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RESEARCH ARTICLE

MR CHOLANGIO-PANCREATICOGRAPHY AS A TOOL FOR EVALUATION OF PATIENTS WITH PANCREATICOBILIARY DISEASES

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Abstract

Objectives Of Study:
1. To describe features of pancreaticobiliary diseases on MRCP.
2. Outlining the extent in terms of involvement of adjacent structures, vessels and soft tissues.
3. To help in deciding further course of management.
4. To identify the anatomical variants.
5. To prove the Magnetic Resonance Cholangio-Pancreatography (MRCP) is one of the best imaging modality for evaluation of pancreatico-biliary disease.

Material And Methods: The present study was undertaken to evaluate the role of MRCP in evaluation of pancreaticobiliary diseases. The study will be done on patients presenting with features suggestive of pancreatico-biliary diseases attending the OPD or admitted in various wards of Krishna Rajendra hospital, Mysore attached to Mysore Medical College & Research Institute, Mysore. A total of 30 patients were included in our study.

Result: Majority of patients in study population were males (60%) while 40% were females. The mean age of the study sample was 37.5 years and maximum numbers of cases were observed in age group of > 40 years. Majority of pathologies observed were benign 18(60%). Pancreatitis was the most common finding (33.3%) followed by Cholangiocarcinoma (20%), Choledocholithiasis (13.4%), Periampullary carcinoma (10%), Ca. Pancreas (6.7%) & Choledochal cyst (6.7%).Pancreatitis is common in males followed by Cholangiocarcinoma, which is common in both males & females.Both benign & malignant strictures have equal predominance. Both benign & malignant strictures are common in proximal CBD.

Conclusion: MRCP is non-invasive, non-ionizing imaging method for evaluation of pancreatico-biliary anatomy and pathology. It is superior diagnostic modality in detection and characterization of pancreatico-biliary pathologies.

Introduction:-

Biliary obstruction may be due to a variety of causes including choledocholithiasis, tumors, & trauma, including injury after gall bladder surgery, with choledocholithiasis being the most common cause. Patients with suspected

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biliary obstruction present with abnormal liver function & symptoms such as jaundice, pale-colored stools, dark urine, itching, right upper quadrant pain, fever, nausea & vomiting. Initial imaging of patients with suspected acute biliary disease (including gall bladder disease) should be performed primarily with US which has a sensitivity for pathologic processes of 83% [1].

US is the first line imaging investigation in patients with jaundice or right upper quadrant pain. Although US is non-invasive, quick & inexpensive, it is very operator & patient dependent. It has limitations especially in the evaluation of distal common bile duct where bowel gas, debris, fluid in the duodenum & obesity can degrade the image quality [2].

Although CT is not the best technique for imaging choledocholithiasis, it is frequently performed for the assessment of jaundice. Widely variable sensitivities have been reported, ranging from 20 to 78%. CT also has its fair share of limitations, especially in demonstrating important pathology, biliary stones. CT has a sensitivity of only 90% for detecting biliary stones [3,4]. Stones having high cholesterol content may be missed as their attenuation resembles fluid; as a result, they are difficult to separate from bile. Mixed stones also may be difficult to detect on CT as they present as soft tissue density; this soft tissue density may merge with the pancreatic parenchyma thereby decreasing the sensitivity of CT.

Endoscopic retrograde cholangiopancreatography (ERCP) is currently the ‘gold standard’ for the diagnosis of biliary obstruction. It is one of the several invasive direct cholangiography techniques. However, it is an imperfect diagnostic tool & other procedures may be more appropriate gold standards for diagnosis in the future [5]. ERCP is a very operator dependent & invasive procedure & it is associated with 1 – 7% related morbidity & 0.2 – 1% mortality [6].

Neoplasms of the bile & pancreatic ducts present major challenge both for diagnosis & treatment. These tumors may arise primarily from the ducts or may involve the pancreatico-biliary tree secondarily by extension from metastatic tumors of the liver, gall bladder, pancreas or adjacent lymph nodes. Before definite therapy, knowledge of the level of obstruction & its cause is essential [7].

In view of limitation of US & CT & invasiveness of PTC, IVC & ERCP, there is a need for an imaging modality which in noninvasive & provides high resolution projection images of the biliary & pancreatic duct.

Magnetic Resonance Cholangiopancreatography(MRCP) is a noninvasive diagnostic technique that was developed for the visualization of the biliary & pancreatic ducts. Its use was first reported in 1991, & since then the method has evolved along with the advances in MRI hardware & imaging sequences [8]. MRCP is an alternative to diagnostic ERCP for imaging the biliary tree & investigating biliary obstruction. MRCP does not expose the patient to the risks associated with ERCP or PTC. These can occur in up to 5% of ERCP procedures [9]. In addition, there is no use of ionizing radiation or iodinated contrast agents. It has, therefore, become the investigation of choice for many conditions when evaluating pancreatico-biliary ductal disease.

Invasive cholangiography remains the investigation of choice when intervention is required. MRCP is particularly useful in patients with complete biliary obstruction after biliary-enteric anastomosis, where ERCP is frequently not feasible, or in patients for whom ERCP or PTC has failed or unsuitable [10].

MRI plays a vital role in diagnosing may conditions of the pancreatico-biliary tract. On MRI, Primary Sclerosing Cholangitis (PSC) shows several characteristic features including bile duct abnormalities & increased enhancement of liver parenchyma. Wall thickening & enhancement of extrahepatic bile duct are also common MRI findings in patients with PSC [11]. Acute pancreatitis can be distinguished from chronic pancreatitis from that due to pancreatic carcinoma [12]. MRI can depict the extent of gall bladder carcinomas & can contribute to the staging of this disease [13]. It is a non-invasive, non-ionizing imaging modality & is unaffected by bowel gas shadow as in US.

With the development of higher magnetic field strength & newer pulse sequences, MRCP with its inherent high contrast resolution, rapidity, multiplanar capability & virtually artifact free display of anatomy & pathology in this region is proving to be examination of choice in patients with pancreatico-biliary diseases [14].

This imaging technique is able to create projectional type images similar in detail & appearance to direct cholangiography. It avoids the use of intravenous (IV) contrast & ionizing radiation & its relatively operator independent. Several recent studies have demonstrated that MRCP is able to accurately identify CBD stones with sensitivity of 81 – 100%. Biliary strictures can also be visualized with sufficient anatomic detail to determine the level of obstruction & in some instances, differentiate benign from malignant causes.

MRCP has potentially two major advantages in neoplastic pancreatico-biliary obstruction. Firstly, MRCP can directly reveal extraductal tumor whereas ERCP depicts only the duct lumen. Second, MRCP lacks the major complication rate of approximately 3% associated with ERCP such as sepsis, bleeding, bile leak & death [14].MRCP is being used with increasing frequency as it is noninvasive procedure. It has high accuracy, and involves no ionizing radiation. Major limitation of MRCP is that it is not easily available and it is costly.

Overall the purpose of this study will be to prospectively assess the accuracy of MR imaging.

Aims And Objectives:-

1. To describe features of pancreaticobiliary diseases on MRCP.
2. Outlining the extent in terms of involvement of adjacent structures, vessels and soft tissues.
3. To help in deciding further course of management.
4. To identify the anatomical variants.
5. To prove that Magnetic Resonance Cholangio-Pancreaticography (MRCP) is one of the best imaging modality for evaluation of pancreatico-biliary diseases.

Review Of Literature:-

Nikola Tesla discovered the Rotating Magnetic Field in Budapest, Hungary in 1882. This was a fundamental discovery in physics. Professor Isidor I. Rabi working in the Pupin Physics laboratory in New York city, observed the quantum dubbed nuclear magnetic resonance (NMR) phenomenon in 1937. Felix Bloch & Edward Purcell discover magnetic resonance phenomenon in 1946. In 1971, Raymond Damadian, a physician & experimenter working at Brooklyn's Downstate Medical Center discovered that hydrogen signal in cancerous tissue is different from that of healthy tissue because tumors contain more water.

It was in 1976 & 1977, when first images of human anatomy were produced by groups at Nottingham university. In 1978, Damadian produced whole body image using field focusing. In 1981, General electric oxford instruments produced images using high field (1.5 T) whole body magnets. Since then there has been widespread clinical application with many sub modalities like multislice, multiecho, spectroscopy, angiography, fast scanning, surface coil, etc.

MRCP was first described in 1986. Subsequent advances have allowed non-invasive cholangiography with diagnostic accuracy.

First clinical application study of MRCP was done by **Wallner BK et al** in 1991 using breath hold 2D T2W gradient echo sequence using Steady State Free Precision (SSFP).

MRI & MRCP PHYSICS

Mri Physics

Principle of MRI is based on the Larmor frequency of hydrogen proton. Hydrogen has a solitary proton within its nucleus resulting in all hydrogen atoms having an inherent positive charge. When combined with the spinning movement of the proton, this positive charge results in the proton behaving as a tiny magnet with both positively and negatively charged poles. Normally, protons in the human body are randomly oriented. However, when subjected to strong external magnetic field, these protons equilibrate to a low energy state, aligning along the direction of the main magnetic field lines. When a RF pulse is generated at the appropriate frequency the atoms are excited to a higher energy state. After the RF pulse is removed, the protons relax back to their low energy state. The rate and nature of this relaxation is defined by the chemical, structural and local magnetic environment in which the protons are found[15 &16].

The release of energy to the chemical lattice environment is known as T1-relaxation. T2-relaxation is due to the spins, which were brought into phase during the RF pulse, beginning to de-phase in response to the local or molecular heterogeneity of the magnetic environment. The timing of the RF pulse can be used to emphasize either the T1-relaxation (T1W) or T2-relaxation (T2W). Signals emitted during relaxation are received by the scanner coils & used to generate MR images [15 & 16].

Mrcp Physics

MRCP is performed by using heavily T2W turbo spin echo sequences & fast gradient echo sequences, in which stationary fluid has resultant high signal intensity [17].

MRCP takes the advantage of the high signal intensity of body fluids on heavily T2W MRI. Static or slow-moving fluid filled structures such as bile & pancreatic ducts appear as hyperintense areas, whereas background tissues generate some signal. This inherent difference in signal intensity enables MRCP to be carried out without a contrast agent [18 & 19].

MRCP is usually performed with heavily T2W sequences by using fast spin echo or SSFSE (Single Shot Fast Spine Echo) technique and both a thick collimation(single section) and thin collimation multisection technique with a torso phased array coil. The coronal plane is used to provide a cholangiographic display and axial plane is used to evaluate the pancreatic duct and CBD[20].

Wallner BK et al in 1991 used breath hold T2W gradient echo sequence using SSFP (Steady State Free Precession). These sequences provided projection cholangiograms. The quality of these images for a dilated biliary tree was acceptable. However visualization of normal caliber pancreatic and bile ducts was extremely limited. Depiction of small structures was not possible essentially due to high signal intensity from intra-abdominal fat reducing contrast between extra hepatic bile ducts and abdominal background. Other draw backs of this sequence were; less signal to noise ratio, requirement to use thick sections and large field of view.

Morimoto et al tried to improve the image quality by introducing 3D-SSFP sequences being able to use thinner slices. However, both 2-D and 3-D sequences suffer from limitations of gradient echo sequences. These sequences are extremely susceptible to motion and magnetic susceptibility artifacts such as bowel and metallic clips. The SSFP sequences also required long breath holds, thereby limiting their image to co-operative and highly motivated patients. To overcome these problems, Fast spin echo sequences were introduced. These sequences were less susceptible to motion artifacts, slow flow and magnetic susceptibility. The signal to noise ratio and contrast to noise ratio was significantly higher than SSFP sequences. Initially 2D fast spin echo(FSE) sequences were introduced; subsequently 3D FSE respiratory triggered sequences were introduced permitting thinner slices. Fast spin echo sequences that are used in MRCP may be breath hold or non-breath hold, the non-breath hold essentially being used for uncooperative patients or who are unable to hold their breath for long period of time. The image qualities of non-breath hold were inferior to the breath hold sequences [21].

The initial breath hold sequences introduced by **Tahera et al**required a longer breath hold time. So, there was need for shorter breath hold sequences. Modified fast spin echo(FSE) sequences were introduced recently. These are RARE (Rapid Acquisition with Relaxation Enhancement) and Half Fourier Acquisition Single Shot Turbo Spin Echo sequences(HASTE) [22].

The RARE sequence is a single shot echo planar sequences introduced by Laubengberger; using a single thick oblique coronal slice 2-7 cms in thickness. This sequence provides a single projectional image of the biliary tree and pancreatic ducts. The advantage of this sequence is that it requires a breath hold of only 2-7 seconds. The disadvantage of this sequence is that, they are single projection images, no source images are available and post processing is not possible. To compensate for this, multiple oblique coronal images are obtained in different planes[23].

HASTE is a Half Fourier Acquisition Single Shot Turbo Spin Echo sequence. Multiple thin slices ranging from 2-7 min in thickness are obtained in 18-20 second breath hold. This technique has the advantages like RARE of eliminating respiratory motion artifacts as well as negligible magnetic susceptibility artifacts from bowel and surgical clips.

Numerous studies have compared the multislice HASTE sequences with 2D/3D FSE and Gradient Echo (GRE) SSFP sequences[24-27]. All the studies concluded that multislice HASTE sequence were significantly superior to other sequences especially in terms of Signal to Noise (S/N) ratio and Contrast to Noise (C/N) ratio. Many recent studies have also compared RARE and HASTE sequences to identify the optimal MRCP sequence.

As mentioned earlier RARE sequences suffer from the drawback of direct projectional images and provide no source images for post processing. The S/N and C/N ratio of RARE are significantly lower than HASTE multi slice sequences. The image quality of HASTE multi slice images appears superior. However, in the visualization of the ampulla, periampullary region and anomalies of pancreatico- biliary tree, the RARE sequences are superior to HASTE. Half Fourier RARE MRCP is a reliable imaging technique for the evaluation of anatomy and complications associated with a surgically altered pancreatico-biliary duct system[28].

A study conducted by **Morimoto et al** shows that single shot RARE provides superior image quality, duct conspicuity with the added advantage of less image artifact and short acquisition time. However, volume averaging can cause bile duct stones to be missed. Therefore, multislice HASTE sequences should still be acquired if choledocholithiasis is suspected. Larger studies are required to assess the diagnostic efficiency of single shot RARE sequences in pancreatic duct and intra hepatic duct disease[29].

Due to high density of bile on HASTE multislice Multiple Intensity Projection (MIP) images, small CBD stones can be missed. RARE image as well as source images of HASTE multislice sequence demonstrates these stones. These studies have revealed no significant difference in image quality between slice thickness of 2 mm and 7 mm in the HASTE multislice technique.

In a study done by **Soto et al** non-breath hold 3D-FSE, breath hold single section half Fourier RARE and breath hold multislice Half Fourier RARE were compared. The 3D MRCP sequences had a similarly high sensitivity and specificity for the detection of choledocholithiasis[30 &31].

For the evaluation of pancreatic parenchyma Gadolinium enhanced images are acquired. The normal peak enhancement occurs at 30 to 45 secs[32 & 33]. The evaluation of viability of the pancreatic parenchyma succeeds best on immediate post contrast image obtained with novel fast GRE T1W breath hold sequence such as FLASH (Fast Low Angle Shot), Turbo FLASH, Fast Field Echo (FFE) or Fast Multiplanar Spoiled Gradient Recalled imaging (FMPSPGR)[34].

Recently phased array multicoil systems for volume imaging have been developed [35 & 36]. The use of body phased array coil improves S/N and C/N ratio as compared to imaging done only with body coil[37 & 38]. Combination of phased array coil, torso phased array coil & rapid sequences enables detection of 1 mm ducts [39]. With phased array coil, abdominal wall motion & the respiratory artifacts are reduced with the wrapped array coil. Disadvantages are the incomplete coverage of the abdomen, the inhomogeneous signal intensity & the expenses of the additional system.

The limitation of MRCP is that ascites or fluid collection may obscure ductal anatomy, which however may be partly overcome by use of multi-oblique method [40].

MRI is increasingly being used to evaluate pancreatic & biliary ductal systems & even the bowel. The potential or MR imaging to provide functional & anatomic information is intriguing & new techniques, including diffusion & perfusion weighted images are being evaluated [41].

Anatomy Of Biliary System

In the 4th week of human gestation, a hepatic diverticulum(figure 1) develops from the ventral foregut that eventually will become the bilobed liver and gall bladder, and a solid stalk connects the developing liver to the descending duodenum. By 3 months of gestation, the entire biliary system and gall bladder have canalized to form a continuous lumen. From hepatocytes, biliary canaliculi form biliary ductules, which in turn unite to form segmental bile ducts.

The typical biliary anatomy (figure-2a) consists of anterior and posterior segmental right hepatic ducts that fuse to form the main right hepatic duct. A variable number of segmental left hepatic ducts likewise join to form the main left hepatic duct.

The main right and left hepatic ducts typically converge approximately 1 cm from the liver margin to form the common hepatic duct. The transition from hepatic duct to common bile duct (CBD) occurs at the site of cystic duct insertion which is typically midway between the convergence of the right and left hepatic ducts and the retro-duodenal common bile duct. The common bile duct consists of supra-duodenal, pancreatic and intra-duodenal segments[42-44]. Terminal portion of CBD is joined by pancreatic duct. The sphincter of Oddi is a muscle that typically encircles the terminal portion of biliary and pancreatic ducts and their common channel (figure 2b)[45-47]. There remains some debate as to whether the sphincter of Oddi is a single continuous structure or consists of two or three separate structures.

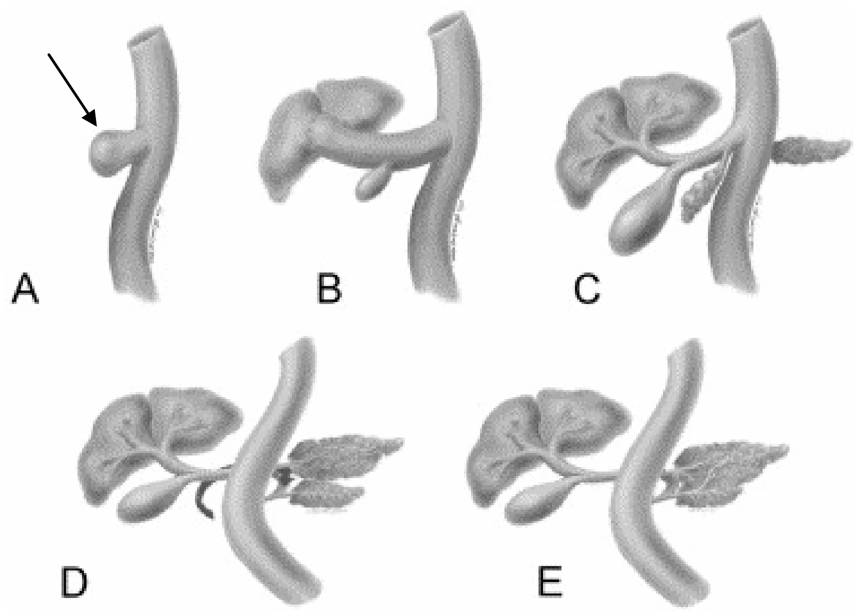
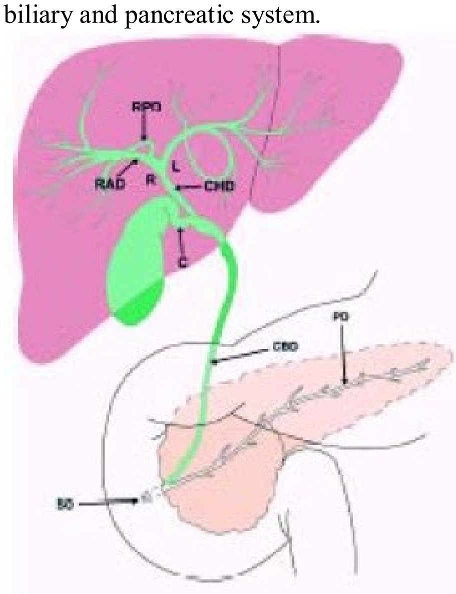


Figure-1:- Diagrams showing development of hepatic bud(arrow) from foregut and subsequent formation of hepato-biliary and pancreatic system.



