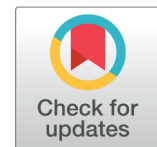


THREE DIMENSIONAL (3D) MAGNETIC RESONANCE CHOLANGIOPANCREATOGRAPHY (MRCP) IN SYMPTOMATIC POST-CHOLECYSTECTOMY PATIENTS: IDEAL IMAGING PLANE OF SOURCE VOLUME IMAGES.



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ABSTRACT

Objective

The purpose of our study was to find out the ideal 3D-MRCP acquisition plane among coronal and axial source datasets for bile duct assessment in patients with persistent post-cholecystectomy pain.

Methods

This cross-sectional analytical study carried out in radiology department of a teaching hospital from 1st January 2016 to 30 May 2017. Seventy-eight symptomatic patients for MRCP in the duration were included. The age range was 20 to 70 years and patients had persistent or recurrent postcholecystectomy symptoms like abdominal pain, vomiting, or jaundice. Data was collected retrospectively from the hospital's database so the need for informed consent was waived off by permission from the hospital's ethical committee. MRCP was performed for all patients on a 1.5 tesla GE MRI machine with breath-hold multi-slice acquisition using dedicated multi-channel surface coils covering the abdomen. Both 2D and 3D MRCP were done. Coronal MIP was reconstructed based on each dataset. Data was analyzed using Microsoft Excel and SPSS version 22. Results were compared for the ideal 3D plane to assess pancreatic and biliary ducts.

Results

The encountered post-cholecystectomy biliary findings were strictures (48%), retained biliary stones (35.8%), which were located either intrahepatic or extrahepatic, most commonly in distal CBD causing obstructive jaundice, and the rest of the patients had either cholangiocarcinoma at the hilum, pancreatitis or post-op complications like complete bile duct transaction, bile duct ligation, etc. The most common finding was biliary stricture. CHD and proximal CBD were better assessed

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for the presence of strictures and stones on 3D coronal (P-value <0.05) as compared to the axial images. Peri-ampullary, distal CBD, intrahepatic, and hilar confluence duct strictures were better visualized on 3D axial (P-value <0.05). 3D axial was also better than coronal raw data sets regarding visualization of calculi in distal CBD, intrahepatic biliary ducts, GB remnant, cystic duct, and hilar biliary confluence. 3D coronal was better for post-op ligature whereas 3D axial was more helpful in deciding the level of duct injury and assessing the site of biliary leakage.

Conclusion

The results of our study suggest that the 3D axial primary dataset of MRCP is preferable for visualization and evaluation of distal CBD, ampulla, and hilar confluence whereas for overall evaluation of bile ducts status, coronal reconstructions with MIP are preferred. The most common finding in our study was biliary strictures.

المخلص

الغرض

معرفة أفضل تمثيل للبيانات ثلاثية الأبعاد للمستوى السهمي والجبهوي المأخوذة من تصوير البنكرياس والقنوات الصفراوية بالرنين المغناطيسي بين مجموعات للمرضى الذين يعانون من آلام مستمرة بعد استئصال المرارة

الطريقة

تم تضمين 78 مريضًا بتصوير بالرنين المغناطيسي للقنوات الصفراوية والبنكرياس. تراوحت الفئة العمرية من 20 إلى 70 عامًا وكان المرضى يعانون من أعراض مستمرة أو متكررة بعد استئصال المرارة مثل آلام البطن أو القيء أو اليرقان. تم إجراء تصوير البنكرياس والقنوات الصفراوية بالرنين المغناطيسي لجميع المرضى على جهاز تصوير بالرنين المغناطيسي 1.5 تسلا. تم إجراء تصوير البنكرياس والقنوات الصفراوية بالرنين المغناطيسي ثنائي الأبعاد وثلاثي الأبعاد. تم إعادة تركيب الصور للمستوى الجبهوي لكل البيانات. تمت مقارنة النتائج بالصور ثلاثية الأبعاد لتقييم قنوات البنكرياس والقنوات الصفراوية.

