Magnetic resonance cholangiopancreatography in conjunction with 3D for assessment of different biliary obstruction causes

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KEYWORDS
Three-dimensional magnetic resonant cholangiopancreatography (3D-MRCP); Maximum intensity projection (MIP); Volume rendering (VR)

Abstract  Objective: To assess the diagnostic value of magnetic resonance imaging in conjunction with 3D-MRCP, with maximum intensity projections and volume rendered images in different biliary obstruction causes.

Patient and methods: This study retrospectively reviewed the radiology records of 29 patients (18 females and 11 males) suffering from obstructive jaundice. All patients were subjected to magnetic resonance imaging (MRI), 3D-MRCP with maximum intensity projection (MIP) and volume rendered (VR) reformatted images for biliary obstruction diseases in Zagazig University Hospitals between November 2008 and January 2010. MR studies were performed with 1.5-T superconductive magnet (Philips Achieva, class II a). The patient ages were ranging from 23 to 66 years (mean age: 34 years). This study was done to evaluate the diagnostic value and accuracy of the new MRI techniques as a non-invasive tool to diagnose and differentiate between benign and malignant variants of biliary obstruction diseases and to facilitate the management planning. All cases were
1. Introduction

MRCP has become widely used in the diagnosis, characterization and differentiation of different biliary and pancreatic duct diseases (1). MRCP provides many obvious advantages, regardless the simplicity, and the safety of the technique, it is non-invasive informative study, not requiring ionizing radiation or administration of contrast agents. It has been demonstrated that the clinical value of using MRCP is similar to that of diagnostic direct cholangiopancreatography and in most instances, MRCP will gradually replace direct cholangiopancreatography for diagnostic purposes and provides an efficient alternation when diagnostic ERCP or PTC is unsuccessful or inadequate (1,2). A non-breath-hold heavily T2-weighted 2D fast spine echo (FSE) sequence was refined in the mid-1990s. The FSE sequences are less sensitive to motion; flow artifacts in 2D within the biliary tree that can occasionally simulate stones or masses and even non-dilated ducts are routinely visualized. The 3D FSE from which a volumetric dataset suitable for further analysis, especially reformating algorithms such as maximum intensity projection (MIP; using thinner slices as possible with 2D sequences, improving image quality). Other improvements include use of surface coils, a fat saturation technique, and image acquisition during quiet respiration (3). The most standard 3D method is direct volumetric rendering (VR) imaging, which can be sufficient for a good 3D visualization of anatomical structures and pathological changes by viewing all slices together in 3D reformatted images (4).

Calculi are the most common surgical causes of the biliary system diseases. Accurate detection of common bile duct (CBD) stones prior to cholecystectomy by MRCP as an emerging radiological tool for evaluation of the biliary tree is mandatory to avoid surgical morbidity associated with residual stones, particularly in the era of laparoscopic biliary surgery (5). Various malignant tumors may originate at these sites and show several similarities regarding their clinical presentation which may include biliary obstruction (6). Cholangiocarcinoma and gallbladder carcinoma are the most common primary malignant tumors of the biliary system. Pancreatic cancer is a common cause for malignant biliary obstruction, often associated with dilatation of the pancreatic duct (double-duct sign) (7).

Neoplasms arising in the bile ducts and ampulla of Vater pose an important clinical challenge. Although benign neoplasms may be encountered, most of these tumors are malignant. Gastrointestinal malignancies, hepatocellular carcinoma (HCC), malignant lymphoma, and others may induce biliary obstruction at different levels via liver metastases, lymph node metastases, or infiltration by continuity (8). Differentiation between benign and malignant strictures in duct is difficult. Benign biliary tumors, stones, strictures, such as an inflammatory stricture secondary to choledocholithiasis, Mirizzi syndrome, extra-hepatic localized form of primary sclerosing cholangitis (PSC) and idiopathic benign focal stricture are the possible differential diagnoses of a bile duct carcinoma (9). The clinical findings and laboratory values including tumour markers are not specific enough to determine the precise cause of a proximal bile duct stricture. The accuracy of alkaline phosphatase isoenzyme in differentiation between benign and malignant extra-hepatic biliary obstruction has been reported to be up to 80% (10).

