrupt termination, which is the classical sign for the presence of carcinoma at the pancreatic head. (Bridges, 2015).

- MRCP performed when ERCP is contraindicated in detecting acute pancreatitis.
- Any dilation, stones, strictures and thoracopancreatic fistulas, which are considered to be common ductal manifestations of chronic pancreatic, can be detected using MRCP. (Yang, et al, 2013)

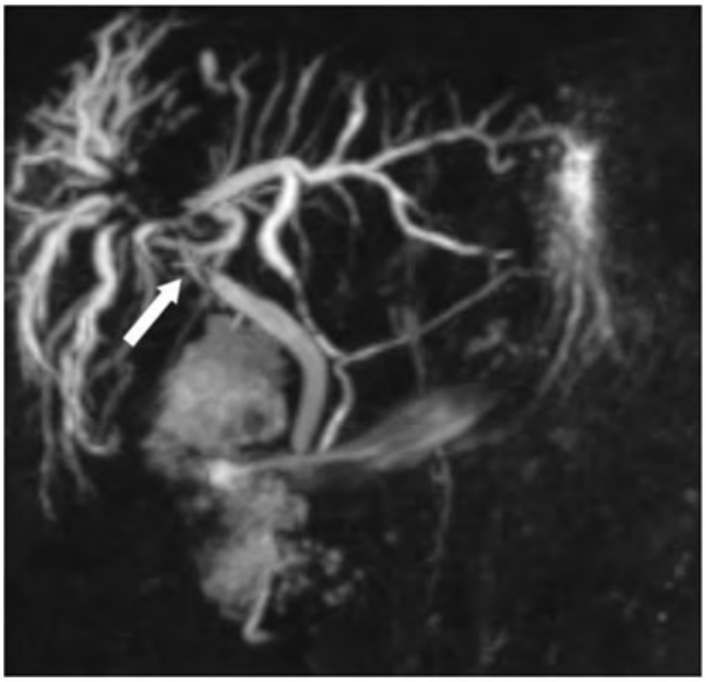


Figure 6.2.2: Demonstrates chronic pancreatitis of a 33-year-old male patient on a Respiratory gated 3D T2 - Weighted TSE sequence. (Yang, et al, 2013)

- Pancreatic Divisum
- 5.5% - 7.5% of people are affected with this disease. (Adatepe, et al, 2017)
- Accounts for upto 14% of pancreatic variations.
- Anterior and posterior portions of the pancreas fail to fuse and therefore resulting in two separate drainage pathways for pancreatic secretions.

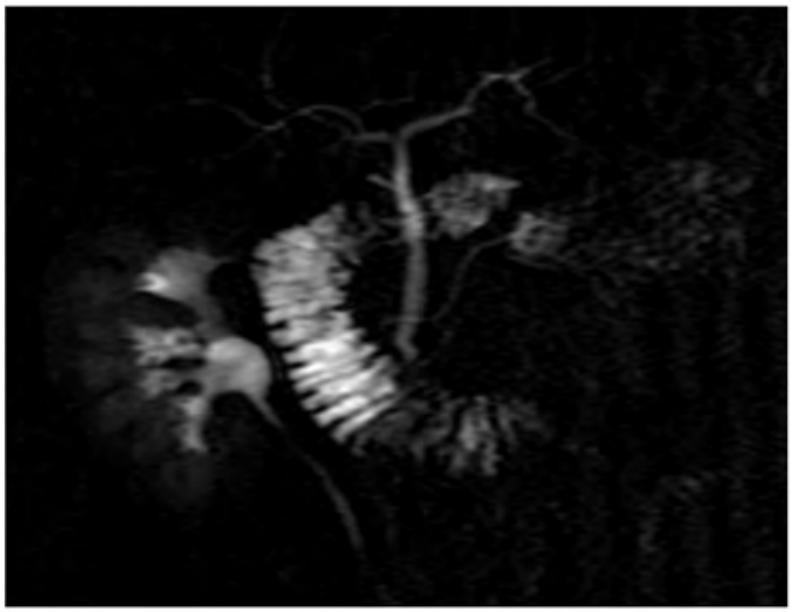


Figure 6.2.3: MRCP of a 30-year-old female patient diagnosed with Pancreatic Divisum on a T2 - Weighted Long TE SS-FSE Thick Slice sequence. (Adatepe, et al, 2017)

10. Contraindications of MRCP

- MRCP is contraindications include:
- Implanted Mechanical Devises (E.g. Cardiac Pacemakers, Insulin Pumps Biostimulator, Neurostimulators, Cochlear Implants, and Hearing Aids).
- First Trimester of Pregnancy
- Intracranial Aneurysm Clips (Unless made of titanium).
- Ferromagnetic Surgical Clips or Stapes
- Metallic Foreign Body in the Eyes
- Metal Shrapnel or Bullet.

11. Limitations of MRCP (TK, 2018)

- According to (TK, 2018) MRCP is restricted with several Limitations including:
- Patients with pacemakers, aneurysm clips, etc.
- Claustrophobic patients.
- Pulsation artifacts from hepatic artery, which may be mistaken for common duct stricture.
- MIP slabs overestimates severity of biliary stenosis.
- Incorrect choice of ROI.
- Fluid in duodenum may mask the common duct if negative contrast was not used.
- Interpretation may be stopped when ampullary regions are poorly visualized.

12. IV Contrast/Volume

According to sixth study guide on the chest, abdomen and pelvis, MRCP protocol very rarely requires IV contrast. If it t does so, for examinations of the live either will be swallowed or injected into the bloodstream. MRI technologist may ask patient have allergies of any kind of drugs or food. Nevertheless, contrast that used for an MRI are Gadolinium. It is important to use the correct type of volume and rate of gadolinium MRA. It is also vital to introduce a correct amount of contrast media at ideal time to get an ideal diagnostic image with a faultless bolus geometry. However, contrast volume of 20 mL is injected via the pressure injector at flow rate of minimum 2.5 mL. It is most likely use to rule out hemangioma in liver. Venous, arterial and portal phases are utilized. However, volume of 20 mL. Hepatobiliary-specific contrast agents allow for accurate and extensive study of biliary tract alterations, especially in assessing postsurgical complications.

13. Conclusion

Hopefully, we have demonstrated the differences in patients who present for MRCP exams and the sequences that are more commonly used to demonstrate the various pathological presentations. One of the main points to take home with all MRI imaging is comfort and the importance of the patient remaining still. The MRCP may be uncomfortable and may often be unable to get comfortable so it is important to take time to give a thorough breath hold instructions otherwise movement is inevitable. Area coverage should include the liver, GB, biliary system and pancreas laterally and often the region that has been requested, not just the individual pathological.

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