النتائج

بعد استئصال المرارة، 48% من المرضى كان لديهم تضيق بينما 35.8% وجد لديهم حصوات صفراوية إما داخل الكبد أو خارج الكبد، والأغلب كن في القناة الصفراوية البعيدة التي تسبب اليرقان الانسدادي أما بقية المرضى كان لديهم سرطان القنوات الصفراوية، التهاب البنكرياس أو مضاعفات ما بعد العملية مثل تحول القناة الصفراوية بالكامل أو ربط القناة الصفراوية. كان أكثر الأعراض شيوعًا هو تضيق القنوات الصفراوية. تم تقييم وجود الحصوات في القناة الكبدية والقناة الصفراوية القريبة بشكل أفضل عن طريق المحور الجبهوي ثلاثي الأبعاد (ذات دلالة إحصائية أقل من 0.05) مقارنة بالصور المحورية. تقييم منطقة ما حول القناة الصفراوية البعيدة، داخل الكبد، ومنطقة نقيير الكبد بشكل أفضل على المحور السهمي ثلاثي الأبعاد (ذات دلالة إحصائية أقل من 0.05). كان المحور السهمي ثلاثي الأبعاد أيضًا أفضل من المحور الجبهوي فيما يتعلق بتصوير الحصوات في القناة الصفراوية البعيدة والقنوات الصفراوية داخل الكبد وبقايا المرارة والقناة الصفراوية. كان المحور الجبهوي ثلاثي الأبعاد أفضل بالنسبة للرباط بعد العملية بينما كان المستوى السهمي ثلاثي الأبعاد أكثر فائدة في تحديد مستوى إصابة القناة وتقييم موقع التسرب الصفراوي.

الخاتمة

تشير نتائج دراستنا إلى أن مجموعة البيانات الأولية السهمية ثلاثية الأبعاد لتصوير القنوات الصفراوية البنكرياسية بالرنين المغناطيسي هي الأفضل لتصوير وتقييم القناة الصفراوية المشتركة

1. INTRODUCTION

Patients with cholecystectomy can have persistent or new-onset symptoms after surgery in the early post-operative (post-op) period or later onset. The earlier post-op cause can be operative complications or biliary manifestations, like retained calculi in ducts. However, the later onset of post-cholecystectomy pain is often termed as a post-cholecystectomy syndrome. The post-cholecystectomy syndrome can be due to biliary strictures involving the sphincter of Oddi or Common Bile Duct (CBD), recurrent calculi or even biliary dyskinesia. Diagnosis of the etiology of early or late post cholecystectomy complications can be made by imaging. Ultrasound is a non-invasive radiation-free imaging modality but has a limited role, primarily if visualizing the biliary tree is the concern. Magnetic resonance cholangiopancreatography (MRCP) is being used as an established technique for evaluating intra and extra-hepatic biliary ducts. Because of its capability to provide non-invasive high-quality visualization of biliary ducts, MRCP has been proven reliable in assessing post-cholecystectomy symptoms [1]. It is a reliable non-invasive alternative to diagnostic endoscopic retrograde cholangiopancreatography (ERCP) [2, 3]. MRCP allows detailed evaluation of pancreatic and biliary tracts like in endoscopic retrograde cholangiopancreatography (ERCP) but with a large field of view (FOV) and excellent patient tolerance providing three-dimensional (3D) projection images.

Different acquisition techniques of MRCP have evolved since the first description by Wallner and colleagues in 1991 [4]. Most current MRCP techniques are based on heavily T2-weighted fast spin-echo (FSE) pulse sequences, giving a luminal image of the bile ducts, which is based on the inherent signal of slow-flowing or stationary bile. Both single-shot projections and multi-slice techniques are available, with the latter being distinguished into 2D and 3D techniques [5]. Maximum intensity projections (MIP) are then obtained in any plane, and these are the images provided to the referring physician. Previous studies have addressed the matter of data acquisition and different techniques regarding respiratory triggering in MRCP. The 3D imaging techniques provide better image quality than 2D sequences [6–8], both in raw images and post-processing techniques. It has been suggested that the combination of different MRCP sequences is more valuable in assessing bile duct anatomy and pathology than relying on a single sequence [9] [10].

It is common for many radiologists, physicians, and surgeons to visualize the MIP image of MRCP only and make a diagnosis. Although MIP images give an excellent representation of biliary trees, emphasis is being made to assess individual primary biliary ducts in the 3D primary raw datasets, which can be acquired in any plane. By acquiring both axial and coronal planes separately, the chance of error in reporting can be decreased with an increased confidence level. But it also increases the scan time and hence leading to patient discomfort. Therefore, an ideal 3D plane needs to be acquired at the scan's start. To the best

of our knowledge, the ideal 3D plane for optimal bile duct visualization has not been evaluated or published so far in Pakistan. Determining an ideal thin-slice 3D source image is the purpose of our study, to directly visualize the problematic areas, including the small early hilar and periampullary strictures. We also considered comparing the optimal acquisition and reconstruction planes for MIP assessment of the intra and extrahepatic bile ducts.