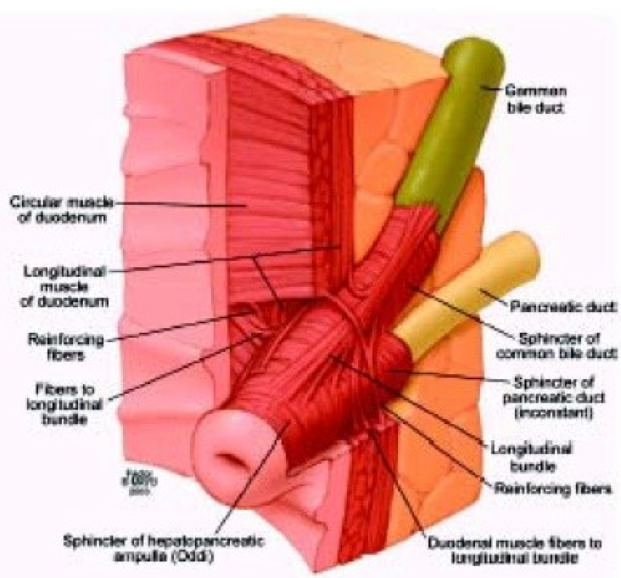


Figure-2a Figure-2b

Figure-2a: Diagram showing normal biliary anatomy. Anterior (RAD) and posterior (RPD) segmental right hepatic ducts join to form the main right hepatic duct, which may vary in length. The right (R) and left (L) main hepatic ducts become extrahepatic proximal to their confluence in the common hepatic duct (CHD), which joins with the cystic duct to form the common bile duct (CBD). Biliary and pancreatic duct (PD) flow is regulated by sphincter of Oddi. Figure 2(b). Diagram of Sphincter of Oddi.

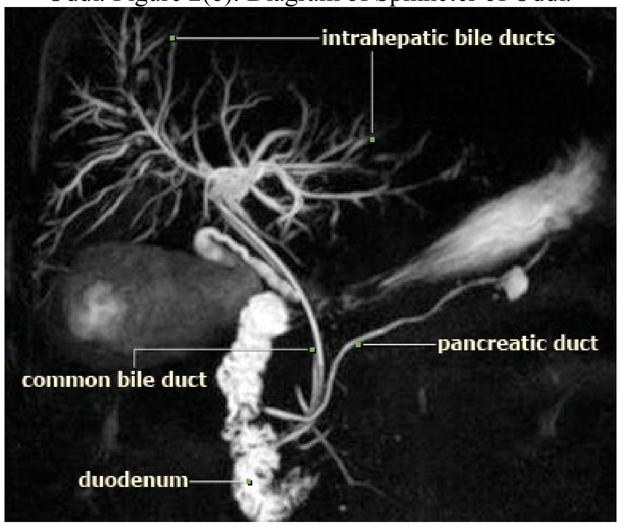


Figure-3:- 3D coronal MRCP image showing normal biliary ductal anatomy Intrahepatic ducts, CBD and pancreatic duct are seen.

There is great variability in the anatomy of hepatic biliary system (Figure 4), gall bladder, and pancreatic ducts. In approximately 30% of the general population, two segmental ducts drain the right hepatic lobe and separately join with the left hepatic duct, cystic duct, or common bile duct [43]. Rarely cystic duct is absent or duplicated. The length and course of cystic duct are frequently anomalous, with the clinically most important anomaly involving the opening of cystic duct into the right hepatic duct. There is less variability in the common bile duct, except in size [42]. In 5 to 15% of population, the common bile duct and main pancreatic duct enters duodenum separately [47, 48].

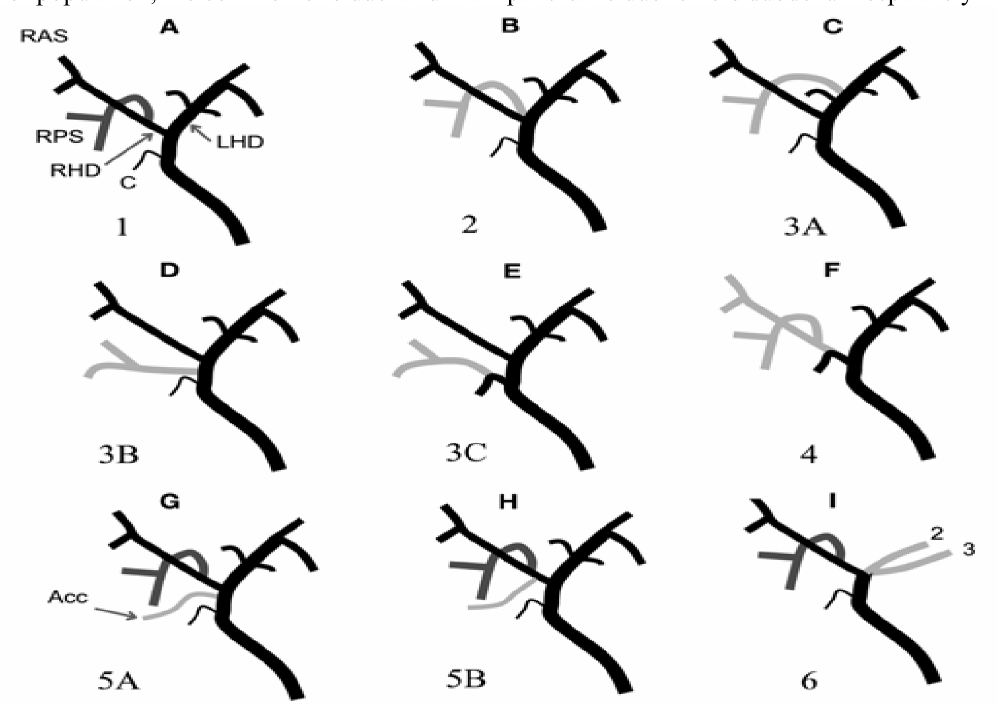
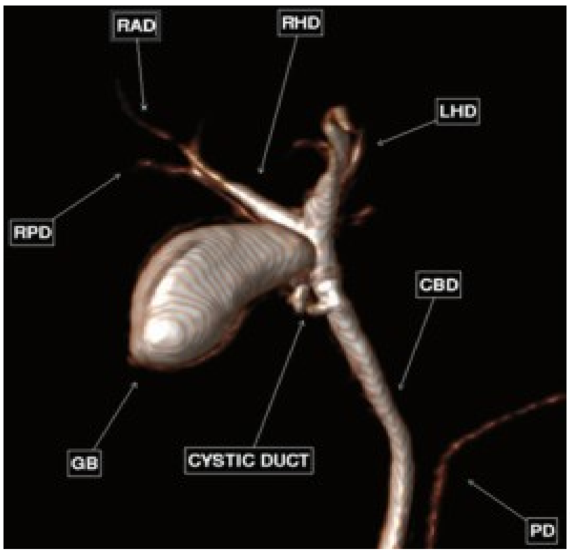
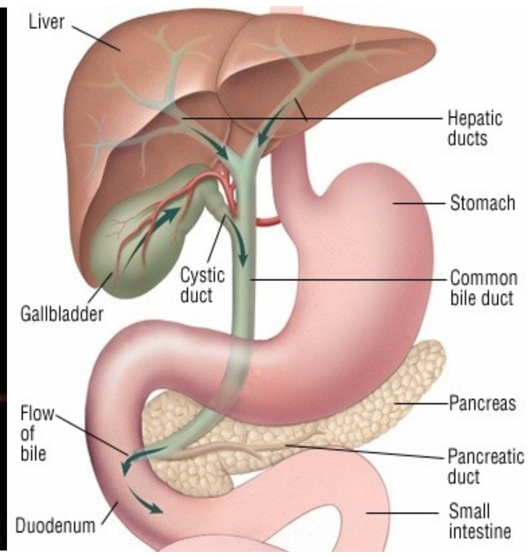


Figure-4:- Schematic diagram of right hepatic duct (RHD) anatomic variants. Shows typical anatomy which found in 58% of general population, Type 1 - Conventional branching (A). Type 2 - Triple confluence of right posterior segmental (RPS) duct (gray line) (B). Types 3 (A, B, C) - RPS drains anomalously into left hepatic duct (LHD), common hepatic duct(CHD) and cystic duct respectively (C, D, E). Type 4 - Right hepatic duct (RHD) drains into cystic duct (F). Types 5 (A, B) - Right accessory duct drains into CHD or RHD (G, H). Type 6 - Segments II and III drain individually into RHD or CHD (I).

The enzymes from the pancreas drain into the small intestine (duodenum) through the ampulla of Vater. Intrahepatic biliary radicals join to form right and left hepatic ducts which later on form common hepatic duct. Cystic duct joins with common hepatic duct to form common bile duct (CBD). CBD in combination with main pancreatic duct opens at ampulla of Vater which is situated on medial side of 2nd part of duodenum. The ampulla of Vater drains the liquids made by the liver called bile, which is initially stored in the gallbladder and then secreted via the common bile duct through the ampulla into the duodenum[9].





Pancreatico-Biliary Diseases

Evaluation of suspected biliary tract disease is a common radiology problem. Advances in CT, US and MRI over the past decade have greatly improved our ability to evaluate the biliary tract. If obstruction is determined to be present, it is necessary for imaging to define the level of obstruction and if possible the cause of obstruction[48].

Because of the strong correlation between the presence of dilated biliary duct system and presence of obstruction, CT, MR and US imaging can accurately predict presence or absence of biliary obstruction. When the intrahepatic duct size at CT or US exceeds approximately 2 mm in diameter & duct visualization becomes confluent rather than scattered, an abnormal biliary tree is present & one should consider the presence of biliary obstruction. Dilated intrahepatic ducts should be diagnosed when the intrahepatic bile ducts exceed 40% of the adjacent intrahepatic portal vein [48].

The CHD is nearly always visualized coursing through the porta hepatis at US or CT. The upper limit of its diameter has been a source of controversy for decades relating to the variation among individuals. Generally, at US, 6-7 mm diameter of CHD or CBD has come to be the most commonly used upper limit size, whereas, in CT it is more common to accept 8 to 10 mm for the CHD or CBD[48]. The diameter of common hepatic duct is often larger in its mid and distal portions, easily identified and used as a measurement at CT than it is proximally, whereas, US most often visualizes the extra-hepatic ducts optimally. In addition, US typically measures the internal luminal diameter, whereas, CT more readily identify the fat around the duct & the measurements include ductal wall too.

Reasons for a dilated extrahepatic ductal system without obstruction have been a source of interest to imagers for decades. When biliary obstruction has been long standing, the elastic fibres in the wall of the duct may be permanently stretched & they will not return to its normal diameter despite relief from the obstruction [49].

There is also some controversy over whether the EHBD increases its diameter in response to cholecystectomy and in aging. A study done by **Bacher et al** has revealed an age dependent change in the diameter of EHBD. The study suggests that the upper limit of the duct in elderly persons be set at 8.5 mm. The study states the mean diameter for people < 50 years was 3.128 mm +/- 0.862 mm & for patients > 50 years was 4.19 mm +/- 1.15 mm. They found that the duct dilated 0.04 cm/ year on US [50].

When obstruction is present the biliary tree will dilate beyond the normal range, but it is important to be aware that there is a time lag from the onset of the acute obstruction & the dilatation. Animal studies have shown that the extrahepatic duct system dilates before the intrahepatic ducts typically requiring 2-3 days of obstruction to dilate [50]. Intrahepatic ductal system requires obstruction of 1 week duration for dilatation to occur. Thus, in early obstruction, the lack of biliary dilatation at imaging does not preclude the presence of biliary obstruction.

Determination of the level of obstruction can be an important indicator for next step in therapeutic or diagnostic intervention with proximal obstructions being better approached by a percutaneous approach and more distal processes evaluated or treated by an endoscopic approach. In addition, the level of obstruction of biliary tract is key factor in developing differential diagnosis.

Key to achieving the proper diagnosis with bile duct is evaluating the zone of transition from dilated to non-dilated or non-visualized duct. Special attention should be paid to this zone of transition regardless of imaging modality being used. With a borderline or equivocally increased extra hepatic duct diameter, re-evaluation of duct size following a fatty meal can help to differentiate obstructed from non-obstructed ducts [49]. **Below is Table showing Common causes of biliary obstruction.**

Intrahepatic Biliary obstruction	**.Portohepatic Biliary obstruction**	**Suprapancreatic biliary obstruction**	**- Intrapancreatic biliary obstruction -**
1. Primary Sclerosing cholangitis (PSC) 2.Space occupying lesions and liver diseases	1.Cholangiocarcinoma 2.PSC 3.Primary Ca GB 4.Metastatic disease 5.Strictures	1. Pancreatic carcinoma 2.Metastasis 3. Pancreatitis 4.Cholangiocarcinoma 5.Choledocholithiasis 6. Strictures	1.Pancreatic carcinoma 2. Pancreatitis 3.Choledocholithi-asis 4.Ampullary Ca 5. Duodenal Ca 6.Cholangiocarcinom anoma

Abdominal US is initial examination of choice in imaging of bile ducts particularly in patients with jaundice, **Yi Tang et al**[51].

US plays and indispensable role in evaluation and follow-up of infants and children with jaundice and in differentiation of obstructive and non-obstructive jaundice without being dependent on ionizing radiation. US provides important information about liver size and texture, the size and clarity of bile ducts[52].

In patients where visualization of most distal portion of CBD is difficult on conventional US. Tissue Harmonic Imaging(THI) shows larger length of duct with relative ease. Improvement in contrast and resolution of side lobe artifacts with THI enhance visualization of the biliary ducts [52].

Painless jaundice is a hallmarkof malignant biliary obstruction. However, there are no absolute distinguishing signs between benign and malignant obstruction. About 80 to 90% of patients with carcinoma of head pancreas present with jaundice. Patients with ampullary carcinoma and cholangiocarcinoma almost always presents with jaundice. Jaundice is late symptom of carcinoma of gallbladder [53].

Both USG and CT are accurate at detecting biliary dilatation and determining the presence of extra hepatic biliary dilatation &obstruction, but they are limited in their ability to define the cause or the exact level of obstruction. US is highly operator dependent and distal biliary lesions are often obscured by overlying bowel gas. Use of MRCP and addition of conventional T1W pre- and post-contrast MR imaging when malignant obstruction is suspected, helps in better evaluation of possible masses, lymph node enlargement or hepatic masses if required. In addition, MR angiography can be performed at the same setting to define vascular anatomy & assess for vascular invasion. The combination of MRI, MRCP & MRA provides the option of complete diagnostic evaluation of pancreatico-biliary neoplasms without the need for invasive or multiple imaging procedures [54].

Kinematic MRCP can be used to define the necessity of biliary intervention in patients with biliary dilatation [40]. Segmental ducts are difficult to visualize with MRCP because of their small caliber & limited spatial resolution & S/N ratio achievable with standard MR pulse sequence. Visualization of the normal (non-distensible) biliary system is necessary for the evaluation of donor candidates for liver related transplantation because of prevalence of variant biliary anatomy. MRCP is often used in pre-operative evaluation of the patients. Intravenous morphine administered prior to MRCP can improve quality by causing Sphincter of Oddi to contract, which increases pressure in & distension of the biliary & pancreatic ducts [55].

Kim et al showed that addition of non-enhanced T1 & heavily T2 weighted sequences increases the diagnostic accuracy in differentiation of benign from malignant causes of biliary dilatation. Further addition of gadolinium enhanced T1W dynamic images did not significantly improve the diagnostic accuracy for differentiating causes of biliary dilatation but increased the level of confidence in 17% to 24% of the cases as compared with that for the combination of MRCP & T1 & T2W images especially in cases of biliary dilatation due to pancreatic carcinoma [56].

Soto et al showed that in patients with biliary obstruction caused by malignant lesions. MRCP demonstrates the site of the obstruction & the severity of bile duct dilatation. Additional cross-sectional MRI images obtained with conventional sequences are necessary to determine the organ of tumor origin & to define the margins of the malignant lesion. Patients with biliary enteric anastomosis also benefit from undergoing MRCP as the primary diagnostic modality, because ERCP may be technically difficult to perform due to the altered anatomy & long afferent loops produced by Billroth II procedures. In some of these patients, the information provided by MRCP is sufficient to help plan therapeutic intervention [57].

Cholelithiasis

Obesity, increasing age, hyper-alimentation, rapid weight reduction, ileal disease or resection and ethnicity are risk factors for developing gallstones[42]. 70-80% of gall stones in western countries are cholesterol and the remainders 20-30% are pigment stones which occur most frequently in patients with chronic hemolytic disorders. 80% of patients with gallstones are asymptomatic and 20% have biliary colic. 1 to 2 % of patients with asymptomatic gall stones develop biliary symptoms. 1 to 2% per year risk is seen in these patients for developing acute cholecystitis and other complications[42].

US has a sensitivity of 90% for detecting gall stones, however size and number cannot be accurately determined sonographically. Diagnosis of cholelithiasis is most confidently made when a 5-mm echogenic focus meets all 3 major criteria. Stones <2 to 3 mm sizes are difficult to visualize on USG. Small stones are usually multiple which assists their detection.

The characteristic findings of gallstones at US are a highly reflective echo from the anterior surface of the gallstone, mobility of the gallstone on repositioning the patient (typically in a decubitus position), and marked posterior acoustic shadowing. When the gallbladder is filled with stones, the resultant appearance is termed the wall-echo-shadow (WES) sign. WES sign must be differentiated from a partially collapsed duodenal bulb, porcelain gallbladder, emphysematous or xanthogranulomatous cholecystitis or calcified hepatic artery aneurysm.

On MRI, gallstones produce little or no signal because of the restricted motion of water & cholesterol molecules in the crystalline lattice of the stone. Gallstones & CBD stones are best seen on T2W images that produce bright bile. MRI is superior to CT in detecting small stones because of inherent high contrast between low signal intensity stones & high signal intensity bile [42].

Most stones produce no signal on MR images & appear as signal void area i.e., hypointense areas in a bright gallbladder on HASTE, RARE & FISP sequences.

Recent study by **Tsai et al** based on the differential signal intensity of gall stones states that 3D fast spoiled gradient echo T1W imaging was able to diagnose the composition of gall stones. Adding 3D fast spoiled gradient echo imaging to the single shot fast spin echo T2W sequence can further improve the detection rate of gall stones and gall stones with differential compositions. Because the 3D fast spoiled gradient-echo images were acquired with fat saturation and the in-phase fast spoiled gradient-echo images were not, the higher intensity of gallstone on 3D fast spoiled gradient-echo images may be caused by fat saturation itself, which increased the apparent brightness of water-bearing stones [58].

In addition to recognizing gall stone as a filling defect on T2W Single Shot Fast Spin Echo Imaging, MR Imaging can also help to distinguish between different types of gallstones like cholesterol stones, pigment stones. Cholesterol stones appear hypointense on T1W images while Pigment stones usually have increased signal intensity on T1W images. The 3D fast spoiled gradient echo T1W is as good as T2W Single Shot Fast Spin Echo imaging in diagnosis of gall stones & can even be better when applied to bile duct stones [58].

Choledocholithiasis

Passage of gall stones in CBD occurs in 10 to 15% of patients with cholelithiasis. Majority of bile duct stones are cholesterol or mixed stones formed in gallbladder. Primary calculi arising de novo in the ducts are pigment stones developing in patients with:

1) Chronic Hemolytic disease.
2) Hepato-biliary parasitism
3) Congenital anomalies of the bile ducts
4) Dilated, sclerosed or strictured ducts [59, 60]

CBD stones may lead to acute biliary obstruction, cholangitis and acute pancreatitis [49]. Currently available modalities for diagnosis are US, CT, MRCP, EUS and ERCP [50]. Choledocholithiasis is one of the most common biliary tract diseases which occur in 8-20% of patients undergoing cholecystectomy and 2-4% of patients after cholecystectomy.

Bile duct stones can be discovered incidentally during the evaluation of gallbladder stones, with an estimated prevalence of 5% to 12%. Common clinical symptoms and signs include pain, fever, and jaundice. Biliary pain confined to the epigastrium or right upper quadrant of the abdomen is the most common presentation.

Although advanced technologies have become more widely available, a clinically oriented approach remains paramount. Atypical as well as typical clinical symptoms should be recognized.

Newer techniques of biliary imaging have simplified the diagnosis of bile duct stones. Noninvasive methods have the lowest risk, whereas invasive techniques have the greater accuracy.