2. Patient and methods

We retrospectively reviewed the medical records of 29 patients undergoing MRCP in conjunction with 3D, VR and MIP images for biliary obstruction diseases at Zagazig University Hospitals. Between November 2008 and January 2010 a total of 47 patients with biliary obstruction were referred to MRI unite after being inspected clinically, and imaged by ultrasound. Twenty-nine cases were selected after exclusion of the neonatal obstructive cases. All MRCPs were performed on a 1.5-T system (Philips, Achieva, class II a) using body coil. The mean age of benign biliary obstruction patients was evaluated by clinical examination, laboratory values, grey and colored scale ultrasonography, conventional MRI, three-dimensional (3D-MRCP), MIP, and VR images. Our results were correlated with the histology of the resected specimen, operative (ERCP) or image-guided biopsy in inoperable patients.

Results: The mean age of benign patients was 30 years compared with 54 years in malignant biliary obstruction. Seventeen patients had benign cases 58.6% (6 cases of benign stricture and 11 cases with choledocholithiasis). The other 12 cases had malignant aetiology. Twenty-three patients were subjected to operative procedures, while the remaining six had ERCP/PTC and stenting. The MRI/ MRCP images were of good quality in all patients. The intra- and extra-hepatic biliary radicals were visualized completely including the proximal and distal extent of the stricture. Regarding the benign cases (16/17) were satisfactorily diagnosed, however, one case was false negative, due to missed small stone at the MIP reconstructions. The 12 malignant biliary obstruction cases were as follows: five cases were cholangiocarcinoma (one peripheral type, one perihilar position, one Klatskin’s type, and two cases of the distal type), three pancreatic neoplastic lesions, two ampullary carcinoma, and two malignant lymph nodes. Regarding the benign cases 3D-MRCP had 94.1% diagnostic accuracy, otherwise more accuracy reported in malignant causes 100%.

Conclusion: 3D-MRCP with MIP creates global images for pancreatico-biliary system. It is as effective as ERCP in detection of biliary obstruction and can precisely determine its level as well. Furthermore, it can provide a road map for management planning. By avoiding the flow artifacts, the false negative results that previously reported in past studies can be reduced.

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30 years compared with 54 years in malignant biliary obstruction cases.

2.1. Patient preparation

The MRCP examination is simple and needs no special patient preparation, other than fasting for 6–10 h to evacuate the patient’s gastrointestinal tract and to avoid artifacts associated with liquid in the stomach or small bowel. Fifteen patients were injected with I.V. contrast medium. Although some fluid signals from fluid-containing organs, such as the spinal cord, gastrointestinal tract and renal pelvis will appear on the MRCP images, in general, they do not affect the imaging diagnosis because of the multidirectional rotation of the MIP reconstructed images.

2.2. MRCP technique

The basic principle used by MRCP, is based on heavily T2-weighted pulse sequences. Therefore, stationary fluid, such as bile, and pancreatic secretions, which have a long T2 relaxation time, exhibits high signal intensity, whereas solid organs, which have a shorter T2 relaxation time, have low signal intensity, and flowing blood has little or no measurable signal. This combination of imaging characteristics means that MR hydrography provides optimal contrast between the hyper-intense signal of fluid-containing organs, such as the pancreaticobiliary ductal tree, and the hypointense signal of the background (11).