2. METHODS

This was a cross-sectional analytical study carried out in the Radiology department of Rehman Medical Institute Peshawar from 1st January 2016 to 30 May 2017. Our sample size was 78 (56% females and 44% males), and it was a non-probability consecutive sampling (all patients coming for MRCP in the duration were included who had a history of cholecystectomy). The age range was 20 to 70 years, and patients presented with persistent or recurrent post cholecystectomy symptoms like abdominal pain, vomiting or jaundice. They had deranged liver function tests. Data were collected retrospectively from the hospital's database, and the need for informed consent was waived off by permission from the hospital's ethical committee. MRCP was performed for all patients on a 1.5T GE MRI with breath-held multi-slice acquisition using dedicated multi-channel-surface coils covering the abdomen. Prior to image acquisition, patients were informed of fasting of at least 4 hours to suppress gastric and enteric fluid signals adequately. No intravenous contrast injection was given. All patients underwent a clinical routine imaging protocol of the liver, including a respiratory-triggered 3D MR cholangiography in the coronal and axial planes. In addition, axial T2WI, T2 FATSAT, Sag T2WI and Dual echo sequences were acquired. Both 2D and 3D MRCP images were acquired. Coronal MIP was reconstructed based on each dataset. Care was taken to exclude the renal pelvis, ureters, and spinal canal. Two radiologists having three years of hepatobiliary reporting independently assessed the raw data sets and MIP images regarding visualization of bile ducts and image quality. Data were analyzed using Microsoft Excel and SPSS version 22 (Armonk, NY: IBM Corp.). Results were compared for the ideal 3D plane to assess pancreaticobiliary ducts. The Chi-square analysis determined the dependence between the qualitative variables. Qualitative variables were given as a number (n) and percentage (%). Descriptive statistics on quantitative variables were given as mean \pm SD. Multivariate analysis was used to treat variables that were found significant in the univariate analysis, and $p < 0.05$ was considered significant.

Image reading: Coronal and axial 3D raw dataset acquisitions were assessed for each duct segment independently. Coronal reconstructed MIP from the coronal dataset was compared with reconstructed MIP from the axial dataset. After each reading session, a consensus was made for the preferred image dataset of any given comparison. Any filling defect was correlated with T2 weighted images for the existence of stones. To assess stric-

tures, cholangitis, biliopathy and ligatures etc., bile duct segments were evaluated using the three-point scale, i.e., 1. Segment not seen; 2. The segment has faintly seen; 3. The excellent depiction, including the proximal and distal portions. This scale was applied to the following segments of the biliary tract: the common bile duct (CBD), the common hepatic duct (CHD), the hilar biliary confluence, ampulla, the right anterior bile duct, the right posterior bile duct, the left hepatic duct and third-order biliary branches. [11]

3. RESULTS

The post-cholecystectomy biliary findings were strictures (48%), retained biliary stones (35.8%), which were located either intrahepatic or extra-hepatic, most commonly in distal CBD causing obstructive jaundice and the rest of the patients had either cholangiocarcinoma at the hilum, pancreatitis or post-op complications like complete bile duct transection, bile duct ligation etc. The most common finding was biliary stricture. CHD and proximal CBD were better assessed for the presence of strictures and stones on 3D coronal (P-value <0.05) as compared to the axial images (Figures 1 & 2) (Tables 1, 2, 3).