US: Stones classically occur as echogenic foci within the fluid filled duct lumen. Stones may appear as echogenic curved line, depicting only the anterior curved stone margin, with markedly diminished echogenicity distally. When stones are small or not within the focal zone of the transducer they may not exhibit distal acoustic shadowing [49]. Caution must be made to avoid a mistaken diagnosis of duct stone from a variety of causes. Intraluminal masses such as blood clot or papillary tumors can simulate an echogenic mass but without distal shadowing. Adjacent calcified lymph nodes can also resemble calculi. Duodenal & colonic gas can make it difficult to visualize portions of the distal duct [49].

Choledocholithiasis is suggested by the presence of a dilated CBD on US or by elevated liver function tests, specifically an elevated total bilirubin or alkaline phosphatase level [49].

US alone lacks the high sensitivity for directly visualizing the stones within the CBD, but the combination of a CBD larger than 10 mm on US & hyperbilirubinemia has a positive predictive value > 90% for choledocholithiasis [49].

Although US & CT are often used in the initial evaluation of patients with suspected choledocholithiasis, neither has a high sensitivity for detection of CBD stones. Sensitivity of US ranges from 18-70% for CBD stones. This variability in sensitivity is in part due to theoperator dependent nature of US & obscuration of bile duct by bowel gas. Sensitivity of CT for detection ranges from 76 to 87%.

Magnetic resonance Cholangiopancreatography (MRCP) and endoscopic ultrasound (EUS) are less invasive than endoscopic retrograde cholangiography (ERC) but can detect bile duct stones with comparable accuracy. At MRCP, CBD stones are seen as low signal intensity filling defects in the high signal intensity bile. On heavily T2W Fast Spin echo images bile has relatively high signal intensity; thus, common bile duct stones as small as 2-3 mm can be detected with MRCP. MRCP is accurate not only in the detection of common bile duct stones but also in determining their size, number and exact location. MRCP is also able to detect stones in dilated ducts & in non-dilated ducts. Axial images are generally more useful in diagnosis of choledocholithiasis because they are degraded by motion artifacts to a lesser extent. It is crucial that all source images or reformatted images be reviewed for choledocholithiasis, since 3D images reconstructed with MIP (maximum intensity projection) may obscure the common bile duct stones. Pneumobilia, adjacent vessel compressing the duct & en face visualization of the cystic duct are great mimickers of stones [49].

MRCP assists in diagnosis of complex manifestations with bile duct calculi such as Mirizzi syndrome. Mirizzi syndrome represents compression of common bile duct by a calculus impacted in the cystic duct. Multi planar capability of MR cholangiography allows identification of both the obstructing calculus and the long cystic duct that parallels the bile duct and predisposes the patient to Mirizzi syndrome.

Kondo et al found that observer performance with volume rendered MRCP was better than that with MIP & thick section MRCP for the diagnosis of choledocholithiasis. Volume rendering may be an efficient technique for the reconstruction of MRCP [31].

Kim et al showed sensitivity & specificity of MRCP for detecting intrahepatic stones of 97% & 93% respectively whereas that of ERCP was 59% & 97% [61].

Early studies focusing on the role of MRCP in the detection of CBD stones yielded sensitivities ranging from 81 to 92% & specifities, ranging from 91 to 100% [50]. Recent technical advances have resulted in improvements in S/N ratio & spatial resolution have further enhanced the MRCP diagnosis of choledocholithiasis. Recent studies note sensitivities of up to 100% & specifities of 92 to 100% matching & in most cases exceeding those of ERCP. Positive predictive value ranges from 96 to 100% [49]

Miller et al quotes that US is highly sensitive (99%) & accurate (93%) for demonstration of ductal dilatation but is slightly less reliable with regard to the location (60 to 92%) & causes (39 to 71%) of biliary obstruction [62].

US has limited sensitivity (55 to 85%) for diagnosis of choledocholithiasis but a high specificity (89 to 91%) & positive predictive value of 92% have been reported [63]. Detection rates for MRCP, EUS & ERCP are over 90%. Comparison of EUS, ERCP & MRCP for diagnosis of choledocholithiasis reveals similar accuracy rates from 85 to 95%. EUS & MRCP are minimally invasive with MRCP being non-invasive [49].

Comparative Studies

Laokpessi et al performed MRCP & US in 147 patients, ERCP in 101 patients & intra-operative cholangiography in 46 patients. MRCP was performed using both FSE & SSFE MRI 1.5T with body & surface coil (Reference standard was stone extraction). MRCP had sensitivity of 93%, specificity of 100% & accuracy of 94.5%. All three modalities performed better than US which has sensitivity of 30%, specificity of 97% & accuracy of 46% [63].

Park et al found that MRCP is better at detecting stones than US (Reference study was surgical findings). RARE sequence was performed with 1.5 T MRI and body phased array coil in 35 patients. MRCP had sensitivity and specificity of 100% and US had sensitivity of 80%, specificity of 100%& accuracy of 89% [64].

Sugiyama et al preferred both US & HASTE MRI with 1.5T & body phased array coil in 97 patients [65]. (Reference standard was ERCP with surgery & follow-up).

Varghese, Liddell et al reported that MRCP was better than US in detection of stones (Standard reference was ERCP, PTC or IOC). They reported sensitivity 31% of and specificity of 100% on US and that on MRCP was 91% and 98% respectively. They preferred FSE MRI 1.5T on 191 patients [67].

Choledochal CYST

This is an uncommon cause of obstructive jaundice. Choledochal cyst is the cystic dilatation of the extra hepatic bile ducts, with or without dilatation of the intra hepatic ducts. It is a common congenital anomaly of the biliary tree. It is 3 to 4 times more common in females and two thirds of the patients remain asymptomatic before the age of 10 years. The classic clinical triad of pain, jaundice and a palpable right upper quadrant lump is seen in 30-60% of patients presenting in the first decade of life and approximately 20% of those diagnosed in adulthood. This condition is thought to be related to an abnormal insertion of the CBD into the pancreatic duct which causes reflux of the pancreatic enzymes into the CBD [67].

Classification of Alonzo-Lej modified by Todani et al(figure 5) [68]

Type I choledochal cysts account for 80-90% of bile duct cysts. They are further subdivided into A, B and C subtypes.
I A: Cystic dilatation of the CBD
I B: Focal segmental dilatation of the distal CBD
I C: Fusiform dilatation of both the common hepatic and common bile duct.
Type II: True diverticulae arising from the CBD. These cysts account for 2% of bile duct cysts.
Type III: Cystic dilatation involving only the intraduodenal portion of the CBD (choledochocele). Account for 1 to 5% of bile duct cysts.
Type IV: Cysts account for approximately 10% of bile duct cysts and are subdivided into types IV A and IV B.
- IV A: Multiple intra and extra hepatic cysts.
- IV B: Multiple extra hepatic cysts only.
Type V: Single or multiple intrahepatic cyst (Caroli's disease)

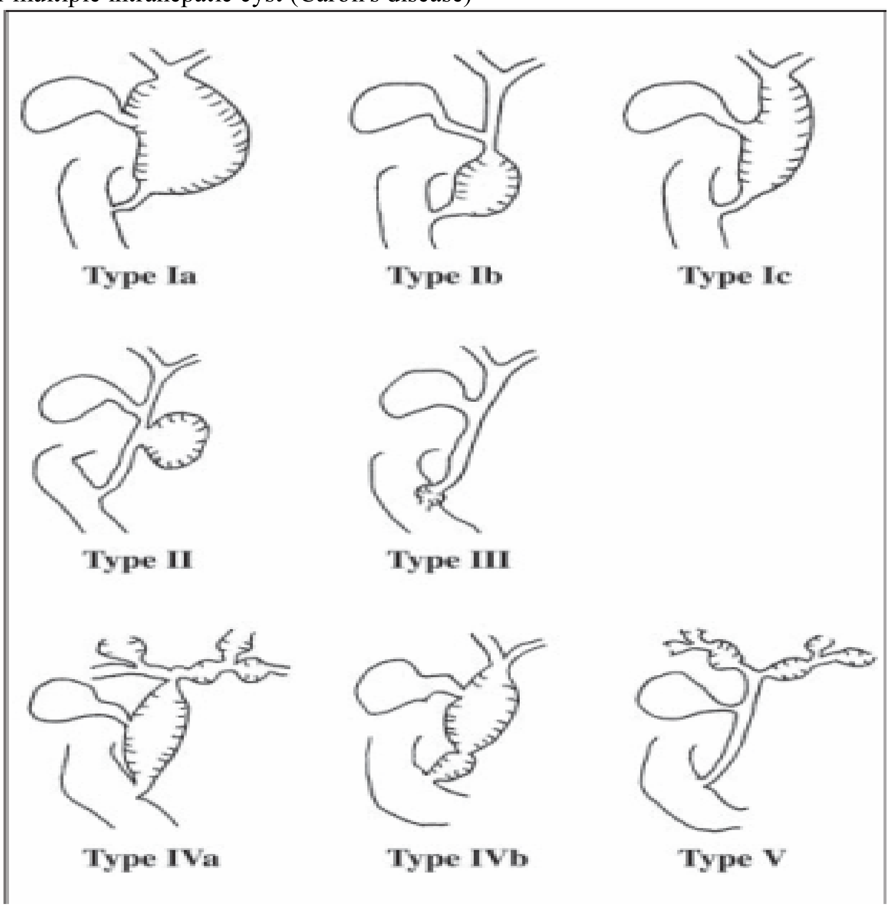


Figure-5:- Diagram showing various types of choledochal cyst.

Caroli's Disease

Caroli's disease is the eponymous designation for congenital non-obstructive dilatation of the large intra hepatic bile ducts [69]. This rare and incompletely delineated entity was first described by Caroli et al. in 1958[70]. Caroli's disease may be multifocal or may be localized to lobe or segment of liver. Most of cases are associated with congenital hepatic fibrosis and medullary sponge kidneys may occur occasionally[71]. Caroli's disease results from a bile duct malformation, which involves neonatal occlusion of the hepatic artery, leading to bile duct ischemia, cystic dilatation, and abnormal growth rate of the developing biliary epithelium and its supporting connective tissue[72]. Incomplete resorption of circular plates leads to the formation of multiple primitive bile ducts surrounding portal vein radicles [69].

The role of imaging in the evaluation of choledochal cyst is to delineate the anatomy of the cyst, determine the relationship of the cyst to the rest of the intra and extra-hepatic biliary tree, evaluate associated complications and biliary tree abnormalities. Sonography (US) is useful in assessing the full extent of biliary duct dilatation and for identifying the communication between the cyst and the biliary tree[73]. It is capable of demonstrating entire intra as well as extra-hepatic biliary tree[74]. It can also demonstrate the presence of calculi, stricture or tumor if present [73]. Surgeons need an exact anatomic map of the pancreatico-biliary ductal union because it is essential that the choledochal cyst be completely resected without pancreatic ductal injury [175].

Choledochal cysts are frequently detected at sonography as an anechoic or hypoechoic cystic lesion in the region of the porta hepatis with communication to the biliary tree. US is the recommended initial imaging study in the new born infant and persistent jaundice in whom differential diagnosis such as biliary atresia might occur together in neonates. However, sonography cannot reveal anomalous pancreatico-biliary ductal union which is generally believed to be the cause of choledochal cyst. In terms of pre-operative evaluation of anomalous pancreatico-biliary ductal union, ERCP is regarded as the most definitive and reliable diagnostic method of revealing anomalous pancreatico-biliary ductal union. However, ERCP is contraindicated in patients with acute pancreatitis and cholangitis and requires the administration of general anesthesia in children. It should be remembered that choledochal cysts and biliary atresia might occur together in neonates. Nuclear hepatobiliary scans confirm excretion of radiotracers into the choledochal cyst but yield limited anatomic delineation [49].

The most common complication associated with a choledochal cyst is stones in the gallbladder, within the cyst, in the dilated intrahepatic biliary tree, or in the pancreatic duct [179]. The second most common complication is a malignant tumor. Common bile duct carcinoma and gallbladder carcinoma are the major malignancies[179,75-77]. The risk of developing cancer seems to be related to bile stasis and contact between epithelium and bile. A choledochal cyst may be confused with several other cystic lesions including hepatic cyst, enteric duplication cyst, pancreatic pseudocyst, hepatic artery aneurysm and spontaneous perforation of the common bile duct. These entities call all be differential with a careful scanning approach and the use of duplex and color doppler imaging. An entire duplication cyst most often has the characteristic "intestinal signature", the "muscular rim" sign which consists of a brightly echoic inner rim (mucosa) and hypo echoic outer rim (muscular layer). Hepatic artery aneurysm may be differentiated with Doppler US [176].

On CT, a choledochal cyst appears as a right upper quadrant, fluid filled structure in contiguity with the extra-hepatic bile duct. Coronal imaging is extremely useful in the demonstration of the communication between the cyst and the biliary tree. This is achievable by CT using multiplanar reformations with or without cholangiographic contrast agents [73]. CT is considered to be more accurate in demonstrating the intrahepatic biliary tree and the status of the distal part of the common bile duct, which may be obscured by bowel gases on sonograms [78]. However, when a cyst is round and markedly dilated with no evidence of intrahepatic ductal dilatation, exact diagnosis is difficult with both CT and US, in such cases biliary origin often cannot be determined[74].

MR Cholangiographic technique allows direct imaging of the cyst in multiple planes[79,80]. Coronal imaging reveals a dilated tubular structure that follows the expected course of the CBD and demonstrates the relationship of the cyst with the rest of the biliary tree. The presence of wall thickening, mural nodularity and wall enhancement in a choledochal cyst raises the possibility of tumor.

The diagnosis of choledochal cyst can be confirmed by ERCP. This method can demonstrate the presence of an anomalous pancreatico-biliary duct junction (APBDJ) and clearly outlines the anatomy of biliary system before surgery[81]. However, ERCP is invasive procedure. MRCP is non-invasive, alternative method to ERCP for evaluating choledochal cysts[82]. Once a choledochal cyst is detected at sonography, MR cholangiography should be performed prior to surgery [73].

Kim et al concluded that MR cholangiography is equivalent or superior to conventional cholangiography in the evaluation of choledochal cysts. The authors compared MR cholangiography with conventional cholangiography in 13 patients with choledochal cysts [82].

Lam et al investigated the use of CT cholangiography versus MR cholangiography in the diagnosis of choledochal cysts in 14 children and had good results with both techniques[79].

Irie et al concluded in a study that MRCP is an important noninvasive diagnostic study for choledochal cysts but that it should not replace ERCP, especially in children. The authors used MRCP in the diagnosis of choledochal cysts in 16 patients[83]. They found that MRCP defined the proximal bile duct better than ERCP but that defects in the distal common bile duct were missed with MRCP in 2 pediatric patients. The anomalous pancreatico-biliary junction (APBJ) was delineated in all 6 adult patients but was missed in 6 of 10 pediatric patients. Hence MRCP with the non- breath hold technique is an accurate, non-invasive method of evaluating anomalous pancreatico-biliary duct lumen in children with choledochal cysts[177].

CBD Strictures

These are common cause of biliary obstruction. They can be benign or malignant. Biliary stricture can be seen with a wide range of non-neoplastic causes. In western countries, iatrogenic stricture is the most common benign biliary stricture and accounts for up to 80% of all benign strictures [84,85]. Cholecystectomy and orthotopic liver transplantation (OLT) are the most common iatrogenic causes of benign biliary stricture. A spectrum of diseases such as chronic pancreatitis, autoimmune cholangitis associated with autoimmune pancreatitis, PSC, recurrent pyogenic cholangitis, HIV cholangiopathy, chemotherapy-induced sclerosing cholangitis, and Mirizzi syndrome can also result in biliary stricture.

Bismuth et al [86] proposed a classification for biliary stricture based on its location (figure 6):

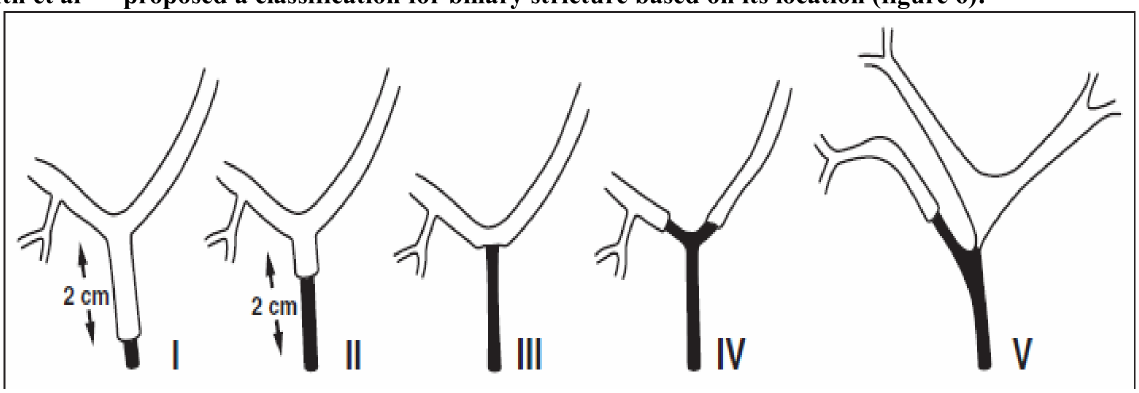


Figure-6:- Drawings show Bismuth classification of benign bile duct strictures.
Type I strictures are located more than 2 cm distal to confluence of left and right hepatic ducts, whereas
Type II strictures are seen within 2 cm from hepatic confluence.
Type III strictures affect confluence, which is patent.
Type IV strictures involve confluence and interrupt it.
Type V strictures involve the hepatic duct associated with stricture on aberrant right intrahepatic branch.

This classification helps the surgeon to choose the most appropriate surgical approach because it defines the level in which healthy biliary mucosa is available for repair and anastomosis. Clinically, benign biliary stricture can present with a wide array of manifestations, ranging from being completely asymptomatic to showing overt clinical and laboratory evidence of biliary obstruction.

US is the initial imaging modality of choice for the detection of biliary dilatation. US is highly sensitive for the detection of biliary obstruction and the level of obstruction; however, the accuracy of US for the detection of the underlying cause varies widely (30–70%) [87,88]. Again,US is also highly operator dependent.

Multi Detector CT helps in the detection of biliary dilatation, the underlying cause of biliary obstruction, and complications such as cholangitis and cholangitic abscess. In addition, multiphase contrast-enhanced CT may help in differentiating benign biliary strictures from its malignant counterpart. A malignant stricture is characterized by arterial and venous hyper enhancement, a wall thickness of greater than 1.5 mm, longer length of the stricture, and greater extent of proximal dilatation compared with its benign counterpart [89]. In addition, the presence of lymphadenopathy and of metastases also helps in differentiating malignant biliary strictures from benign biliary strictures.

ERCP has been the gold standard investigation for the evaluation of biliary obstruction. The major advantage of ERCP involves obtaining a tissue diagnosis to differentiate benign from malignant causes.

Unlike ERCP, MRCP offers the advantage of noninvasive imaging without the risk of any procedure-related complications, allows evaluation of the biliary system beyond a tight stricture, and allows assessment of the hepatic parenchyma and other intraabdominal viscera. Additional advantages of MRCP include evaluation of biliary enteric anastomosis and evaluation of biliary system during the immediate postoperative period[90].

At MRCP or ERCP, typical malignant common bile duct (CBD) strictures manifest as irregular, asymmetric strictures with a shouldered margin, whereas benign strictures tend to have smooth and symmetric borders with tapered margins[91]. Abrupt cut off of distal CBD in contrast to smooth tapering has traditionally been considered a sign of malignancy. However, some studies have shown that this finding is not reliable for distinguishing between benign and malignant strictures [92].

Shanbhogue et al[90] studied features of benign biliary strictures and concluded that wide gamut of conditions can cause benign biliary stricture, some of which can cause significant diagnostic dilemmas. Some of these entities exhibit a specific pattern of biliary involvement and thus have specific imaging manifestations. Intra- and extrahepatic biliary strictures with “beading” and with peripheral pruning favors primary sclerosing cholangitis (PSC). IgG4 sclerosing cholangitis predominantly affects elderly men with elevated serum IgG4 levels and presents as hilar or distal CBD strictures. Recurrent pyogenic cholangitis is a disease of Southeast Asia and immigrants from Southeast Asia and mainly affects the left lateral and right posterior intrahepatic ducts, resulting in bile lakes and intraductal calculi. Papillary stenosis is unique to AIDS cholangiopathy, the incidence of which decreased drastically after the introduction of Highly Active Antiretroviral Therapy (HAART).