<table>
<thead>
<tr>
<th>Table 1 Demographic data.</th>
<th></th>
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<tbody>
<tr>
<td>Patient no.</td>
<td>29</td>
</tr>
<tr>
<td>Patient age</td>
<td>23–66 years old</td>
</tr>
<tr>
<td>Mean age</td>
<td>30 years in benign cases, 54 years in malignant cases</td>
</tr>
<tr>
<td>Gender (F/M)</td>
<td>18 females, 11 males</td>
</tr>
</tbody>
</table>
| Clinical presentation     | * Pain RT  
                          | Upper quadrant 23  
                          | Epigastric 2  
                          | * Jaundice 27  
                          | * Fever 4 |

**Fig. 1** Female patient with distal small CBD stone: (A) coronal oblique T2WI; (B) 3D-MRCP; (C) MIP cholangiogram image in which the biliary tree clearly identified shows a small stone (arrow) in the distal CBD with proximal dilation of the ducts and GB stones.
2.3. Imaging sequences

Conventional MR imaging Sagittal and coronal T1 and T2WIs (information about the liver parenchyma was obtained).

The first step in performing MRCP is to localize the pancreaticobiliary duct. In many instances, this is accomplished by acquiring a scout MRCP obtained in a slice thickness of 30–70 mm (12,13):

– Single-shot fast spin-echo sequence (SSFS) for T2-weighted MRCP technique.
– Coronal oblique respiratory-triggered 3D fast spin-echo sequence; slice thickness, 3 mm; TR, 2000; echo train length, 128; field of view, 320; signals acquired, 2; average examination time, 6 min.
– Axial respiratory triggered 3D fast spin-echo sequence; slice thickness, 3 mm; TR, 2000; TE, 700; echo train length, 100; field of view, 300; signals acquired, 2; average scan time, 3 min. The axial sequence was added to minimize the risk of missing small preapillary lesions.
– A maximum-intensity projection and volume rendered images (secondary reconstruction) using the coronal oblique as a source image was performed for each patient (3).

2.4. MR image interpretation

– Calculi were diagnosed when rounded, ovoid, or irregularly shaped signal voids were identified within a dilated or non-dilated bile duct.
– Stenosis was defined as a transition of ductal dilation to signal void or a tapered appearance of CBD.
– Abrupt narrowing of the CBD.
– The presence of a mass and a stricture with an irregular margin, asymmetric dilatation or long length stricture.
– Diagnosis was made by interpretation of each single sequence. If there were discrepancies in interpretation between the different sequences, appearance of source axial and coronal oblique images took precedence. In conjuction with the 3D-MRCP, MIP volume rendered images. Our results were correlated by the operative data, histology of the resected specimen, ERCP or image-guided biopsy in inoperable patients.

3. Results

In our study the demographic data (Table 1) for the over all 29 biliary obstruction cases. Female dominance were found in