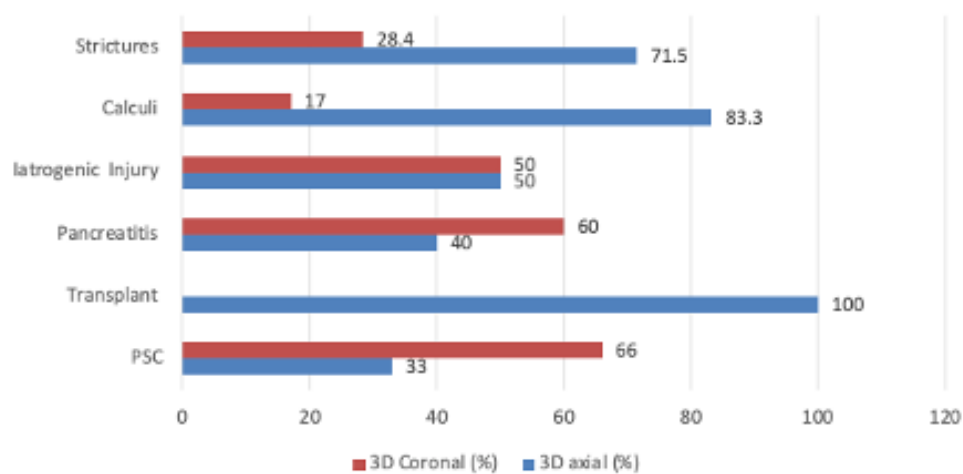


Figure 1 Post cholecystectomy findings on MRCP and a better 3D assessment plane on MRCP (red=axial, blue=coronal).

Periampullary, distal CBD, intrahepatic and hilar confluence duct strictures were better visualized on 3D axial (P-value <0.05). 3D axial was also better than coronal raw datasets regarding visualization of calculi in distal CBD, intrahepatic biliary ducts, GB remnant, cystic duct, and hilar biliary confluence (Figure 3 & 4). 3D coronal was better (P-value <0.05) for post-op ligature, whereas 3D axial was more helpful deciding the level of duct injury and assessing the site of biliary leakage (Table.3). In the case of coronal data acqui-

Table 1 Visualizing calculi in biliary ducts at any level was better in 3D Axial, whereas only the distal CBD calculi were better seen in the coronal plane.

LEVEL OF STONE IN BILIARY DUCT	IDEAL 3D PLANE
Distal CBD	coronal
CHD	axial
Intrahepatic ducts	axial
Cystic duct	axial
GB remnant	axial

Table 2 All the biliary duct strictures were better visualized on axial planes except the extra-hepatic central duct, which was better visualized on the coronal plane.

Stricture in Biliary duct segment	Ideal 3D plane
CBD	coronal
CHD	coronal
Intrahepatic (post-transplant)	axial
Hilumbiliary confluence	axial
Ampulla	axial
Anastomotic stricture	axial
Ischemic stricture (post-transplant)	axial

Table 3 Level of duct injury and site of the biliary leak was better assessed on axial images, whereas the site of ligation was better identified on coronal images

Bile duct injury / post-op complication	Ideal 3D plane
CHD injury	Axial
ligature	Coronal
Fluid collection	T2 FSE

tion, MIP was helpful in the visualization of the hilar confluence of bile duct segments and the overall view of the biliary tree (Figure.5). Pancreatic duct anomalies and pancreatitis-related findings were better visualized on 3D coronal images. Regarding MIP reconstruction, image quality acquired from both coronal and axial did not differ significantly. Post laparoscopic biliary complications were complete bile duct transaction, bile duct ligation, benign strictures, cholangiocarcinoma at the hilum, pancreatitis. They retained biliary stones located either intrahepatic or extra-hepatic, most commonly in distal CBD, causing obstructive jaundice. There was no significant difference between the coronal and axial acquired dataset (P value > 0.05) regarding overall technical image quality (including axial and coronal reconstructed MIP of a given dataset).