Seung Hong Choi et al[89] conducted study in 50 patients on Differentiating Malignant from Benign Common Bile Duct Stricture with Multiphasic Helical CT and concluded that hyperenhancement of the involved CBD during the portal venous phase is the main factor distinguishing malignant from benign CBD strictures.

Carcinoma Gall Bladder

Gallbladder carcinoma is the fifth most common gastrointestinal malignancy and the most common biliary tract malignancy worldwide[127]. Predisposing risk factors include cholelithiasis, chronic biliary infections (Opisthorchis viverrini, Salmonella typhi), primary sclerosing cholangitis, and porcelain gallbladder[127]. The clinical presentation of gallbladder carcinoma is nonspecific and may include abdominal pain, weight loss, fever, and jaundice, any of which can be seen in cholecystitis and other benign gallbladder conditions as well as in other abdominal malignancies.

Although sonography has a relatively high sensitivity for the detection of tumor at advanced stages, it is limited in the diagnosis of early lesions and is unreliable for staging. Therefore, CT and, increasingly, MRI are more widely used for further characterization of potentially malignant gallbladder lesions and metastatic survey. CT, or MRI, the presence of a large gallbladder mass that nearly fills or replaces the lumen, often directly invading the surrounding liver parenchyma, is highly suggestive of gall-bladder carcinoma.

Onoyama et al[128] in his study reported a correct preoperative diagnosis of Ca GB in only 34% of cases, with an incorrect diagnosis being especially common in patients with associated cholelithiasis and those without any advanced changes.

CT has been widely used in the diagnosis of Ca GB for the appearance of the primary tumor (mass replacing gallbladder, wall thickening, intraluminal polyp), for the extension study, and for staging the tumor [127]. The tumor is usually heterogeneous, containing hyperdense areas due to necrosis and unequal uptake, which is preferentially peripheral with necrotic (low-uptake) areas. Dual-phase spiral CT studies can even show early uptake in arterial phase, either peripheral or heterogeneous, in the latter case simulating a hepatocellular carcinoma. Biliary invasion can occur by direct spread of the lesion along the hepatoduodenal ligament or by compression from infiltrated adenopathies.

Kumaran et al[129] studied 15 patients with double phase helical CT, arterial and portal (3-mm collimation slices and reconstruction every 2 mm) venous phases. Their overall assessment was that helical CT is very useful to determine resectability/non-resectability with a global accuracy of 0.93.

Ca GB on MR appears as a hypo- or isointense mass or wall thickening in T1 in relation to the liver and is usually hyperintense and poorly defined in T2 sequences[127]. In early phase, the uptake of contrast is heterogeneous and preferentially peripheral and tends to slowly progress in a centripetal manner in dynamic studies, which is characteristic of adenocarcinomas. Assessment of the invasion of neighboring organs and adenopathic infiltration is facilitated by the combination of enhanced sequences in T2 with fat suppression, dynamic post-gadolinium T1-weighted images in arterial phase and venous phase.Two recent studies evaluated the usefulness of MR and MRCP in the pre-surgical diagnosis of Ca GB[130,131].

Schwartz et al retrospectively studied MR findings in 34 patients with known diagnosis of Ca GB and compared them with intra-operative observations in 19 of these cases and with histopathologic diagnosis in 15. MR was able to demonstrate 17 out of 19 cases of hepatic invasion of >2 cm. Schwartz identified four out of the six cases with involvement of the omentum[130]. Similar results were obtained by **Tseng et al**[131] in 18 patients with Ca GB; MR correctly detected 11 of 12 patients with hepatic invasion, 13 patients with node involvement, 15 of 16 with bile duct involvement and none of patient with peritoneal involvement.

Kim et al[132] added MRA to MR in T1-, T2-weighted sequences and MRCP, which facilitated the diagnosis of vascular infiltration, crucial before attempting curative resection.

Periampullary carcinomas arise within 2 cm of the major papilla in the duodenum and include four different types of malignancies, namely, those originating from:
(a) the ampulla of Vater itself
(b) the intrapancreatic distal bile duct
(c) the head and uncinate process of the pancreas
(d) the duodenum.

Their origins are difficult and often impossible to discern based on clinical settings and results of preoperative imaging, as well as on surgical specimens[133].

Overall survival is highest for patients with ampullary and duodenal cancers, intermediate for patients with bile duct cancers, and lowest for those with pancreatic cancers[133].

The ampulla of Vater comprises the junction of the biliary and pancreatic ducts and is surrounded by the sphincteric system of Oddi. In 75% of cases, the major duodenal papilla is in the descending duodenum. In these cases, the terminal pancreatic duct is inferior and anterior to the CBD. In 25% of cases, the major duodenal papilla is in the horizontal duodenum. In these cases, the pancreatic duct is positioned vertically and parallel to the left border of the CBD [134].

Kim et al[133] reviewed Magnetic resonance (MR) images of pathologically proved periampullary carcinomas (29 ampullary carcinomas, 27 distal common bile duct carcinomas, 21 pancreatic carcinomas, six duodenal carcinomas, and six unclassified carcinomas) of 89 patients. He concluded that ampullary carcinoma manifests as a small mass, periductal thickening, or bulging of the duodenal papilla. Pancreatic carcinoma is characterized by a discrete parenchymal mass, which enhances poorly on dynamic gadolinium-enhanced images. Dilatation of side branches of the pancreatic ducts is frequently seen in pancreatic carcinoma but not in other periampullary carcinomas. Distal bile duct carcinoma manifests as luminal obliteration and wall thickening or as an intraductal polypoid mass. A dilated proximal bile duct, a non-dilated distal bile duct, and a dilated or non-dilated pancreatic duct may form the three-segment sign. MR Cholangiopancreatography and sectional MR imaging are useful in determining the origins of periampullary carcinomas.

Pham et al[135] in his study of periampullary Ca concluded that, volumetric oblique coronal reformations are a useful non-invasive method to provide diagnostic information about periampullary abnormalities as well as show secondary features important for local staging and management.

Sugita et al in their study of periampullary tumors concluded that, MR imaging correctly depicted location, extension, and origin of tumor. High-spatial-resolution MR imaging has potential for pre-surgical staging of tumors in this region[136].

MRCP has evolved as an accurate diagnostic modality for the evaluation of pancreaticobiliary diseases; however, there is still a limitation in the evaluation of periampullary disease. This is because of the small but relatively complex anatomy of this region and because the tapered area of the distal biliary and pancreatic ducts contains little or no fluid. Physiologic contraction of the sphincter of Oddi also makes it difficult to evaluate the periampullary area. The combination of MRCP with conventional T1- and T2-weighted MR imaging, including gadolinium-enhanced dynamic MR imaging, is important for the evaluation of periampullary disease in terms of both detection and evaluation of the extent of a periampullary mass. Marked and abrupt dilatation of the distal bile duct or the pancreatic duct in the absence of stone disease or pancreatitis is suggestive of ampullary carcinoma. Pancreatic masses are usually more clearly delineated on gadolinium-enhanced spoiled GRE images than on unenhanced T1- or T2-weighted images[133]. In patients with periampullary carcinomas of bile duct origin, the distal segment of the bile duct below the obstruction was also frequently seen on MRCP images; hence, three segments (the proximal and distal segments of the bile duct, and the main pancreatic duct) were depicted in the periampullary area (we call this the three-segment sign)[133]. Duodenal carcinomas may manifest as polypoid or fungating, ulcerative, and annular constrictive or infiltrative masses and are associated with lymphatic metastases in 22%–71% of cases. Therefore, the ability of MR imaging to depict the mass depends on the size of the tumor and the degree of narrowing of the duodenal lumen[133].

Cholangiocarcinoma

Cholangiocarcinoma is a primary tumor arising from the bile duct epithelium and is the second most common primary hepato-biliary cancer after hepatocellular carcinoma. At histopathological analysis, cholangiocarcinomas are predominantly adenocarcinomas (95% of cases), although other histologic types have also been described [117]. Cholangiocarcinoma is mainly a tumor of the elderly, with peak prevalence during the 7th decade of life and a slight male predilection[117].

Cholangiocarcinomas can be classified anatomically as intrahepatic (peripheral), perihilar, or extra-hepatic. Perihilar cholangiocarcinoma arises at the bifurcation of the hepatic ducts, whereas intrahepatic (peripheral) cholangiocarcinoma arises from beyond second-order bile ducts (Fig. 7) [118]. Intrahepatic cholangiocarcinoma can be classified into three types on the basis of gross morphologic features: mass-forming (the most common), periductal infiltrating, and intraductal growth[126].

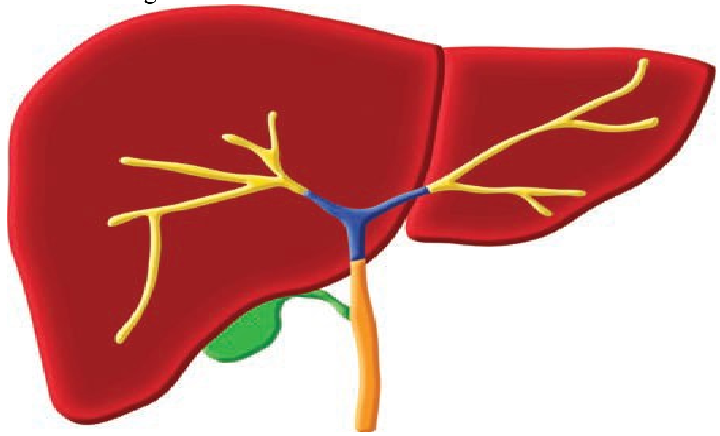


Figure-7:- Drawing illustrates the locations of the three types of cholangiocarcinomas: intrahepatic (peripheral) (yellow), perihilar (blue), and extrahepatic (orange).

Risk Factors for Cholangiocarcinoma

1. Liver flukes (Opisthorchis viverrini, Clonorchis sinensis)*

2. Hepatolithiasis (recurrent pyogenic cholangitis)*
3. Primary sclerosing cholangitis (PSC)
4. Viral infection (human immunodeficiency virus, hepatitis B virus, hepatitis C virus, Epstein-Barr virus)
5. Anomaly and malformation (anomalous pancreatico-biliary junction and choledochal cyst, fibrocystic liver diseases [e.g., Caroli disease])
6. Environmental or occupational toxin (thorotrast, dioxin, polyvinyl chloride)
7. Biliary tract–enteric drainage procedures
8. Heavy alcohol consumption

Primary sclerosing cholangitis (PSC), choledochal cyst, familial polyposis, hepatolithiasis, congenital hepatic fibrosis, clonorchiasis, and a history of exposure to thorotrast are common risk factors for cholangiocarcinoma[119]. A higher prevalence of positive anti–hepatitis C virus has been reported to be associated with cholangiocarcinoma[120].

US is the initial screening imaging modality for evaluating biliary dilatation in patients with jaundice because it is inexpensive and widely available. With the use of modern high-resolution equipment, the sensitivity of US in detecting Klatskin tumor has risen dramatically in recent years, from a reported low of 33% in 1983 [121] to a reported high of 96% in 1996 [122]. Biliary dilatation is the most common indirect sign of a cholangiocarcinoma, with the abrupt change in ductal diameter indicating the site of the tumor. Klatskin tumors manifest with segmental dilatation and disruption of the confluence of the RHD and LHD at the porta hepatis. Often there is hepatic lobar atrophy, biliary dilatation, and crowding of bile ducts. A definitive mass is rarely seen at US. US may be helpful in establishing the level of obstruction, but an intraductal or infiltrating lesion causing the obstruction may be difficult to visualize.

With use of US, **Neumaier et al** [123] were able to establish the level of intrahepatic biliary obstruction in 100% of patients with ductal ectasia but demonstrated a tumor in only 37.1% of cases.

With the emergence of multidetector scanners, CT has become the noninvasive diagnostic test of choice for detailed evaluation and staging of cholangiocarcinomas. Multidetector CT is versatile and widely available. It depicts the level and cause of biliary obstruction and helps to survey the entire abdomen for disease staging. Cholangiocarcinomas are usually hypo- to iso-attenuating relative to the normal hepatic parenchyma at unenhanced CT. After the intravenous administration of contrast material, most cholangiocarcinomas remain hypoattenuating during the arterial and portal venous phases and show enhancement during the delayed phase, findings that reflect their hypovascular desmoplastic composition[124,125]. Volumetric multidetector CT with advanced post-processing allows comprehensive evaluation of cholangiocarcinomas in a single examination.

MR imaging with MR cholangiography and dynamic contrast-enhanced MR angiography is yet another multifaceted modality for the comprehensive evaluation of cholangiocarcinoma. Relative to the normal liver parenchyma, mass forming cholangiocarcinomas are typically hypo to isointense on T1-weighted MR images and variably hyperintense on T2-weighted MR images depending on the amount of mucinous material, fibrous tissue, hemorrhage, and necrosis within the tumor. On fat- saturated T1-weighted images obtained following intravenous contrast material administration, minimal or incomplete enhancement is seen at the periphery on early images, whereas delayed progressive enhancement is seen on late-phase images; these findings represent neoplastic cells at the periphery and desmoplastic response at the center of the lesion However, smaller lesions with less fibrosis may show intense homogeneous enhancement during the arterial phase, with prolonged enhancement during the delayed phase. Satellite nodules are seen in about 10%–20% of cases of cholangiocarcinoma and should be looked for on the dynamic data set, since they indicate a poor prognosis. Concurrently performed high-quality T2-weighted MR cholangiography can further complement contrast-enhanced MR imaging in depicting the site of ductal obstruction and associated upstream biliary dilatation [126].

The reported accuracy of MR cholangiography in localizing the site and determining the cause of biliary obstruction is 100% and 95%, respectively [126]. 3D MR cholangiography, which consists of inherently continuous data, allowsreformatted images to be acquired in various anatomic planes and then rotated, thereby improving the visibility of the biliary tree and cholangiocarcinomas [126].

Morphologic Classification:
Cholangiocarcinoma is classified into mass-forming, periductal infiltrating, and intraductal growth types:

Mass-forming Type
Mass-forming cholangiocarcinoma is characterized morphologically by a homogeneous mass with an irregular but well-defined margin and is frequently associated with dilatation of the biliary trees in the tumor periphery. The mass shows an irregular margin with high signal intensity at T2-weighted imaging and with low signal intensity at T1-weighted imaging. Both the peripheral and the centripetal enhancement may be more prominent at MR imaging than at CT[126].

Periductal Infiltrating Type
Periductal infiltrating cholangiocarcinoma is characterized by growth along a dilated or narrowed bile duct without mass formation and manifests as an elongated, spiculated, or branchlike abnormality. At CT and MR imaging, diffuse periductal thickening and increased enhancement due to tumor infiltration can be seen, with an abnormally dilated or irregularly narrowed duct and peripheral ductal dilatation (Fig 7). This type of tumor is rare in intrahepatic cholangiocarcinoma, but most hilar cholangiocarcinomas are of this type[126].

Intraductal Type
Diffuse and marked ductal dilatation with an intraductal mass that enhances at contrast enhanced MR imaging, marked intrahepatic duct dilatation with no mass or stricture, an intraductal polypoid mass within localized ductal dilatation, an intraductal cast like lesion within a mildly dilated duct, or a focal stricture-like lesion with mild proximal ductal dilatation[126].

Pancreatitis
Pancreatitis is the most common pancreatic disease in children and adults and one of the most common causes of morbidity and mortality worldwide[93].

The diagnosis of acute pancreatitis is usually based on clinical and lab findings with clinical severity best determined by Ranson's criteria or Acute physiology and Chronic Health Evaluation. (APACHE) II criteria[102].

Causes of Acute Pancreatitis:
(1) Biliary Tract disease
(2) Alcohol abuse
(3) Peptic ulcer
(4) Trauma, Surgery (CABG), hypotension, shock.
(5) Pregnancy
(6) Hyperlipoproteinemias types I, IV & V
(7) Hypercalcemia
(8) Drugs (Azathioprine, Estrogens, Corticosteroids, Thiazides)
(9) Hereditary Pancreatitis
(10)Infectious agents (Mumps, Varicella)
(11) Scorpion bites
(12) ERCP
(13) Post-transplantation

Over one-half of cases of acute pancreatitis in adults are related to cholelithiasis or alcohol consumption, whereas trauma, viral infections, and systemic disease account for the majority of cases in children. Alcohol consumption accounts for the majority (80%) of cases of chronic pancreatitis in adults in developed countries, whereas malnutrition is the most common cause worldwide. Idiopathic pancreatitis is considered to be the most common cause of chronic pancreatitis in children (up to 30% of cases). In truth, however, hereditary and tropical pancreatitis are responsible for the majority of cases of chronic childhood pancreatitis[93].

US findings in acute pancreatitis can be classified by distribution (focal or diffuse) and by severity mild, moderate and severe. US findings may be negative in the milder forms of acute pancreatitis. Focal pancreatitis, presenting as focal isoechoic or hypoechoic enlargement of the pancreas without extra pancreatic manifestation generally occurs in the pancreatic head. These patients are usually alcohol abusers. Differentiation from neoplasm may be difficult because both conditions create a focal hypoechoic mass on sonogram. If the serum amylase level is normal and patient is asymptomatic, the mass is likely to represent a neoplasm. If the signs and symptoms are severe associated with calcification the focal hypoechogenicity is more likely to be caused by inflammatory mass.

Complications of Pancreatitis:
(1) Pancreatic pseudocyst
(2) Obstruction of the stomach, small bowel, colon or bile duct
(3) Pseudocysts dissecting into adjacent organs
(4) Gastrointestinal hemorrhage
(5) Chronic pancreatitis

In diffuse pancreatitis, the pancreas becomes increasingly hypoechogenic relative to the normal liver and increases in size. Assessment of relative pancreatic echogenicity may be difficult because of the alcohol induced fatty liver present in a large number of these patients. The pancreas may appear inhomogeneous. The pancreatic duct may be compressed or dilated. US is an insensitive test in the detection of pancreatic necrosis and other complications and, therefore, should not be used to assess the severity of pancreatitis. However, US may be helpful in diagnosis of gall stones, follow-up of fluid collections and pseudocysts in selected cases. US may also be used to guide interventional procedures, such as catheter drainage, but in general CT is preferred.

Traditionally, CT has been used to help confirm the diagnosis, assess disease severity, detect complications, and provide a "road map" for interventional procedures. CT also plays a pivotal role in evaluating the impact of various medical and surgical treatments [93].

CT has four major indications in patients with suspected or known acute pancreatitis:
(a) to establish the diagnosis and exclude other serious intra-abdominal conditions;
(b) to assess the severity of the pancreatitis;
(c) to detect pancreatic and extra-pancreatic complications, such as pancreatic necrosis, abscess formation, and involvement of surrounding solid organs, vascular structures or gastrointestinal tract, and
(d) to guide percutaneous interventions, such as aspiration and drainage of fluid collections[94].

Balthazar et al[95] constructed a CT severity index (CTSI) for acute pancreatitis that combines the grade of pancreatitis with the extent of pancreatic necrosis.

Prognostic indicators	Characteristics	.Points
Pancreatic inflammation -	Normal pancreas	0
	Focal or diffuse enlargement of the pancreas	1
	Intrinsic pancreatic abnormalities with inflammatory changes in the peripancreatic fat	2
	Single, ill-defined fluid collection or phlegmon	3
	Two or more poorly defined collections or presence of gas in or adjacent to the pancreas	4
Pancreatic necrosis -	.No necrosis	0
	30% or less	2
	.30%- 50%	4
	greater than 50%	6

Total score of CT severity index is 10. A Score of 7-10 denotes severe pancreatitis, 4-6 denotes moderate pancreatitis and 0-3 is mild pancreatitis.

In the assessment of acute pancreatitis, MRI can depict the presence and extent of necrosis and peri-pancreatic fluid collections. Recently **Amano et al**[96] demonstrated the superiority of unenhanced MRI over CT in the detection of mild acute pancreatitis. The rationale for using MRI instead of CT in these cases is, because mild pancreatitis cannot be well visualized by CT. However, several authors recommend intravenous gadolinium administration in imaging severe acute pancreatitis, particularly for the assessment of pancreatic parenchymal perfusion and presence of necrosis[97]. Moreover, gadolinium has a good renal tolerance and is better tolerated than the iodinated contrast agents used in CT.