<table>
<thead>
<tr>
<th>Causes</th>
<th>NO</th>
<th>MRI diagnosis</th>
<th>Conventional MRI findings</th>
<th>3D-MRCP, MIP, VR findings</th>
</tr>
</thead>
<tbody>
<tr>
<td>Choledocholithiasis</td>
<td>11</td>
<td>Mid CBD (3 patients), distal CBD (7 patients)</td>
<td>Low signal stone, ranging size from 5 to 12 mm (Fig. 1)</td>
<td>Oval/rounded filling defect with proximal dilatation</td>
</tr>
<tr>
<td>Benign strictures</td>
<td>6</td>
<td>Common bile duct stenosis (3 patients) Sclerosing cholangitis (1 patient) Chronic pancreatitis (2 patients)</td>
<td>Dilated biliary tree proximal to the obstruction level Patchy strictures intra- and extra-hepatic with enhanced walls Diffuse intra- and extra-hepatic BD with dilated pancreatic main ducts and side branches</td>
<td>Smooth short stricture Multiple strictures, diffuse, irregular narrowing, of IHD and EHBD Long, smooth, progressive narrowing of entire pancreatic portion of the CBD and pancreatic duct</td>
</tr>
<tr>
<td>Malignant causes</td>
<td>12</td>
<td>Cholangiocarcinoma (5 patients) * Peripheral type (1 patient) * Perihilar (1 patient)</td>
<td>III-defined hepatic mass infiltrating the GB and biliary tree before the common hepatic confluence Parietal thickening depicted better on enhanced images as a ring or spot. Dilated biliary till the common hepatic confluence</td>
<td>Abrupt cut off of the peripheral biliary tree and irregular filling defect in the GB Stenotic lesion (ranging from 1 to 4 cm) in length with irregular contour A long stricture of the proximal common hepatic duct and bifurcation</td>
</tr>
<tr>
<td>* Klatskin’s type (1 patient)</td>
<td></td>
<td>Heterogeneous mass at the confluence of the common hepatic duct. Diffusely dilated IHB with a stop at the level of the common hepatic duct (Fig. 2)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>* Distal type (2 patients)</td>
<td></td>
<td>Asymmetrically thickened bile duct wall at the transition zone, mass was seen in one case</td>
<td></td>
<td>Focal stenosis</td>
</tr>
<tr>
<td>Pancreatic carcinoma (3 patients)</td>
<td></td>
<td>Heterogeneous pancreatic head mass (Fig. 3)</td>
<td></td>
<td>Irregular narrowing of the CBD and the pancreatic duct with abrupt transition (typical “double duct” sign)</td>
</tr>
<tr>
<td>Ampullary carcinoma (2 patients)</td>
<td></td>
<td>III-defined mass in the anatomical site, cause irregular distal stricture Identified enlarged L.Ns and the obstruction level</td>
<td></td>
<td>Dilated biliary ducts and abrupt termination of the distal CBD occurs Smooth eccentric compression</td>
</tr>
<tr>
<td>Malignant L.Ns (2 patients)</td>
<td></td>
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Table 2 MRI, 3D-MRCP, MIP, VR images appearance correlated with final postoperative findings.
62.1% (18 cases), while male cases were 37.9% (11 cases). The mean age in malignant cases was 54 years.

Seventeen patients had benign causes 58.6% (6 cases of benign stricture and 11 cases with choledocholithiasis). Gall bladder stones were found in 6 cases of the choledocholithiasis.

In two patients extensive extra-biliary hyper-intense signal of free fluid (ascites) was seen in MRCP which completely disappeared in MIP and VR images.

Regarding the benign cases 16 out of 17 cases were diagnosed, one false negative case, due to missed small stone in MIP reconstructions.

In this study 3D-MRCP with MIP had 94.1% diagnostic accuracy in the benign cases, otherwise more accuracy is gained in malignant causes (100%).

4. Discussion

MRCP is a non-invasive imaging method that is highly sensitive and specific for the detection of different biliary obstruction diseases. It is fast, safe, well tolerated by most people, and has few contraindications with no recorded morbidity or mortality. Using the new imaging techniques as the 3D sequence with MIP and volume rendered images add more diagnostic accuracy and hence increase the superiority of MRCP for the diagnosis of biliary obstruction pathologies over all other investigation methods.

In our study the patients with malignant strictures were older than patients of benign type. Similar results have been reported in the literature (14), except for a retrospective study by Kim et al. (15) in which they found that patients with both benign and malignant strictures belonged to similar age groups.

In our study the benign biliary diseases represent the most common causes (85.6%). Most of benign cases were choledocholithiasis 11 out of 17 of all benign cases. 3D-MRCP technique can provide diagnostic quality images, and detect bile duct dilation as well as biliary stones. Both coronal images and 3D images that rotated at different angles are useful (Fig. 1). An axial plane tends to better outline the most distal common bile duct and pancreatic duct segments. A missed small sized stone (<3 mm) is resulting in one false negative diagnosis, so, microlithiasis cases are considered a problem for the MRCP interpretation. Similarly Zidi et al. (16) stated that, small stone diameter lower than 5 mm is a limiting factor in MRCP diagnosis of choledocholithiasis. Also reported initially MRCP achieved about 75% sensitivity and 75% specificity in diagnosing obstruction but did not detect stones <3 mm in diameter if the bile ducts were not dilated (17). Adding the 3D-MRCP and MIP images to the studies achieved more