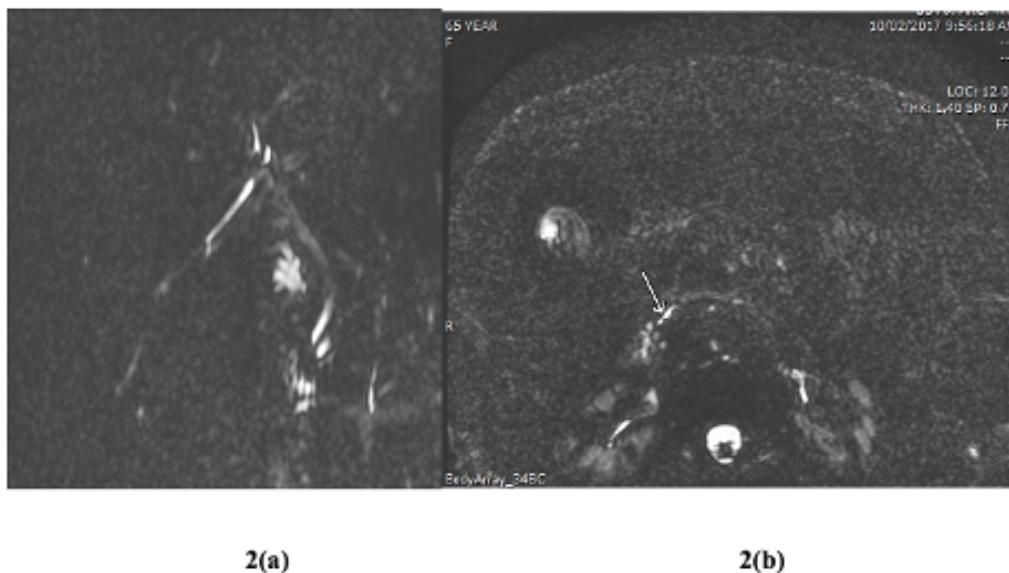


Figure 2 (a)There is a non-visualization of the ampulla and the pancreaticobiliary confluence on the coronal image, which might raise concern for the possibility of ampullary stricture. However, the following image at the level of ampulla shows normal pancreaticobiliary confluence seen on the axial image (b), suggesting a normal ampulla with no stricture (arrow).

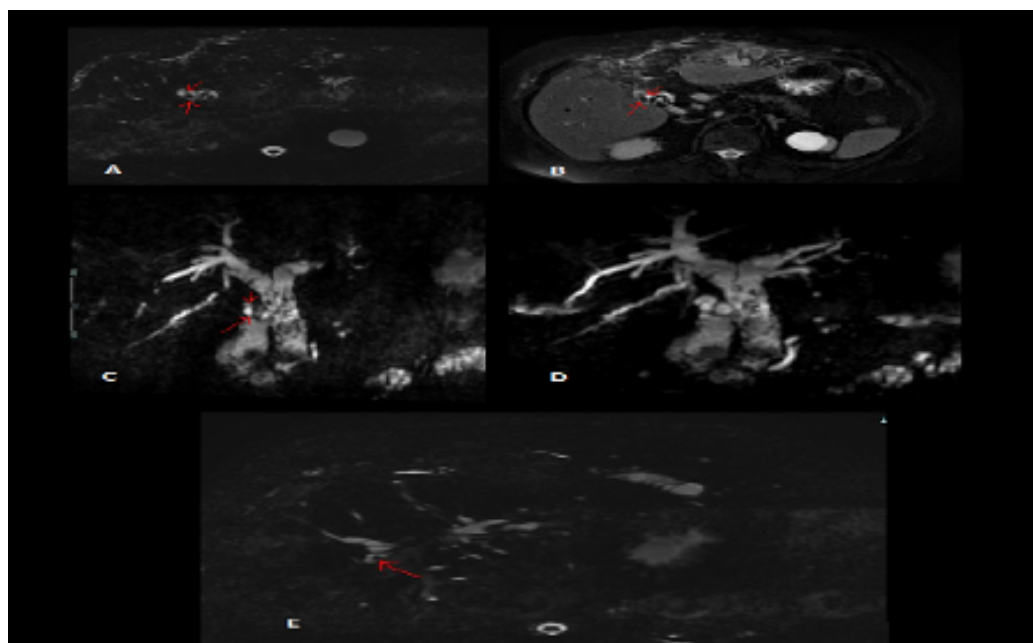


Figure 3 (A)Axial image from raw data showing a GB remnant containing calculi, seen as outpouching from CBD (arrow), better visualized on axial T2 (B). Coronal raw data showing outpouching with multiple calculi (C), which are being suppressed on MIP-ped image (D). (E) Axial image at a higher-level showing stone in intrahepatic duct. Note that it is only visible on axial image, when compared with coronal image(C).