Lecesne et al[98] proposed a pancreas protocol including T2- weighted fast SE, fast-suppressed T1-weighted fast SE, and a series of T1-weighted gradient echo sequences prior and immediately following gadolinium administration. With this protocol, the authors reported that MRI is a reliable method for staging acute pancreatitis and is at least as helpful as CT is in reaching a prognosis. The enlargement of the gland is well demonstrated on any sequence. Parenchymal edema and areas of hemorrhage are better shown on unenhanced T1-weighted images. T2-weighted sequences are most sensitive in demonstrating fluid collections and are especially helpful in determining the amount and extent of debris in presumed fluid collections.

Chronic Pancreatitis

Chronic pancreatitis is an inflammatory disease characterized by progressive and irreversible structural damage to the pancreas resulting in permanent impairment of both exocrine and endocrine functions.

US findings consist of changes in size and echo texture of the pancreas, focal mass lesions, calcification, pancreatic duct dilatation and pseudocyst formation. Bile duct dilatation and portal vein thrombosis are other associated findings. Focal mass or enlargement is found in 40% of patients. Irregular dilatation of pancreatic duct occurs in chronic pancreatitis. In advanced cases, the duct becomes tortuous. The differential diagnosis between chronic pancreatitis and pancreatic carcinoma in a patient with duct dilatation can be difficult. Pseudocyst formation is reported in 25-40% of patients with chronic pancreatitis. Dilatation of CBD is present in 5-10% of pts with chronic pancreatitis and characteristically causes smooth gradual tapering, although abrupt tapering is rarely seen. Porto-splenic vein thrombosis has also been reported to occur in 5.1% of patients and cavernous transformation may be present.

A Revised Cambridge classification of chronic pancreatitis has been proposed and preliminary studies indicate good correlations based on findings of ERCP and US [99].

Revised Cambridge Classification of Chronic Pancreatitis

Class*	Ultrasound Features
Normal	Visualization of entire gland and demonstration and measurement of MPD
Equivocal	Less than two abnormal signs - Main duct enlarged (less than 4 mm) - Gland enlargement (up to twice normal) - Cavities (less than 10 mm) - Irregular Ducts
Mild	Focal reduction in parenchymal echogenicity
Moderate	Two or more abnormal signs - Echogenic foci in parenchyma - Increase or irregular echogenicity of wall of main duct - Irregular contour of gland, particularly focal enlargement
Marked	- Large cavities (greater than 10 mm) - Calculi Duct obstruction (> 4 mm) - Major duct irregularity - Gross enlargement of MPD (> 4 mm) - Contiguous organ involvement

(*If pathologicalchanges are limited to one third of the gland or less they are classified as focal)

The diagnosis of chronic pancreatitis on MRI is based on signal intensity and enhancement changes as well as morphologic abnormalities in the pancreatic parenchyma, pancreatic duct and biliary tract. The imaging findings can be divided into early and late findings.

Early findings include low signal intensity pancreas on T1W fat suppressed images, decreased and delayed enhancement after I.V contrast administration and dilated side branches. Late findings include parenchymal atrophy or enlargement, pseudocysts and dilatation and beading of pancreatic duct often with intraductal calcification.

These changes are best visualized on unenhanced and gadolinium enhanced T1W fat suppressed images. The normal pancreas enhances uniformly and intensely on early arterial phase contrast enhanced T1W images and exhibits rapid wash out of gadolinium on subsequent images. Normal pancreas has signal on unenhanced T1W fat suppressed images. In contrast, a pancreas with chronic fibrosis and glandular atrophy exhibits a decreased and heterogeneous enhancement on early arterial phase images and increased relative enhancement on delayed images. Administration of secretin during MRCP may help detect subtle side branch abnormalities and allow non-invasive assessment of the exocrine pancreas. In addition, MRCP is highly accurate for identifying pancreatic divisum. However, its association with chronic pancreatitis remains controversial. Duct abnormalities such as dilatation, irregularity and stones and complications of chronic pancreatitis such as pseudocysts are best depicted by thin section T2W HASTE or SSFSE and thick slab T2W Half Fourier RARE MRCP images[100].

MRCP is sensitive for depicting strictures of the pancreatic and biliary tract. CT is more sensitive than MRI for detection of calcifications associated with chronic pancreatitis.However, MRI best depicts the intraductal stones and duct obstruction. The typical appearance of benign strictures on MRCP is gradual tapering with a funnel like narrowed segment [100].

Pseudocyst

Pseudocysts are encapsulated collections of pancreatic secretions that occur in or around the pancreas. Although most resolve spontaneously, complications such as infection, hemorrhage, and gastric or biliary obstruction may occur (Fig. 11). Pseudocysts can be communicating with the main pancreatic duct (Fig. 12) or non-communicating (Fig. 13). MRI can depict pseudocysts and can be used to characterize their content and thus to guide drainage. Uncomplicated pseudocysts are typically unilocular and encapsulated fluid collections that exhibit high signal intensity on T2WI and low signal on T1WI. Complicated pseudocysts and other pancreatic collections may contain solid debris, which is depicted best by MRI [101].

Pancreatic Necrosis

Severe acute pancreatitis occurs in approximately 20-30% of cases and it is usually associated with pancreatic necrosis and increased complications and mortality. Determining the extent of necrosis is important because it has significant correlation with patient prognosis. OnT2W images necrosis can be of low signal intensity or when liquefied, hyperintense. At times necrosis may be better identified on MRI than CT[101].

Vascular: Arterial pseudoaneurysms, hemorrhage into pseudocysts, arterial bleeding, and splenic or portal vein thrombosis are vascular complications of chronic pancreatitis that may be seen on MRI. In patients with chronic splenic vein thrombosis, the vein may not be visualized. Short gastric and gastroepiploic collaterals constitute useful complementary findings[100].

Pancreatic Abscess

Abscesses usually occur up to 4 weeks after the onset of acute pancreatitis and can appear similar to pseudocysts. They are suggested when gas is present in a pancreatic or peripancreatic collection. MRI can reveal air fluid levels or large pockets of gas but CT is more sensitive for small collections of gas[101].

Hemorrhage Or Pseudoaneurysm

They can occur in patients with severe necrotizing pancreatitis or as result of rupture of a pseudo-aneurysm when it constitutes a life-threatening emergency. Hemorrhagic fluid collections are more evident on MRI than CT because of the following:
(1) High signal intensity of methemoglobin on T1W images.
(2) Low signal intensity hemosiderin rim on T2W images
(3) Signal abnormalities due to hemorrhage remaining visible longer on MRI than CT.

Contrast enhanced sequences confirm the diagnosis by showing enhancement of the pseudo-aneurysm as comparable to arteries and its connection to the vessels. Although CT is currently the primary technique used to evaluate patients for acute pancreatitis, recent advances allow MRI to be used for the diagnosis and detection of complications. MRI has the potential advantage because of its lack of ionizing radiation and lack of nephrotoxicity from iodinated contrast[101].

Groove Pancreatitis

Groove pancreatitis is a type of focal chronic pancreatitis affecting the groove between the head of the pancreas, duodenum and common bile duct. The predominant MRI finding of groove pancreatitis is a sheet like fibrotic mass between the pancreatic head and thickened duodenal wall associated with duodenal stenosis and cystic changes in the duodenal wall. The recognition of groove pancreatitis is important for differentiation from pancreatic and duodenal carcinomas[100].

Tamura et al[102] in his study of chronic pancreatitis concluded that, use of ERCP tends to result in overestimation of the caliber of the MPD. MRCP can enable accurate evaluation of the condition of the pancreatic duct and its changes in patients with chronic pancreatitis.

Congenital Anomalies Of Pancreas And Pancreatic Duct

Congenital anomalies and normal variants of the pancreatic duct and the pancreas may not be detected until adulthood and then are often detected as incidental findings in asymptomatic patients[103-107]. Because an increasing number of patients undergo MRI, MR Cholangio-pancreatography (MRCP), and CT examinations, these anomalies are recognized more frequently. At the same time, the rapid advances in and emergence of surgical and endoscopic procedures, such as insertion of stents in the minor papilla for pancreatic Divisum [104], make recognition of these variants, particularly those of clinical significance, very important. Congenital anomalies and normal variants of the pancreas and the pancreatic duct include pancreas divisum, annular pancreas, ectopic pancreatic tissue, variations of pancreatic contour, fatty replacement and fat sparing of the pancreas, pancreatic cysts, and variations of pancreatic ducts.

Pancreas Divisum

Pancreas divisum is the most common congenital pancreatic ductal anatomic variant, occurring in approximately 4–14% of the population at autopsy series, 3–8% at ERCP, and 9% at MRCP[103-107]. The abnormality results from failure of the dorsal and ventral pancreatic anlage to fuse during the sixth to eighth weeks of gestation. In most cases of pancreatic divisum, no communication exists between the dorsal and ventral pancreatic ducts (fig.8c). In some patients, the ventral pancreatic duct may be absent. In all cases, most pancreatic secretions drain through the minor ampulla. The clinical relevance of pancreas Divisum remains controversial. Most patients with pancreas divisum are asymptomatic[104-107]. However, in some patients, this anomaly is associated with recurrent episodes of pancreatitis. Of those with idiopathic recurrent pancreatitis, 12–26% of patients have pancreas divisum, as opposed to 3–9% of the general population[107]. It is postulated that in pancreas divisum, the duct of Santorini and the minor ampulla are too small to adequately drain the secretions produced by the pancreatic body and tail[103-107].

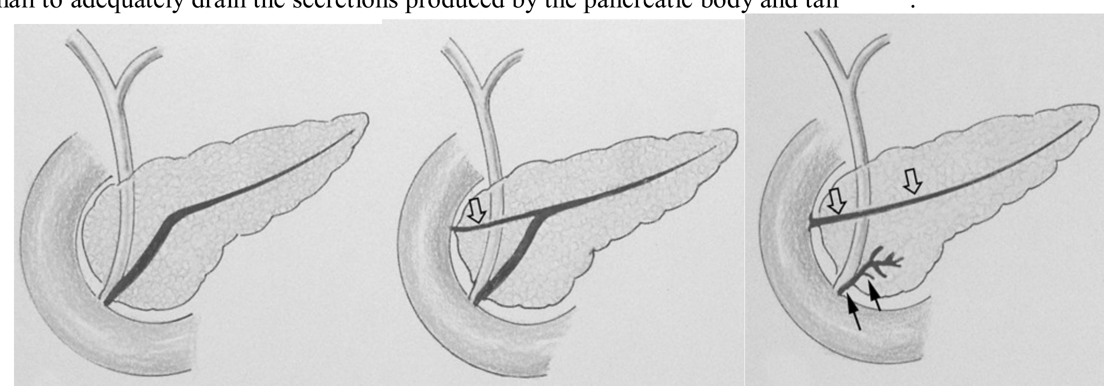


Fig. 8A **Fig. 8B** **Fig. 8C**

Figure-8:- Diagram of pancreatic ductal anatomic variants.

8A: Main pancreatic duct joining common bile duct drains via major papilla.

8B: Main pancreatic duct drains via major papilla. Accessory duct (Duct of Santorini) (open arrow) is patent and drains via minor papilla.

8C: Typical pancreatic divisum with small ventral duct (arrows) drains via major papilla. Larger dorsal duct (open arrows) drains via minor papilla.

For many years, ERCP has been the primary means of diagnosing pancreas divisum. MRCP provides a noninvasive means of diagnosing pancreas divisum without the use of contrast material and avoids the risk of ERCP-induced pancreatitis. The main features of pancreas divisum when using MRCP include the dorsal pancreatic duct in direct continuity with the duct of Santorini, which drains into the minor ampulla, and a ventral duct, which does not communicate with the dorsal duct but joins with the distal bile duct to enter the major ampulla[105]. With the advent of MDCT scanners, pancreas divisum may be seen using CT as well[106]. Recent research shows that the administration of secretin improves the sensitivity of MRCP in diagnosing Pancreatic Divisum[108].

Manfredi et al[108] studied usefulness of magnetic resonance (MR) Cholangiopancreatography (MRCP) before and after secretin administration in diagnosing santorinicele and concluded that S-MRCP helps in identifying pancreas divisum and santorinicele, which may be the cause of impeded pancreatic outflow in patients with pancreas Divisum. Cystic dilatation of the distal dorsal duct, just proximal to the minor papilla, termed "santorinicele".

Annular Pancreas

Annular pancreas is a rare anomaly (1/20,000 people) in which a band of pancreatic tissue surrounds the descending duodenum, either completely or incompletely, and is in continuity with the head of the pancreas [103,109]. The most widely accepted theory of etiopathogenesis is that the ventral pancreatic anlage is responsible for the anomaly by dividing early into two segments[109]. The ventral pancreatic bud consists of two components that normally fuse and rotate around the duodenum so that they come to lie posteriorly and inferiorly to the dorsal pancreatic bud. Occasionally however, the right portion of the ventral bud migrates along its normal route but the left migrates in the opposite direction. By these means the duodenum becomes surrounded by pancreatic tissue. Since it forms a 'ring like structure' around the duodenum it is known as an annular pancreas (fig.9). The anomaly may be discovered incidentally in asymptomatic patients [109]. In others, annular pancreas is associated with duodenal stenosis, postbulbar ulcerations, pancreatitis, or biliary obstruction.

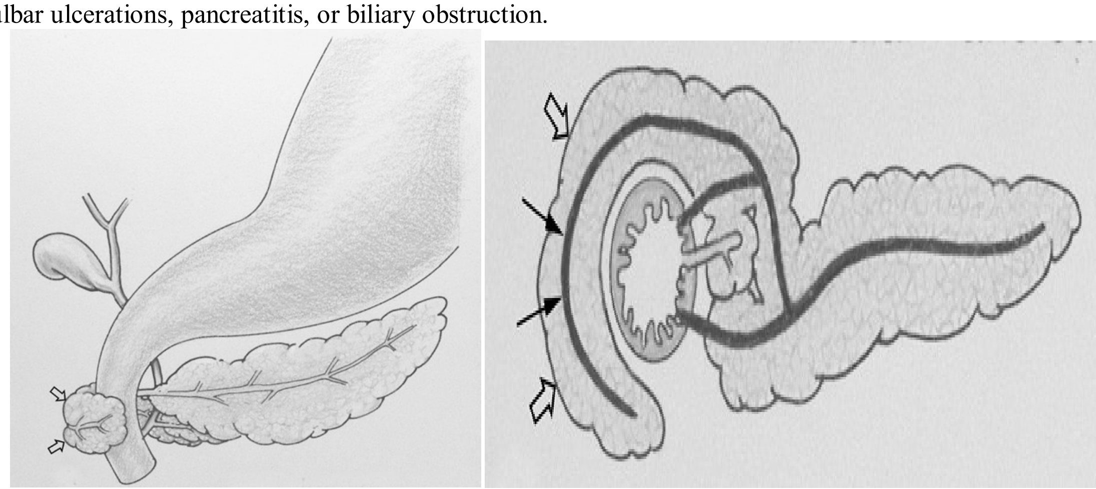


Fig.9A **Fig.9B**

Figure-9:- Diagram of annular pancreas (development)

9A:Frontal view shows pancreatic tissue (arrows) encircling descending duodenum.

9B: Axial view shows pancreatic tissue (open arrows) with accessory pancreatic duct (arrows) encircling duodenum.

Before the advent of CT, MRI, and MRCP, the diagnosis of annular pancreas was usually established by ERCP, as an aberrant pancreatic duct communicating with the main pancreatic duct and encircling the duodenum. CT or MR images may show normal pancreatic tissue, with or without a small pancreatic duct, encircling the duodenum [109]. The findings at upper gastrointestinal examinations are often characteristic in that narrowing of the second portion of the duodenum. Surgical resection is recommended for symptomatic cases.

CA PANCREAS

Pancreatic ductal adenocarcinoma is the fifth leading cause of cancer death in the Western hemisphere with a peak incidence in patients between 60 and 80 years old. Factors associated with an increased risk of pancreatic cancer include smoking, chronic pancreatitis, diabetes, prior gastric surgery, and exposure to radiation or chemicals such as chlorinated hydrocarbon solvents [110, 111]. A number of syndromes are identified with an increased incidence of pancreatic cancer, including familial atypical multiple-mole melanoma syndrome, hereditary nonpolyposis colorectal cancer, hereditary pancreatitis, Peutz-Jeghers syndrome, and hereditary breast–ovarian cancer syndrome[112].

Table-1:- TNM staging Ca Pancreas.

Classification	Description

T (Tumor)	
Tx	Primary tumor not assessed.
Tis	Carcinoma in situ.
T1	Tumor is ≤ 2 cm in maximum diameter and confined to pancreas.
T2	Tumor is > 2 cm and confined to pancreas.
T3	Tumor extends beyond pancreas but does not involve celiac axis or superior mesenteric
T4	artery.
N(Nodal Involvement)	Primary tumor involves either celiac axis or superior mesenteric artery.
Nx	
N0	Regional lymph nodes not assessed.
N1	No involvement of regional lymph nodes.
M (Metastases) Mx	Involvement of regional lymph nodes.
M0	Distant metastasis cannot be assessed.
M1	No distant metastases.
	Distant metastasis present.

Imaging often begins with transabdominal sonography (TAS) to identify a cause of abdominal pain or jaundice. Sonography can screen for gallstones, signs of cholecystitis, and for the presence and level (intrahepatic, suprapancreatic, or intrapancreatic) of common bile duct obstruction. However, the presence of obscuring overlying bowel gas and the variable skill of the operator limit the sensitivity of this technique for identification and staging of pancreatic tumors.

Sensitivity of MR imaging and CT in the detection of malignancy was 100% and 92% (95% CI, 0.90–0.94), respectively. The positive predictive value was 90% for MR imaging and 80% for CT, and the negative predictive value was 100% for MR imaging and 67% for CT[142].

After Sonography, CT is the modality most used as the primary modality for diagnosis and staging. The relatively hypovascular tumor is best detected during the pancreatic parenchymal phase of enhancement, approximately 35–50 secs after the beginning of contrast medium injection [113, 114]. On the other hand, liver metastases are best imaged during the portal venous phase of liver enhancement, approximately 60– 70 secs after the beginning of contrast medium injection. A “dual-phase” technique is therefore often used to obtain information regarding staging and metastases. Thin- section imaging is vital for optimizing lesion detection; thin-section imaging diminishes the impact of volume averaging on obscuring small lesions.

MR imaging offers several benefits for imaging of the pancreas. It inherently offers better soft-tissue contrast than CT before the administration of an IV contrast agent, and images can be obtained in multiple planes. MR imaging can be performed in patients with a history of allergy to iodinated contrast agents and in those with renal insufficiency. However, CT offers higher spatial resolution. MR imaging protocols typically include T1-weighted spin-echo or fast spoiled-gradient breath-hold sequences with or without fat suppression, T2-weighted fast spin-echo with fat suppression sequences, and dynamically enhanced T1-weighted spoiled-gradient breath-hold with or without fat suppressions. MRCP images obtained with long echo times have been used to create cholangiographic images. Images in MRCP can be acquired in any plane to provide additional information on the level of obstruction of the biliary or pancreatic ductal systems, with a sensitivity and specificity that rivals that of Endoscopic Retrograde Cholangiopancreatography[115].

In the setting of pancreatic carcinoma, MRCP readily depicts the ducts obstructed by the pancreatic mass & localizes the obstruction to the pancreas. MRCP identifies not only the dilated ducts located proximal to the obstruction, but also the ducts that are narrowed & encased by the tumor. When the mass is located in the pancreatic head, the “double duct” sign is often observed. Although this sign raises the possibility of pancreatic carcinoma, it is a non-specific sign that may also occur in association with chronic pancreatitis. When MRI & MRA are performed in the same examination setting as MRCP, an assessment for resectability can be made. In those patients with unresectable disease, MRCP is useful in planning palliative endoscopic & percutaneous procedures [49].

Liver Metastases from pancreatic cancer typically appear as low signal intensity masses on the pre-contrast fat suppressed T1W SGE images & exhibit irregular rim enhancement on immediate post gadolinium fat suppressed T1W SGE images. These metastases appear minimally hyperintense on T2W HASTE or SSFSE images. MRI is more effective than CT in differentiating metastases from other hepatic masses including hemangiomas or cysts. Peritoneal metastases are better depicted on MRI than on CT. Lymphadenopathy is well shown as high signal intensity foci in a background of low signal intensity fat on the early interstitial phase (45 secs)gadolinium enhanced fat suppressed T1W SGE & fat suppressed T2W images [49].