![Fig. 2](image-url) Klatskin tumor in 48-years-old male patient. (A) Ill-defined infiltrating mass in the CHD confluence (arrow), cirrhotic liver and ascites also noted. (B–D). Coronal oblique 3D MRC, MIP, VR cholangiogram a shows hilar cholangiocarcinoma invading the CHD, left hepatic duct, and right hepatic duct beyond the bifurcation.
sensitivities approaching 100% and specificities > 90% in detecting biliary lithiasis in agreement with authors (3), who stated that the detection accuracy of stones < 6 mm is likely to improve with the newer 3D sequences. However, Liu et al. (18) assumed that such small stones might be ignored because they may pass without inducing postoperative symptoms.

The typical ductal manifestations for different benign strictures were clearly identified either by presence of smooth short strictures that were the key for diagnosis of benign stricture what ever its cause (recent passage of stone or previous pyogenic cholecystitis), rather than the presence of multiple strictures, diffuse, irregular narrowing of IHD and EHBD that were found in one case of sclerosing cholangitis. Moreover, in chronic pancreatitis 3D-MRCP, MIP, VR images are also suited for the detection of prominent dilatation of side branches, a feature of chronic pancreatitis that can help in distinguishing it from pancreatic cancer, and pseudocysts. Proper easy diagnosis of all biliary strictures were not surprising as many researchers had reported specificity and accuracy of 97% and 100%, respectively, by using combined conventional MRI and MRCP (19). Cholangiocarcinoma was found in our study in five cases. Different imaging findings were reported for the conventional MRI and also by 3D-MRCP with MIP and VR images (Table 2). Malignant strictures are usually long as they have an infiltrative growth pattern, which spreads intramuraally beneath the epithelial lining. They are irregular with an asymmetric dilatation because of the nature of involvement of the bile duct. Similarly, Park et al. and Pasanen et al. findings concluded that the presence of a mass, stricture with long length (> 1.2 cm) and an irregular margin and asymmetric dilatation of the bile ducts help in the diagnosis of a malignant stricture (20,21). In addition; 3D reconstructed images were helpful in identifying the extent of common bile duct infiltration as well as the intra-hepatic ducts, and considered as an excellent pre-operative drawer of the biliary system anatomy (Fig. 2).

As reported by Anderson et al. (22) MRI with MRCP was significantly more accurate than CT in differentiation between malignant and benign lesions in patients with suspected distal biliary tumors, mainly due to the information obtained on the MRCP images of the biliary and pancreatic duct anatomy. Biliary ducts both proximal and distal to a high-grade obstruction may not be sufficiently opacified by ERCP or PTC (23). In addition, ERCP may result in sepsis because of over distension of the obstructed biliary duct with stagnant bile that is colonized by bacteria.

Fig. 3 Pancreatic head adenocarcinoma in a 50-year-old male. (A) T2 FSE Coronal oblique view shows the distal stenosis caused by mass (arrow). (B and C) On MIP and VR reconstructions of coronal multisection MRCP showing dilated pancreatic duct (arrow) and consecutive upstream dilatation (“double duct sign”) more clearly by volume render images.
5. Conclusion

Information carried out by using the conventional MR imaging is not enough to make a decision. However, by using 3D reconstructions, multiplanar and reformatted images of the biliary tract provide quick and clear visualization of the complex relationships between the anatomy and pathologic changes.

Furthermore, it increases our confidence in the diagnosis and contribution to understand the disease process. In fact, in most cases 3D imaging does not add quantitative information rather than the 3D-MRCP, but the main advantage with respect to cross-sectional anatomy is represented by different rendering of data, more familiar to the human eye. It also gives the surgical staff both information and the adjuncts they need in patient management and surgical planning for biliary diseases.

Acknowledgment

The words stand short when coming to express our deep gratitude to Professor Dr. Fathy A Tantawy for his unique management and surgical planning for biliary diseases.

References