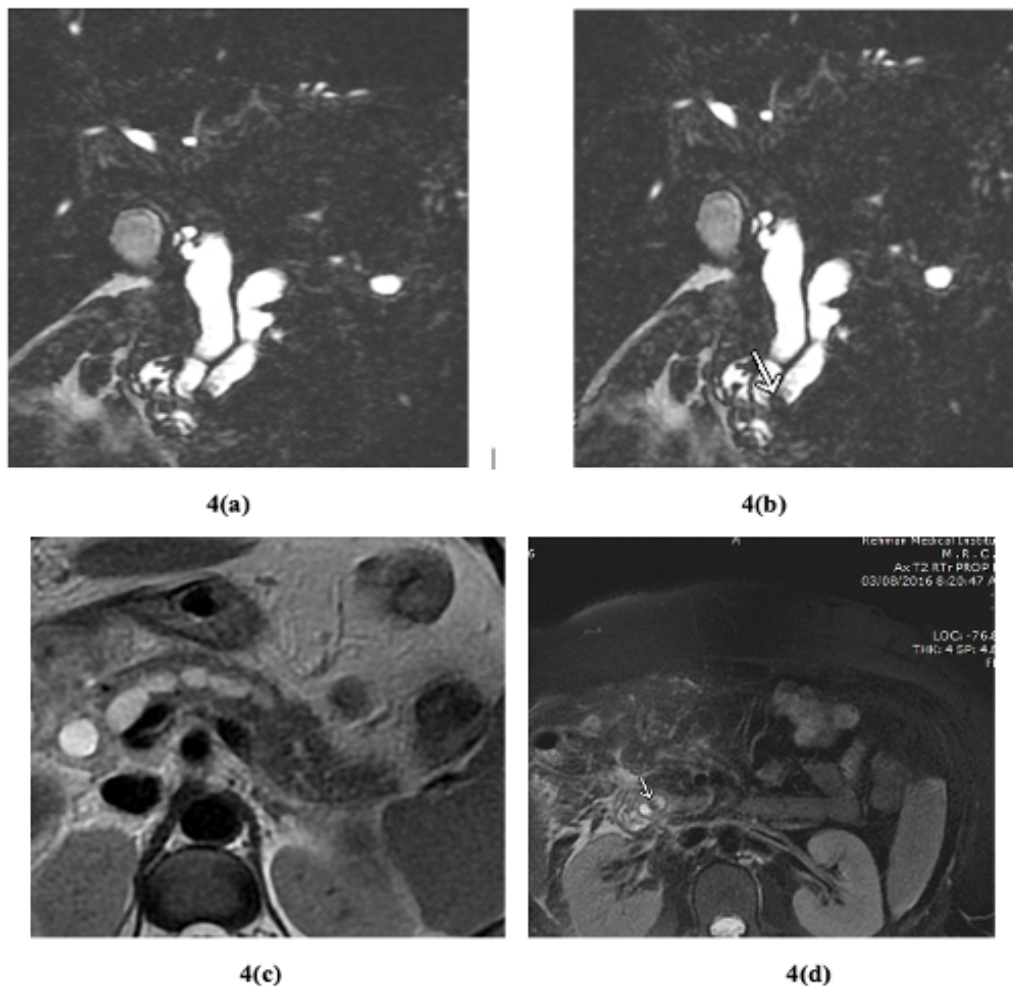


Figure 4 (4a and 4b): MRCP 3D Coronal images showing double duct sign with dilated central pancreatic duct and CBD. Intrahepatic biliary ducts are also dilated. Arrow points at a possible signal void focus at the ampulla, causing an obstruction. This drawback of relying only on the coronal plane is that this filling defect can be misinterpreted as an ampullary stricture with possible mass. 4(c): axial T2WI showing grossly dilated MPD and distal CBD. 4(d): axial T2 FATSAT image at the level of ampulla showing an obstructing calculus (arrow) causing biliary obstruction. Surrounding fat stranding is concerned for resultant acute pancreatitis.

4. DISCUSSIONS

3D MRCP images can be acquired in all three planes. In contrast to single-shot techniques, 3D MRCP has the advantage of facilitating secondary reconstructions. Coronal reconstruction with or without MIP has been preferred, regardless of the initial acquisition plan. Even in our study, these findings were supported by good intra and inter-observer agreement. One of the reasons for coronal image routine preference might be that these images



Figure 5 Coronal MIP showing iatrogenic biliary stricture in proximal CBD with resultant obstruction. Note the better visualization of overall biliary assessment on MIP image.

are similar to image impressions of ERCP and conventional cholangiograms. However, it is common to observe a signal drop-out or artifact in biliary tree on 3D coronal MRCP images, which can lead to over-reporting of stricture, lesion or impacted stone, and sometimes the FSE T2WI does not help. For this reason, 3D images should be obtained in more than one plane. At our center, we have included it in our protocol for a few years now to obtain 3D images in axial and coronal planes reducing the error in reporting with an increased confidence level. However, it has caused the procedure lengthening with increased time scan with increased patient discomfort. So, the ideal and more suitable 3D plane needs to be acquired at the scan's start. Literature shows that the perfect source image plane for bile duct evaluation with 3D technique has not been evaluated.