Kamisawa et alfound that diffusion-weighted MRI (DWI) can be used to differentiate autoimmune pancreatitis (AIP) from pancreatic cancer. In a study of 13 patients with AIP and 40 patients with pancreatic cancer High-signal intensity areas, were diffuse or solitary in patients with AIP, but solitary in patients with pancreatic cancer. Pancreatic cancer more often had a nodular shape, while AIP more often had a longitudinal shape. Apparent diffusion coefficient (ADC) values were significantly lower in AIP than in pancreatic cancer, and an optimal ADC cutoff value of 1.075×10^{-3} mm^2/s could be used to distinguish AIP from pancreatic cancer[116].

Materials & Methods:-

Study Place

The present study is conducted in Department of Radiodiagnosis, Mysore Medical College & Research Institute, Mysore.

Study Duration

The present study is conducted over a period of one year nine months commencing from January 2019 to September 2020.

Study Population

Sample Size

The study comprised a total of 30 patients referred to Radiology department with suspected pancreatico-biliary disease who met the following criteria.

Inclusion Criteria

All patients who are detected to have any of the following pancreatico-biliary diseases on MRCP:

1. Acute & chronic pancreatitis
2. Pancreatic Malignancy
3. Cystic disease of bile duct (choledochal cyst, choledochocele)
4. Stones & strictures of the pancreas
5. Sclerosing Cholangitis
6. Primary Biliary Cirrhosis
7. Anatomic variants such as pancreatic divisum, aberrant cystic duct & other duct anomalies
8. Biliary diseases
9. Post-surgical biliary complications
10. Cholangiocarcinoma

Exclusion Criteria

1. Cardiac Pacemakers
2. Ferromagnetic aneurysm clips
3. Intraorbital metallic foreign bodies
4. Severe claustrophobia
5. Metallic orthopedic implants

Study Design

patient selection done as per inclusion & exclusion criteria

COMPLETE CLINICAL HISTORY OF THE PATIENT OBTAINED

SCAN DONE

FINDINGS CONFIRMED

DATA OBTAINED & STORED

DATA ANALYSIS

EQUIPMENT

The patient was scanned using 1.5 Tesla MRI scanner (GE Optima MR360).

Mri Scan Parameters

The following parameters were used for the patients

Sequences

Parameters	T2 FRFSE	Coronal SSFSE	Axial SSFSE	Axial 2D FIESTA	T1 FIRM	3D MRCP RTr
TR (ms)	405	4.1	4.1	3.3	.525	1204
TE (ms)	80	1.96	1.96	-1.63	-13	650
Flip Angle	90	10	10	-90	-90	90
FOV (mm)	300	295	295	- 300 -	- 300 -	260
ACQ Matrix	268x184	188x147	188x147	256x204	256x136	256x205

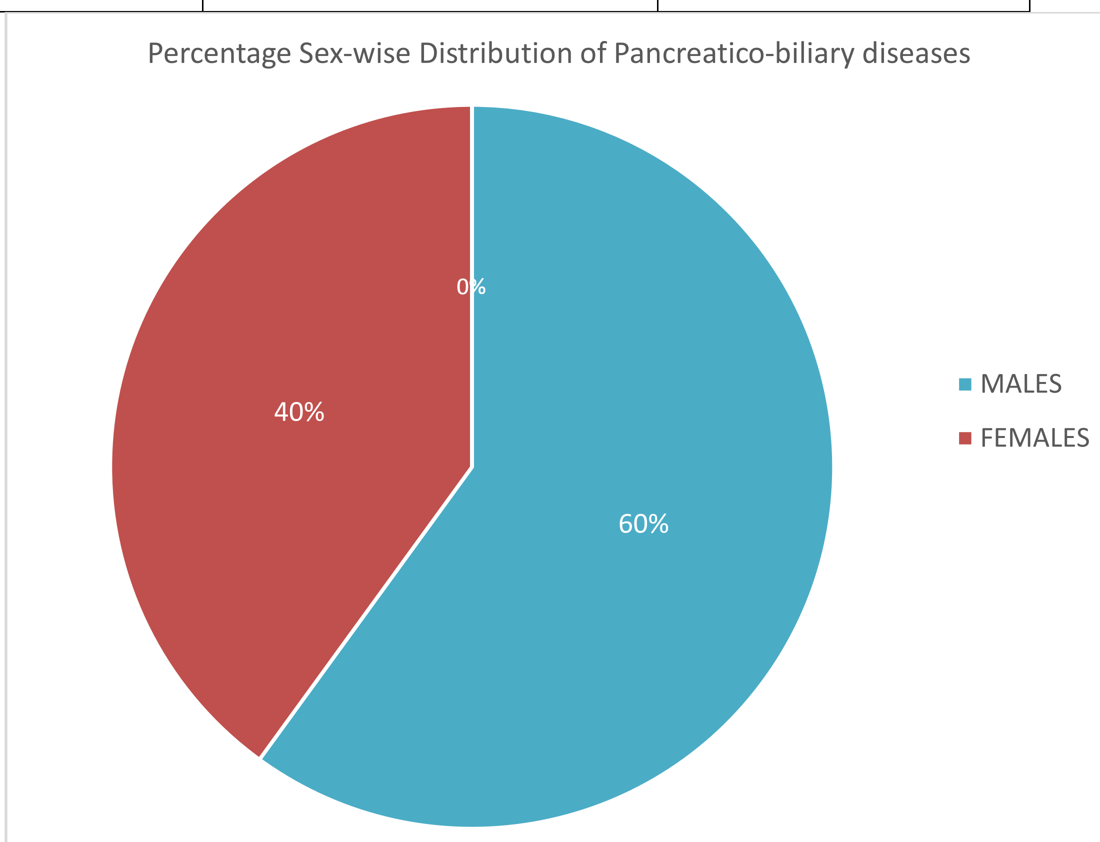
Size (mm)						
Slice Thickness (mm)	5.0	2	2	5.0	-5.0	-
TA	0.40 secs	16.3 secs	16.3 sec	0.68 secs	2.58 min	5.27 min

Observations & Results:-

A total of thirty patients who were clinically diagnosed as having pancreatico-biliary diseases were sent for MRCP & were included in the present study

Table No. 01:- Sex-Wise Distribution In The Pancreatico-Biliary Diseases.

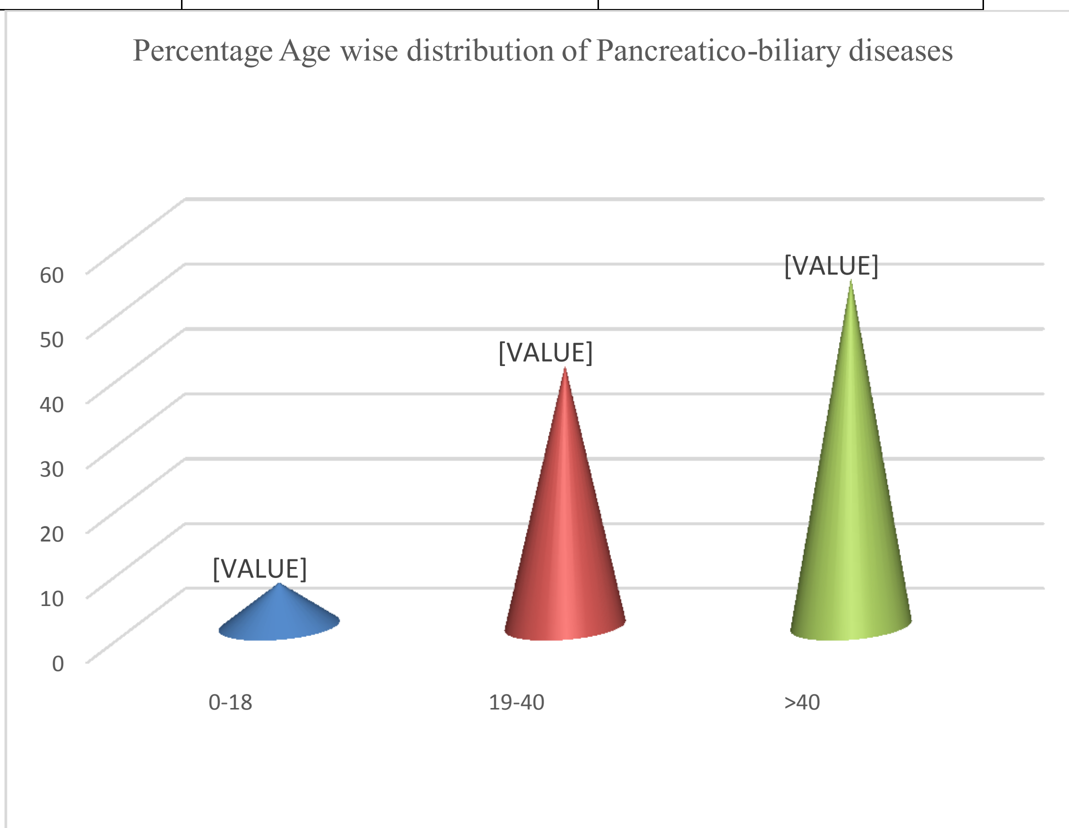
SEX	NO. OF CASES	PERCENTAGE (%)
MALES	18	60
FEMALES	12	40
TOTAL	**30**	**100**



Out of the 30 patients studied, 18 (60%) were male and 12 (40%) were female patients. In the present study, there is male preponderance, male: female ratio being 1.5:1.

Table No. 02: Age-Wise Distribution In Pancreatico-Biliary Diseases

AGE (YEARS)	NO. OF PATIENTS	PERCENTAGE (%)
0-18	02	6.6
19-40	12	40
> 40	16	53.4
TOTAL	30	100

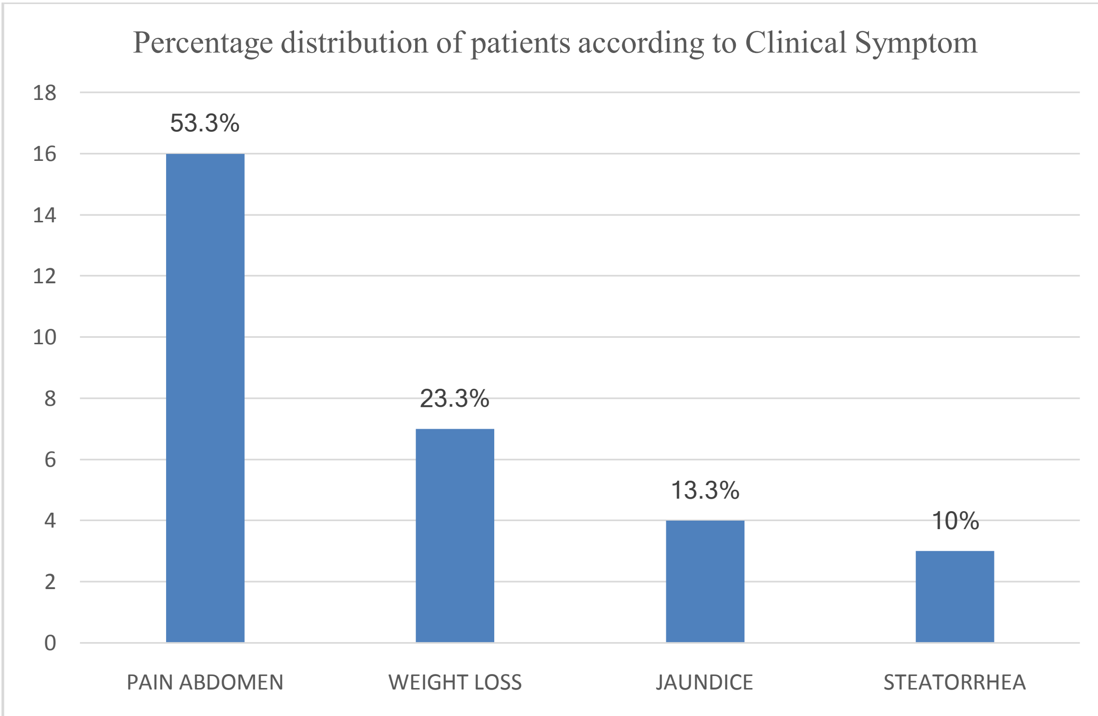


Out of the total 30 patients included in the study, maximum 16 (53.4%) were in the age group of > 40 years followed by 19-40 years age group which included 12 (40%). Least number of patients 2 (6.6%) were in the age group of 0-18 years. The mean age of study population was 37.5 (range 5-70 yrs).

Table no. 03:- Clinical symptoms presented by a patient with various pancreatico-biliary diseases.

SYMPTOMATOLOGY	NO. OF PATIENTS	PERCENTAGE
PAIN ABDOMEN	16	53.3%
WEIGHT LOSS	07	23.3%

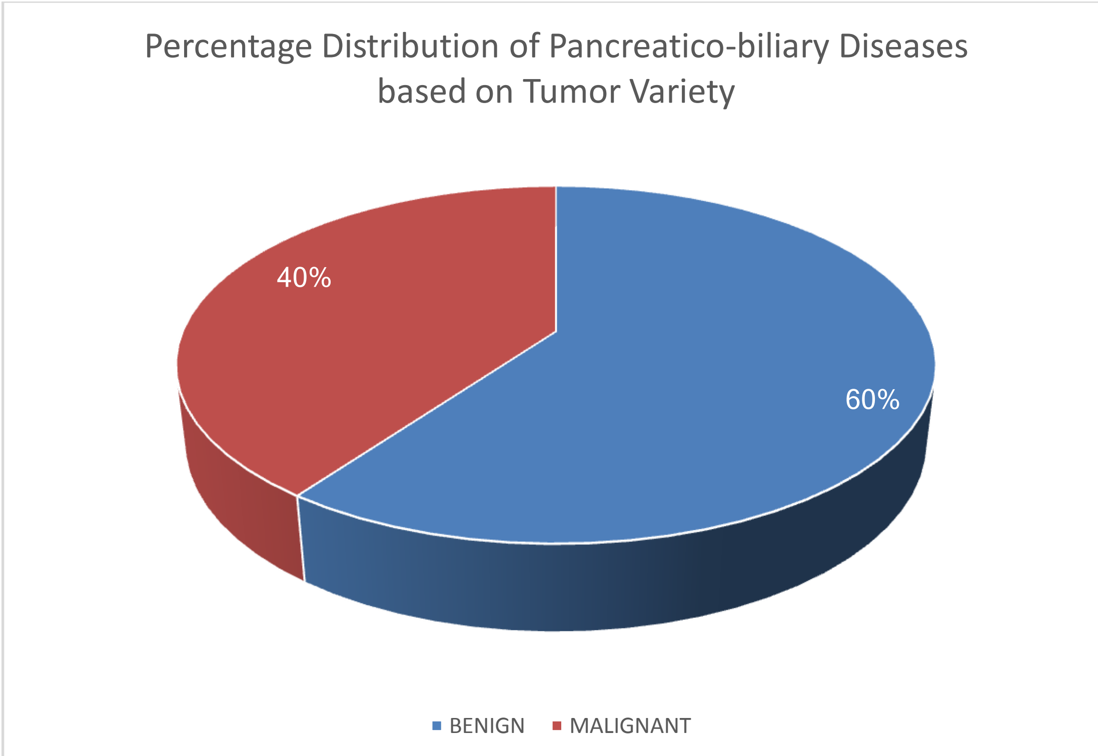
JAUNDICE	**04**	**13.3%**
STEATORRHEA	**03**	**10%**
TOTAL	**30**	**100**



Out of the total 30 patients included in the study, most common clinical presentation was pain in abdomen seen in 16 (53.3%) patients followed by weight loss seen in 7 (23.3%) patients, while least common presentation was steatorrhea seen in 3 (10%) patients. Most of patients presented with combination of symptoms.

Table No. 04:- Distribution Of Pancreatico-Biliary Diseases Based On Type Of Tumour Variety As Observed On Mrcp.

TYPE	NO. OF PATIENTS	PERCENTAGE (%)
BENIGN	**18**	**60%**
MALIGNANT	**12**	**40%**
TOTAL	**30**	**100 %**



Out of the total 30 cases included in the study, 18 (60%) patients had benign disorders, while 12 (40%) patients had malignant disorders. Few of patients with benign pathologies had combination of pathologies.

Table No. 05:- Number Of Patients Showing Various Diseases As Observed On Mrcp.

TYPE OF DISEASE	CASES	PERCENTAGE (%)
BILIARY ATRESIA	1	3.3
CHOLEDOCHAL CYST	2	6.7
CHOLEDOCHOLITHIASIS	4	13.4
POST-OPERATIVE STRICURE	1	3.3
CHOLANGIOCARCINOMA	6	20
CARCINOMA GALL BLADDER	1	3.3
PANCREATITIS	10	33.3
CARCINOMA PANCREAS	2	6.7

PERIAMPULLARY CARCINOMA	3	10
TOTAL	**30**	**100**

Out of the total 30 cases included in the study, most common disorder observed was Pancreatitis seen in 10 (33.3%). Second most common disorder was Cholangiocarcinoma seen in 6 (20%) patients.

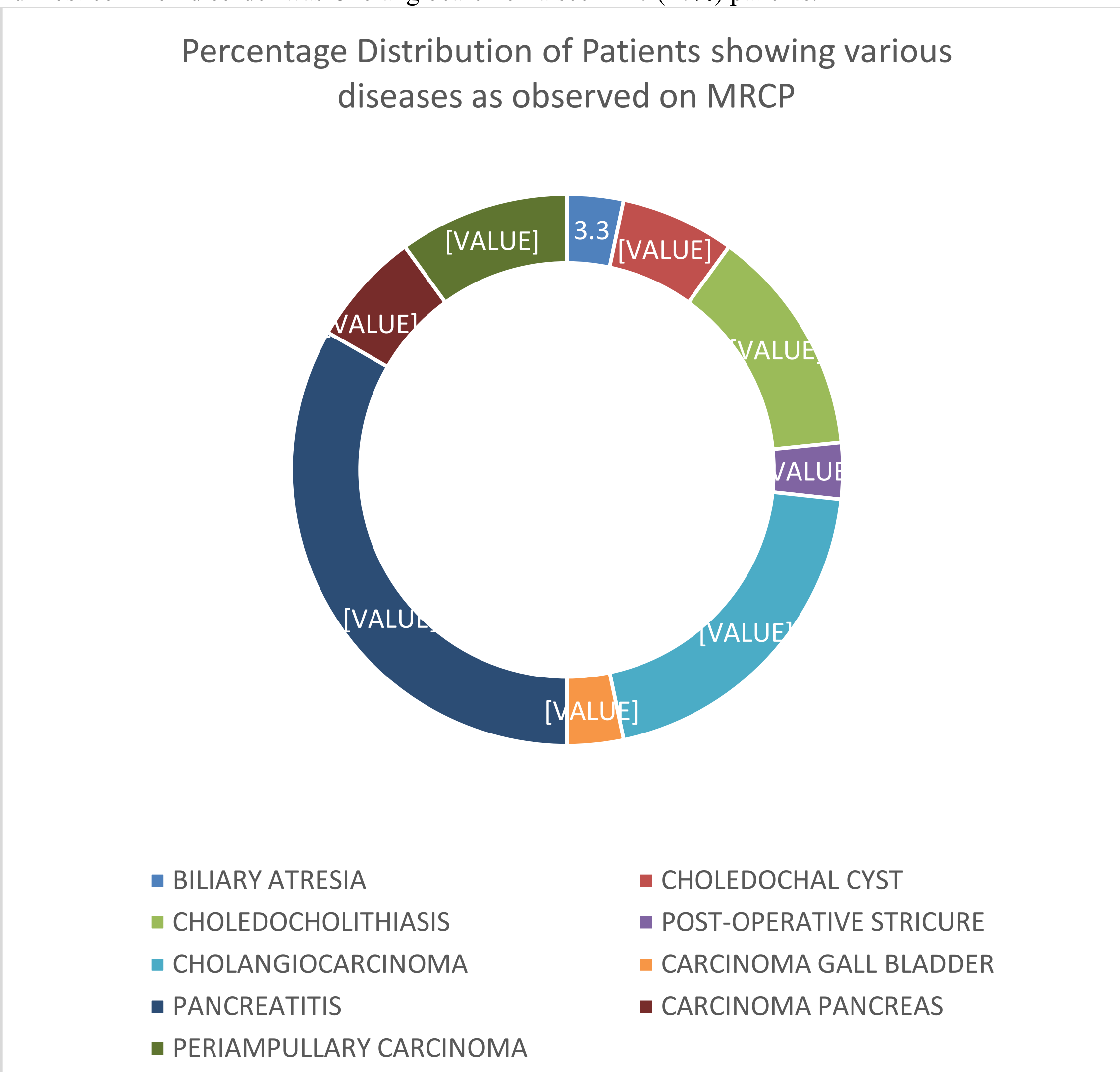
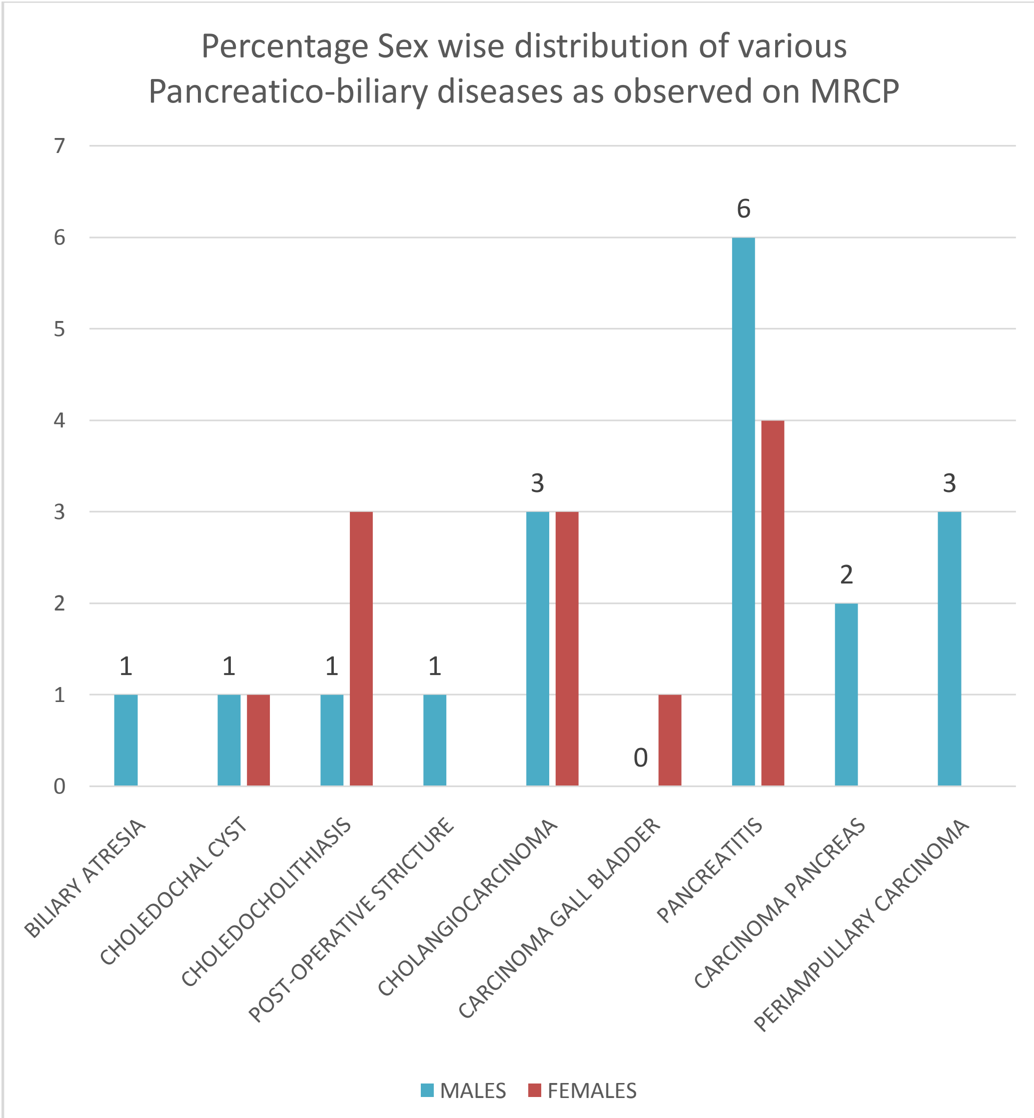


Table No. 06:- Sex Wise Distribution Of Various Diseases As Observed On Mrcp.

TYPE OF DISEASE	MALES	PERCENT-AGE (%)	FEMALES	PERCENT-AGE (%)
BILIARY ATRESIA	01	5.6	00	00
CHOLEDOCHAL CYST	01	5.6	01	8.3
CHOLEDOCHOLITHIASIS	01	5.6	03	25
POST-OPERATIVE STRICTURE	01	5.6	00	00
CHOLANGIOCARCINOMA	03	16.6	03	25
CARCINOMA GALL BLADDER	00	00	01	8.3
PANCREATITIS	06	33.4	04	33.4
CARCINOMA PANCREAS	02	11	00	00
PERIAMPULLARY CARCINOMA	03	16.6	00	00
TOTAL	**18**	**100**	**12**	**100**

Out of the total 30 cases included in the study, most common disorder observed was pancreatitis seen in 10 (33.3%) patients with equal male& female preponderance. Second most common disorder was Cholangiocarcinoma seen in 6 (20%) patients with again equal male &female preponderance.



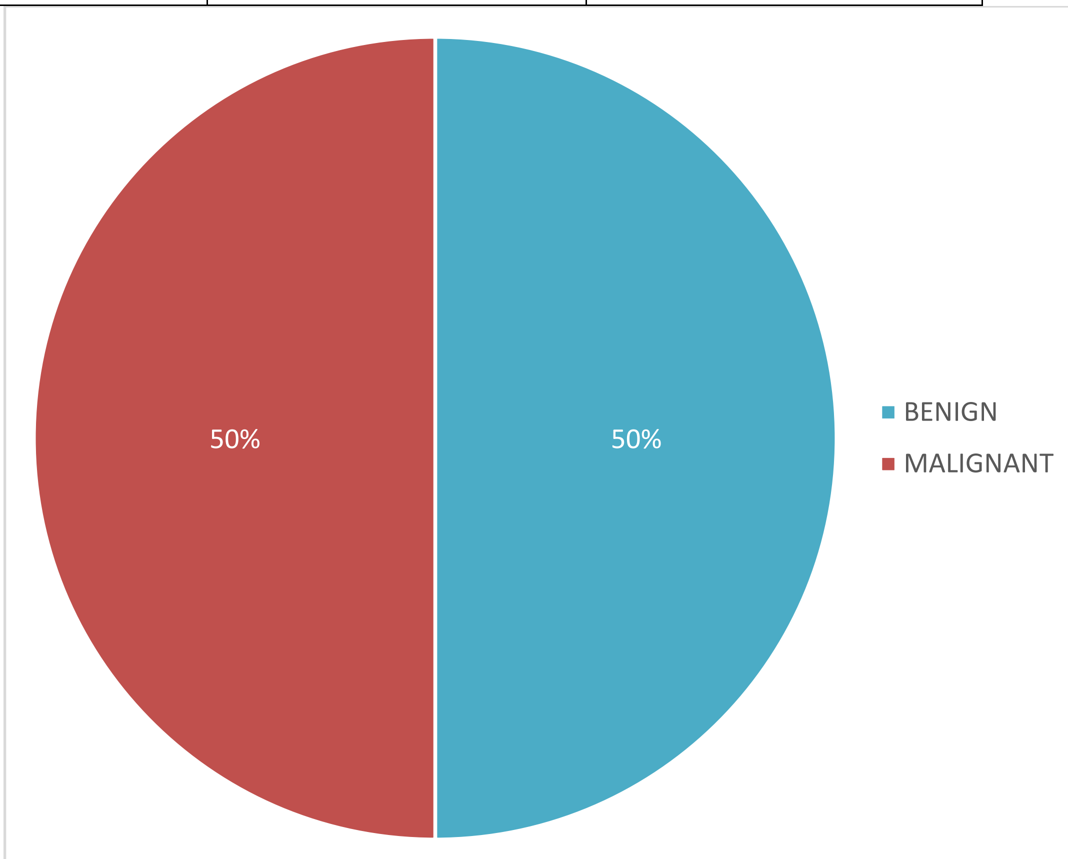
Out of the total 30 cases included in the study, 18 (60%) had benign disorders.The most common benign disorder observed was pancreatitis seen in 10 (33.3%) patients with equal male& female preponderance. Second most common benign disorder was Choledocholithiasis seen in 4 (13.4%) patients with female preponderance. Least common was 1 case of post-operative stricture (3.3%) seen with male preponderance.

Out of the total 30 cases included in the study, 12(24%) patients had malignant disorders. The most common pathology was cholangiocarcinoma seen in 6 (20%) patients with equal male & female preponderance. Second most common pathology was Periampullary carcinoma 3 (10%) with male preponderance. Least common was Carcinoma of gall bladder seen in 1 (3.3%) patients with female preponderance.

Table No. 07:- Distribution Of Pancreatico-Biliary Diseases Based On Type Of Stricture As Observed On Mrcp

TYPE OF STRICTURE	NO. OF PATIENTS	PERCENTAGE (%)
BENIGN	6	50

MALIGNANT	6	50
TOTAL	**12**	**100**

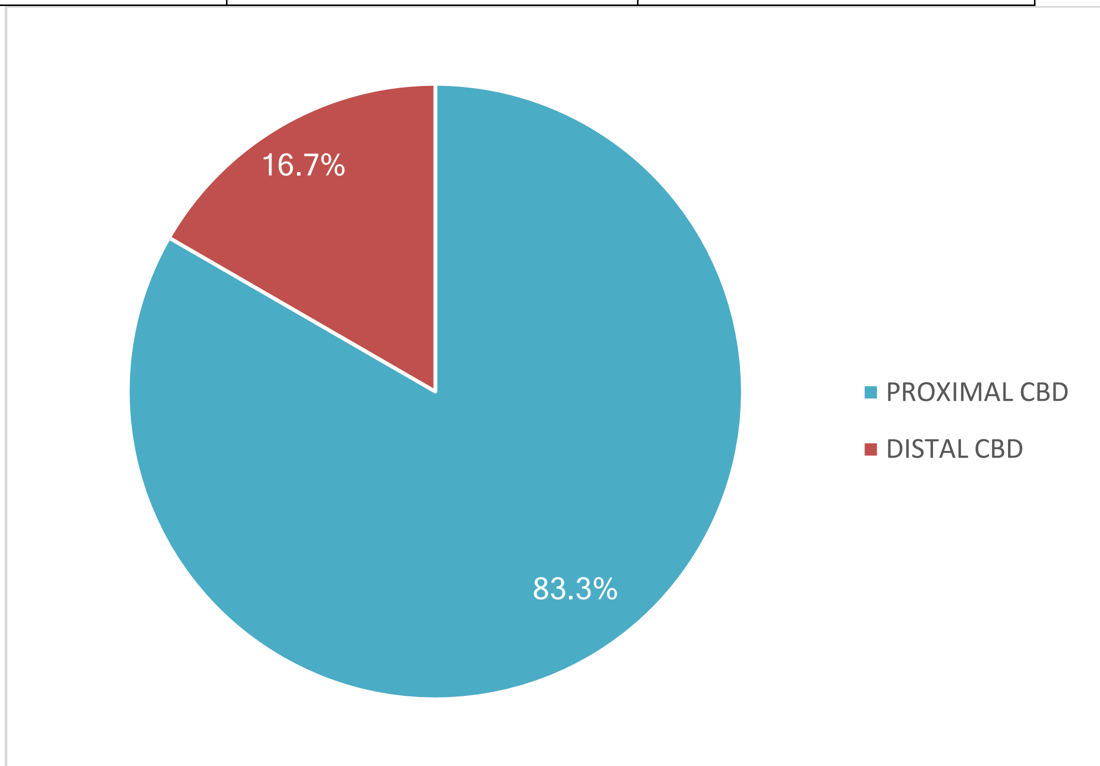


The present study revealed, both benign & malignant strictures are equally common in occurrence.

Table No. 08:- Distribution Of Site Of Stricture Among Benign Pancreatico-Biliary System As Observed On Mrcp.

SITE OF BENIGN STRICTURE	NO. OF PATIENTS	PERCENTAGE (%)
PROXIMAL CBD	5	83.3
DISTAL CBD	1	16.7

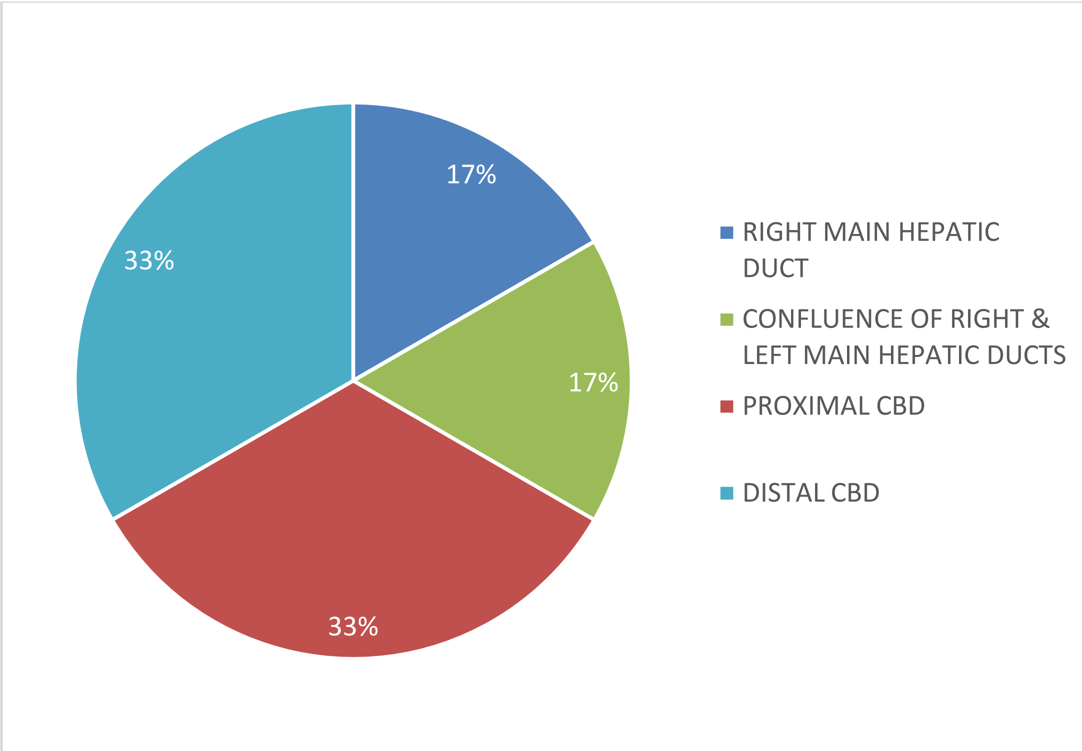
TOTAL	**6**	**100**



The present study revealed proximal CBD benign strictures are more common than distal CBD benign strictures.

Table No. 09:- Distribution Of Site Of Malignant Stricure In Pancreatico-Biliary System As Observed On Mrcp

SITE OF MALIGNANT STRICTURE	NO. OF PATIENTS	PERCENTAGE (%)
RIGHT MAIN HEPATIC DUCT		
LEFT MAIN HEPATIC DUCT		
CONFLUENCE OF RIGHT & LEFT MAIN HEPATIC DUCTS		
PROXIMAL CBD		
DISTAL CBD		
TOTAL	**6**	**100**



The present study revealed that proximal & distal CBD malignant strictures are equally common.

Discussion:-

Evaluation of suspected biliary obstruction has traditionally involved a variety of imaging modalities including ultrasonography (US), computed tomography (CT) & invasive cholangiography. These techniques have limitations because of poor visualization of intraductal stones on US & CT & the need for invasive procedures like ERCP & PTC. MRCP is a non-invasive imaging modality that provides good visualization of the hepato-biliary system.

Regarding clinical symptoms most common clinical presentation in our study was pain in abdomen seen in 16 (53.3%) patients followed by weight loss seen in 7 (23.3%) patients, while least common presentation was steatorrhea seen in 3 (10%) patients. Almost all patients presented with combination of symptoms. **Schwartz et al**[143] in his study reported that most common presentation was jaundice seen in 68% patients followed by pain in abdomen seen in 25% patients. This may be because of dedicated study of malignancy. In our study percentage of pain in abdomen (53.3%) was more, this may be because of inclusion of almost all benign and malignant pathologies including pancreatitis.

6 cases of cholangiocarcinoma were evaluated in one case of cholangiocarcinoma diagnosed by MRI there was infiltration into the gallbladder & minimal local spread. Per operative findings were those of carcinoma of gallbladder. This is a known limiting factor on imaging when both, the gall bladder & bile duct are involved. MRI helped in defining the level, extent & staging of the disease in the pre-surgical evaluation. **Guibaud et al**[137], **Barish M A & Soto**[26]&**Pavone et al**[138] who concluded their studies with sensitivities ranging from 80 to 86 % & specifities of 96 to 98 % & diagnostic accuracies of 91 to 100 % for level of obstruction.

In 3 cases of periampullary carcinoma, MRI was able to delineate the extent, level & local infiltration & helped in staging of the lesion. The assessment of the periampullary lesions was difficult on US in obese patients & bowel gas shadows was also a limiting factor. **Sugita et al** in his study of 25 cases of periampullary tumors reached a sensitivity of 88%, specificity of 100% & diagnostic accuracy of 96% [136]. Morphology of the gland can be seen but the caliber of main pancreatic duct was difficult to visualize.

In 4 cases of choledocholithiasis, MRCP clearly shows the IHBR dilatation, caliber of CBD & the site of the calculus, especially in the distal CBD which is difficult to visualize on US. **Varghese et al** who reported 91%

sensitivity, specificity of 98% & diagnostic accuracy of 97% on MRCP[66]. **Sugiyama et al** reported 91% sensitivity, specificity of 100% & diagnostic accuracy of 97% on MRCP[65]. **Caroline Reinhold et al** showed a sensitivity of 90%, specificity of 100% & accuracy of 97% on MRCP [139]. Ability to detect bile duct stones at CT depends on a number of factors related to the stone (size, shape, position, density), bile duct (dilated vs non-dilated), technology used (conventional vs helical CT), technique used (slice thickness, reconstruction interval, pitch, kVp, administration of contrast material), Pure cholesterol stones are iso- or slightly hypoattenuating relative to bile, making them difficult, if not impossible, to detect. This imposes a theoretic upper limit for the CT detectability of choledocholithiasis of approximately 80%.Heavily calcified stones are relatively easily identified, whereas soft-tissue density stones can be isoattenuating to surrounding tissue, making them difficult to identify. The attenuation of biliary stones varies with their composition.On MRCP CBD stones are seen as hypointense filling defects within lumen of CBD on T2W SE images. Advantage of MRCP is that stones as small as 3 mm can be visualized [114].

In 2 cases of choledochal cysts, MRCP yielded diagnostic information by providing exact anatomic map in pre-surgical evaluation. **Kim et al** in his study of 20 patients concluded the same [140].

In 1 case of biliary atresia, MRCP detected with an accuracy of 100%, **Seok Joohan & Myung-Jun Kim** in a study of 47 patients showed MRCP had a sensitivity, specificity & diagnostic accuracy of 100%, 96% & 98% respectively [141]. US serves as a good initial modality for evaluation in neonates presenting with cholestatic jaundice.

In our study pancreatitis was seen in 10 (33.3%) patients. Out of 10 cases, 6 (20%) were male suggesting male predilection. This may be because of alcoholism which is one of causative factor for pancreatitis.

Ultrasound will not show much change in cases of acute pancreatitis. Pseudocyst and necrotic changes were detected rarely in acute pancreatitis. Exact extent was not appreciated due to bowel gas and probe tenderness.

Shadan et al[144] reported chronic pancreatitis in 10% cases. **Tamura et al**[102] reported overall sensitivity and specificity values of MRCP for delineating pathologic pancreatic changes were 88% and 98% respectively.