In the first approach towards projection cholangiography utilizing MRI in 1991, Wallner and colleagues used a heavily T2-weighted gradient-echo sequence to assess bile duct dilatation. They concluded that imaging in the coronal plane provided a good view of the biliary system [4], whereas no additional information was found by imaging in the sagittal plane. An ideal thin-slice 3D source image was the purpose of our study, specifically to directly visualize the problematic areas, including the small early hilar and periampullary strictures. For single-shot FSE techniques, it has been suggested in previous studies that

straight coronal and initial left posterior oblique images depict the common hepatic duct and the left hepatic duct. In contrast, the CBD and right hepatic ducts are seen better on a left posterior image obtained at a steeper angle [11]. Our results showed that 3D axial images were better for assessing hilar biliary confluence, intrahepatic ducts, ampulla and distal CBD. In contrast, the 3D coronal volume images were more helpful for determining the rest of the main extrahepatic duct, i.e., the common hepatic duct and proximal and mid-CBD. Lesions at the ampulla and periampullary region are difficult to assess radiologically on MRCP as imaging characteristics of benign and early malignant conditions in these areas overlap. Moreover, although some entities can be well evaluated with the high spatial resolution provided by CT scan, others are better assessed with MR imaging or MRCP to different diseases that should be timely managed medically from those that require intervention [12].

MIP technique and the final MIP-ped coronal images are obtained from primary datasets by increasing slice thickness with overlapped images. MIP can be obtained from any 3D plane. In our study, we observed that the orientation of the primary dataset (coronal or axial) for acquiring MIP images was negligible. The ideal MIP image, however, was found to be coronal. It is a practice in most of the local and international centers to rely on the final provided MIP images by the MR technician. This can lead to and has been observed to result in under-reporting (missing small early strictures) and over-reporting (giving a distal CBD stricture). This was also assessed in our study. The benefit of MIP coronal images observed in our study was to get an overall view of the entire pancreaticobiliary tree, which helped diagnose the type of pancreas divisum, site of post-obliterated biliary ligature stricture and level of obstruction in extra-hepatic ducts. At detailed dataset analysis, however, in case of coronal data acquisition, the technical image quality of the coronal MIP was significantly better than the reconstructed axial MIP. In the case of axial data acquisition, there was no significant difference regarding the technical image quality of the reconstructed MIP.

A well-known limitation of MIP is that minor filling defects may be obscured due to partial volume effects, and overestimation of ductal narrowing and pseudo-stricture may result from MIP reconstruction [13]. Therefore, MIP reconstructions mustn't be appraised separately but always in combination with the acquired dataset and other morphological sequences.

Post cholecystectomy patients with persistent or recurrent pain are a challenge for their physicians. ERCP is avoided as the initial imaging due to contract-related and invasive procedural side effects. MRCP proves helpful in such patients as a noninvasive tool; it rules out or detects the presence of biliary calculi, site of strictures and even the earliest signs of pancreatitis-related pancreatic duct changes. ERCP should be done if indicated on

MRCP, like evaluating a distal CBD stricture, retrieving stones from ducts, or cytological brushings from a suspected biliary neoplastic process.

Our results show that 3D primary raw data source images are essential in depicting small intraductal pathologies such as calculi and early biliary neoplastic processes. Our results indicate a higher global accuracy for 3D primary raw data sequences versus MIP images in diagnosing the level and probable cause of pancreaticobiliary obstruction and stress the limitations of relying on MIP images alone. 3D volume source image in one plane should be sufficient for visualization of biliary tree including the ampulla and hilum. Such studies should be done at a larger scale comparing ideal plane for 3D volume images. For every MRCP, a 3D axial primary source dataset should be acquired to visualize hilum and peri ampullary ducts better. It can be reconstructed and MIPped in a coronal plane to assess the biliary tree for a traditional approach.

5. CONCLUSIONS

Our study suggests that 3D primary volume source images in the axial plane are better for visualization of the ampulla, distal CBD, intrahepatic ducts, and confluence. In contrast, coronal reconstructions with MIP are preferred to evaluate bile ducts status.

CONFLICT OF INTEREST

There is no conflict of interest to declar

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