Out of 6 (20%) patients of Cholangiocarcinoma evaluated 3 (10%) were male while 3 (10%) were female suggesting equal preponderance. **Shadan et al**[144] reported cholangiocarcinoma in 4% cases, **Bhatt et al**[145] reported Klatskin tumor in 12% cases. **Bloom et al**[117] reported Cholangiocarcinoma in 2.3% cases. Cholangiocarcinoma is primarily tumor of elderly with peak prevalence in 7th decade and slight male predilection. In our study majority of cases of Cholangiocarcinoma were seen in 6th to 7thdecade.

MRI helps in defining level of obstruction, extent of tumor and staging for pre-surgical evaluation. In some case there is involvement of GB fossa as well as hilar region by mass lesion, in such cases it becomes difficult to define whether Ca GB extending to hilar region or it is Primary Hilar Cholangiocarcinoma, so this becomes limiting factor for MRCP.

Out of total 3 (10 %) cases of periampullary carcinoma diagnosed on MRCP, all weremales, suggesting male predilection. In our study majority of cases were in the age group of > 40 years. **Shadan et al** reported periampullary Ca in 2% cases. **Bhatt et al** reported Periampullary Ca in 4% cases.This may be possible due to less sample size (50 patients) in both above mentioned authors.

Periampullary carcinomas arise within 2 cm of the major papilla in the duodenum and include four different types of malignancies, namely, those originating from (a) the ampulla of Vater itself, (b) the intrapancreatic distal bile duct, (c) the head and uncinate process of the pancreas, and (d) the duodenum. Ca head of pancreas is associated with dilatation of both CBD and PD called as “double duct” sign. Overall survival is highest for patients with ampullary and duodenal cancers, intermediate for patients with bile duct cancers, and lowest for those with pancreatic cancers[146-148].

Ca GB was seen in 1 (3.3%) cases in our study. **Shadan et al**[144] reported Ca GB in 4% cases which are closely consistent with our findings, while **Bhatt et al** reported it in 2% cases. MRI helps in defining extent, local spread for pre-surgical evaluation.

Bhatt et al[145] in his study of 50 cases reported cholangiocarcinoma in 12% cases, Ca GB in 2% cases and Periampullary Ca in 4% cases. **Shadan et al**[144] in his study of 50 cases reported cholangiocarcinoma in 4% cases, Ca pancreas in 8% cases, Ca GB in 4% cases and Periampullary Ca in 4% cases. **Schwartz et al**[143] in his study of 32 cases reported cholangiocarcinoma in 21.8% cases, Ca pancreas in 37.5% cases, Ca GB in 28.1% cases and Periampullary Ca in 6.2% cases. **Soto et al** in his study of 43 cases reported cholangiocarcinoma in 13.9% cases, Ca pancreas in 18.6% cases, Ca GB in 4.6% cases and Periampullary Ca in 9.3% cases. **Upadhaya et al** [149] in his study of 100 cases reported cholangiocarcinoma in 9% cases, Ca pancreas in 9% cases, Ca GB in 19% cases and Periampullary Ca in 10% cases. In our study of 30 cases Cholangiocarcinoma was seen in 6 (20%) cases, Periampullary Ca in 3 (10%) cases and Ca GB in 1 (3.3%) cases.

Overall Percentage distribution of malignant pathologies in our study closely matches with **Bhatt et al** and **Schwartz et al**. Larger percentage in **Upadhaya et al** may be due to slightly larger sample size (100 patients).

Advantages of MRCP over US:

1. Provides high resolution images of biliary tree.
2. Diagnostic images both above and below obstruction are possible.
3. 3-D images of biliary tree can be obtained which can help in diagnosis and treatment planning.
4. Can be used in obese patients, children and those patients who are poor sonographic candidates due to technical factors or limited field of view as in postoperative patients.

Advantages of MRCP over CT:

1. Provides high resolution images of biliary tree.
2. 3-D images of Biliary tree can be obtained which can help in diagnosis and treatment planning.
3. Pure cholesterol stones are iso- or slightly hypo-attenuating relative to bile,making them difficult to detect on CT.
4. Stones as small as 3 mm are visualized on MRCP.
5. Accurate in the diagnosis of anatomic variants of biliary tree.
6. Ability to detect pancreatic divisum.
7. Characterization of strictures (benign/malignant).

Advantages of MRCP over ERCP:

1. Non-ionizing.
2. MRCP can directly reveal extraductal tumor whereas ERCP depicts only the duct lumen.
3. MRCP lacks major complication rate of approximately 3% associated with ERCP such as sepsis, bleeding, bile leak and death.
4. MRCP has advantage of adding a 3D imaging and fast multiple imaging planer capabilities.
5. MRCP is more sensitive than ERCP in demonstrating fluid collections and may show their connection with the pancreatic duct.

Advantages of MRCP in evaluation of Pancreatico-biliary pathologies:

1. There is no use of ionizing radiation.
2. Accurate in the diagnosis of anatomic variants of biliary tree.
3. It provides all pre-operative information required by surgeon.
4. -Status of GB and CBD
5. -GB calculi and Cholecystitis
6. -Size of Calculus
7. -Gall Bladder mass lesion
8. -GB wall thickness
9. -GB wall surface
10. -Diameter and presence of calculus in CBD
11. -Exact location of Calculus in CBD
12. -Benign or malignant stricture of CBD
13. Main role of MRCP will be to reduce or eliminate need for diagnostic ERCP which is invasive procedure and provide road map for therapeutic ERCP.
14. MRCP is able to produce highly accurate cholangiographic images, similar to that of direct cholangiography[91].
15. MRCP is rapidly developing noninvasive modality for evaluation pancreatico- biliary pathologies.

Pitfalls Of MRCP:

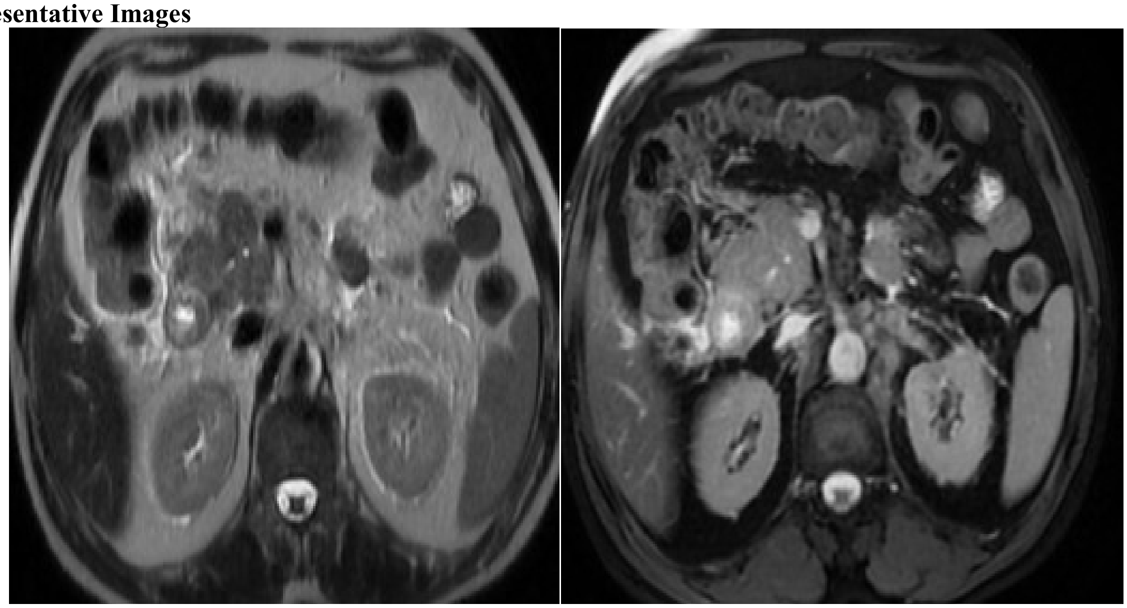
1. Respiratory motion artifacts.
2. Requires breath hold for breath hold sequences which is not possible if patient is very sick, asthmatic.
3. Susceptibility artifact.
4. MIP 3D reconstructed images may completely obscure a very small filling defect due to the partial volume effect.
5. Limited spatial resolution compared to ERCP in which there is direct opacification of ducts with contrast.

Summary

A total of 30 patients, suspected clinically of pancreatico-biliary diseases underwent MRCP examination, were taken for the purpose of the study.

1. The mean age of the study sample was 37.5 years with a range of 05 to 70 years.
2. Maximum number of cases were in > 40 years age group.
3. Majority of patients were males.
4. Pain abdomen, steatorrhea, weight loss, jaundice & vomiting were the most frequent presenting complaints.
5. Pancreatitis was the most common finding followed by Cholangiocarcinoma, Cholelithaisis, Periampullary carcinoma, Ca. pancreas & Choledochal cyst.
6. Pancreatitis is common in males followed by Cholangiocarcinoma, which is common in both males & females.
7. Both benign & malignant strictures have equal predominance.
8. Both benign & malignant strictures are common in proximal CBD.
9. MRI & MRCP proved to be a sensitive, non-invasive imaging modality that helps in detection, diagnosis of the disease & provides valuable information of therapeutic & prognostic significance.

Representative Images



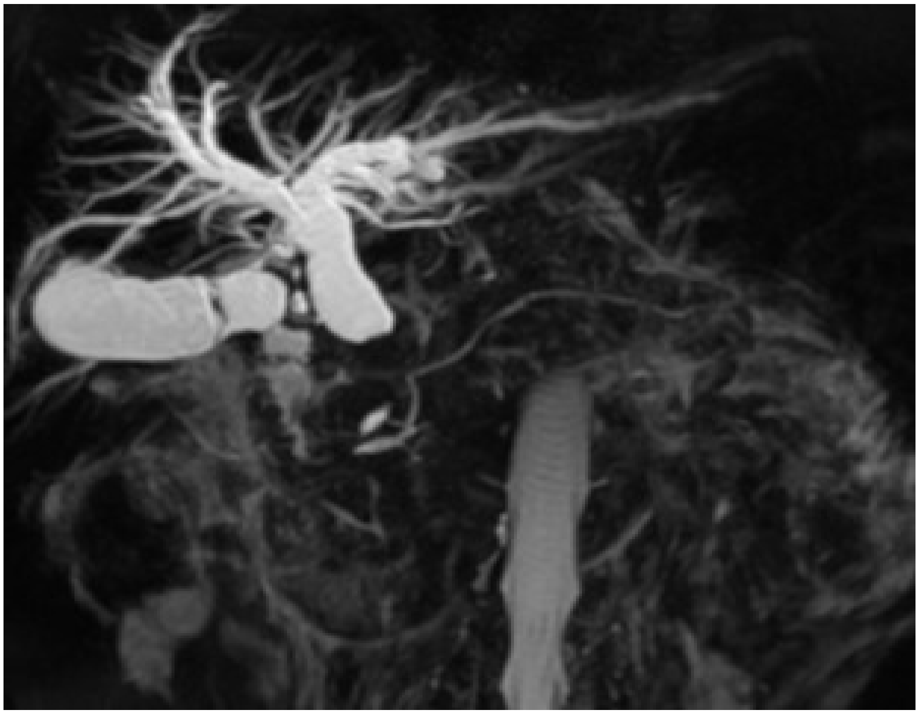
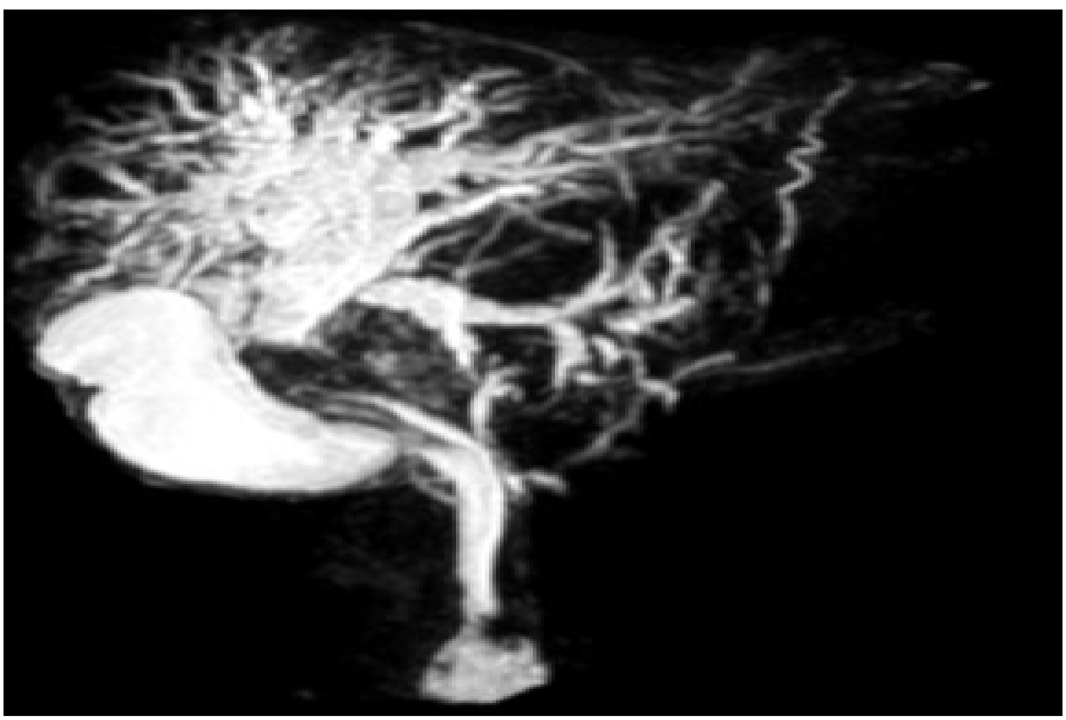


Figure-18 a, b & c:- Ill-defined mass lesion noted between 2nd part of duodenum and head of pancreas with ill-defined margins & loss of fat planes showing moderate enhancement. Moderate dilation of CBD measures 16 mm with abrupt cut off at the mass (periampullary carcinoma).



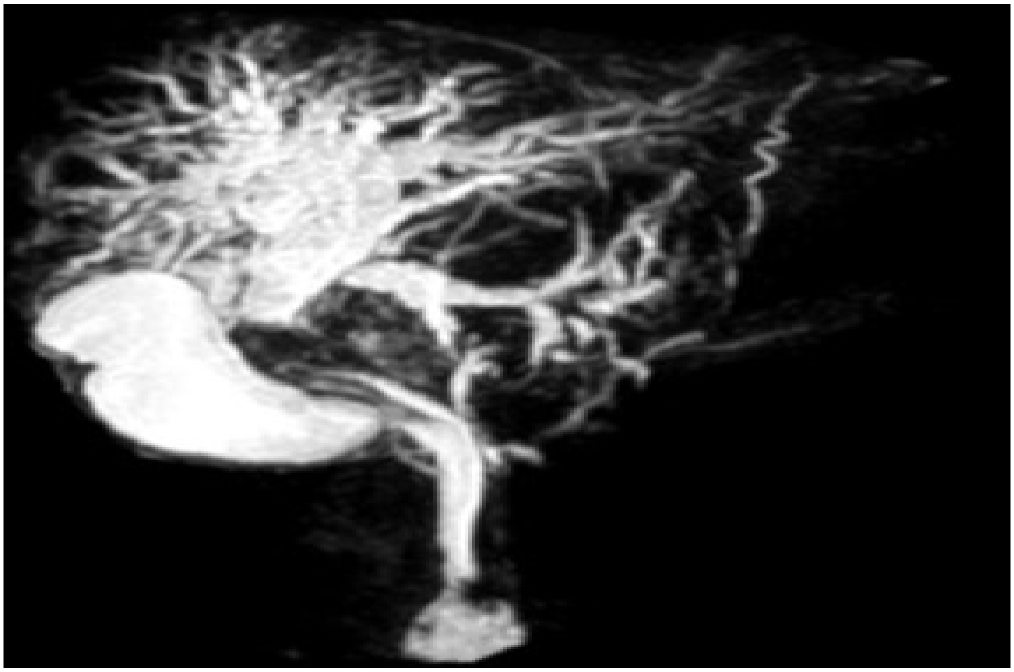


Figure-19 a & b:- 3D MRCP shows a hypointense lesion noted at the level of porta amputating biliary confluence and is epicentered on CBD causing dilated biliary radicles (Cholangiocarcinoma).

Fig-20:- 3D MRCP shows dilatation of CBD (maximum diameter of 9 mm)& intrahepatic biliary radicles with smooth tapering at the level of Ampulla of Vater with no evidence of calculi or mass lesion, possibly due to stricture.

Fig-21:- Case of Chronic Calcific Pancreatitis. CBD is dilated measuring 10mm in maximum diameter. Multiple T2 hypointense calculi are noted in the CBD.

Main pancreatic duct is dilated measuring 11mm in maximum diameter.
Multiple T2 hypointense calculi are noted in the main pancreatic duct.
Diffuse mild intrahepatic biliary radicles dilatation is noted.Abrupt narrowing of the terminal CBD is noted at Ampulla of Vater.

Fig-22:- 3D MRCP in a 13-year-old with jaundice, shows a fusiform dilatation of the common bile duct portion of extrahepatic bile duct, suggestive of Choledochal cyst type 1c.

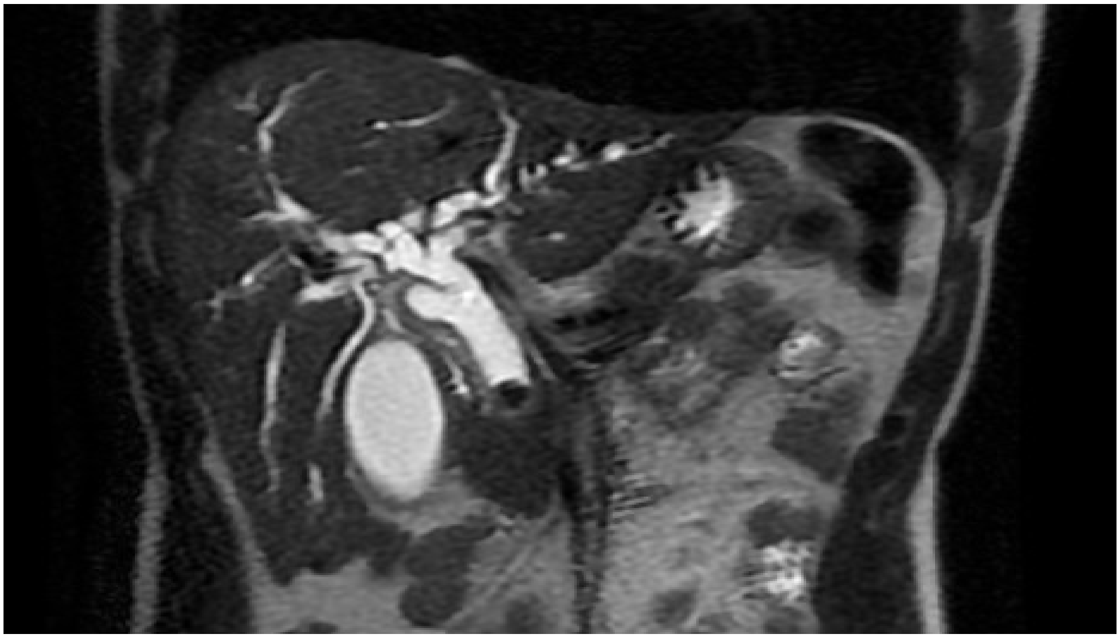


Fig-23:- Coronal SSFSE image shows CBD & intrahepatic biliary dilatation secondary to a hypointense calculus in distal CBD, suggestive of choledocholithiasis.

Conclusion:-

The introduction of MRCP now readily permits the study of anatomy & pathology of the biliary tree including pancreatic duct very easily.

Based on the results of our study, the following conclusions can be made:

1. MRI serves as an accurate & non-invasive, non-ionizing imaging method for evaluation of pancreatico-biliary anatomy & pathology.
2. US still remains the primary investigative modality of choice.
3. Combination of MRI & MRCP allows safe surgical management decisions.
4. Potentially useful in patients undergoing biliary enteric anastomosis for knowing the level & extent of strictures.
5. Very useful tool in case of obese patients & children.
6. Drawbacks:

a) Claustrophobia
b) No therapeutic & interventional procedures can be carried out
c) Breath holding is not possible in elderly, children & debilitated patients
d) Time consuming

There is now enough evidence to suggest that the efficacy of MRI & MRCP is at par with that of ERCP & can be considered as the gold standard for evaluation of the pancreatic-biliary system.

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