Diagnostic accuracy of 3d mrcp in comparison with conventional mri in the evaluation of normal anatomical variants and pathologies of the biliary tract.

Poster No.: C-1095
Congress: ECR 2016
Type: Scientific Exhibit
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Keywords: MR, Gastrointestinal tract, Biliary Tract / Gallbladder, Abdomen, Cholangiography, Inflammation, Obstruction / Occlusion, Artifacts
DOI: 10.1594/ecr2016/C-1095

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Aims and objectives

The expanding spectrum of biliary tract and gallbladder disease makes it necessary for the radiologist to precisely assess the normal anatomy, anatomical variants, pathology, etiology, location, level and extent of disease. This study aims to discuss the invaluable addition of conventional MRI sequences to MRCP in the evaluation of biliary tract and gallbladder and its merits in the evaluation of pathologies indistinct on MRCP alone.

Objectives of the study:

• To evaluate patients with clinical suspicion of biliary tract and gallbladder pathology with conventional Magnetic resonance imaging and magnetic resonance cholangiopancreatography.

• To compare the image quality, visualization and clarity of normal anatomical variants and biliary tract pathologies with magnetic resonance cholangiopancreatography and conventional MR imaging.
Methods and materials

Patients

Institutional review board approval was obtained.

Written informed consent was obtained before each examination.

Study was conducted on ninety patients (46 men and 44 women; age range: 5-70 years) referred to MRCP for the evaluation of biliary or pancreatic diseases between the period of January 2014-September 2015.

Pre-procedural preparation:

There were no dietary restrictions before imaging, and no oral contrast material or anti-peristaltic agents were used.

Procedure:

MRCP was performed in a 1.5 T MR imaging unit (Achieva, Philips Medical Systems) with a 16 element body phased array coil, centered below the xiphisternum. Each patient underwent imaging with conventional T2W TSE, T1W TFE, T2W BTFE MRCP sequences, which included axial thick slab imaging for all and coronal MR imaging for the BTFE sequences, followed by a navigator triggered coronal 3D MRCP sequence. MIP sequences were further reconstructed from the coronal navigator triggered 3D MRCP sequences.

Table 1: Acquisition parameters

<table>
<thead>
<tr>
<th>PARAMETERS</th>
<th>T2W TSE</th>
<th>T1W TFE</th>
<th>T2W BTFE</th>
<th>3D MRCP NAV</th>
</tr>
</thead>
<tbody>
<tr>
<td>Scan mode</td>
<td>M2D</td>
<td>M2D</td>
<td>M2D</td>
<td>3D</td>
</tr>
<tr>
<td>FOV: RL AP FH</td>
<td>280 221 199</td>
<td>290 236 199</td>
<td>400 300 239</td>
<td>260 90 260</td>
</tr>
<tr>
<td>Slice thickness</td>
<td>7mm</td>
<td>7mm</td>
<td>7mm</td>
<td>0.8mm</td>
</tr>
<tr>
<td>Acq TR Acq TE</td>
<td>333 -</td>
<td>-</td>
<td>-</td>
<td>1204 650</td>
</tr>
</tbody>
</table>
Methodology:

1. **Technical quality**: for each of the two arms of the study, only studies with adequate, readable technical quality were included.

2. **Assessment of ducts**: the biliary tree was divided into 8 segments - right hepatic duct, left hepatic duct, common hepatic duct, cystic duct, proximal common bile duct, mid common bile duct, distal common bile duct and main pancreatic duct.

3. **Anatomical variations**: anatomical variants were divided into 4 major groups (intrahepatic duct confluence variation, cystic duct insertion variation, choledochal cysts, and pancreatic divisum) and were assessed on both MRI and MRCP sequences. A scoring of 1-4 was assigned to each variant based on delineation of the variant on each sequence (1- Well delineated, 2- fairly well delineated, 3- poorly delineated and 4-not visualized).

4. **Visibility of pathology**: pathologies were also assessed with the same scoring 1-4 (1- Well delineated, 2- fairly well delineated, 3- poorly delineated and 4-not visualized) within 2 arms of comparison: T2W BTFE/ T2W TSE/ T1W TFE and navigator triggered 3D MRCP. Some of the pathologies were assessed with different sequences of conventional MR imaging; for example, pneumobilia was assessed using the T1W fat suppression sequence to differentiate air from stones and T2W TSE sequence was used when the BTFE sequence was inadequate in sections or information.

**Statistical methods**:

1. Each comparison was performed separately for each of the anatomical variants. Observations were made within the two arms of the study by a comparison that was performed with strict threshold criteria. For the comparison, only those segments that
were well delineated (grade of 1) were considered to be visible. The average difference in the number of visible variants per patient between the 3D MRCP and conventional MRI sequences, with P values were determined by using kappa statistics.

2. Pathologies were divided into intraluminal filling defects and biliary tract obstruction due to various causes. Final diagnosis was compared with ERCP, computed tomography or histopathology correlation. Assessment of pathology in the multiple arms of comparison was graded in the same manner as the visibility of ducts (1-4) in relation with the accuracy of each arm (T2W BTFE/T2W TSE/T1W TFE, 3D MRCP and MIP) in the diagnosis of the pathology being studied and open EPI software was used to calculate sensitivity, specificity, positive predictive value, negative predictive value and diagnostic accuracy of 3D MRCP, MRI and MIP in the evaluation of the two groups of pathologies.
Results

Fig. 1: Frequency of anatomical variants in this study population

References: Dr. Bhavana Budigi, Bangalore IN

7 patients (10%) were diagnosed with choledochal cysts, 2 (2.8%) patients with pancreatic divisum, 42 patients (60%) with cystic duct insertion variations and 29 patients (41.4%) with intrahepatic duct confluence variations. All variants were compared on both 3D MRCP and conventional MRI sequences. In conventional MRI, all anatomical variants were analyzed on the T2W BTFE coronal sequence.
Of the 42 patients with cystic duct insertion variations, 24 were of the type II variety (low junction between cystic duct and CHD), 2 were of type III (low insertion with common sheath), 2 were of type IV (high junction with CHD), 2 were of type V (absence of cystic duct), 7 were of type VIII (posterior crossing of CHD by the cystic duct with anterior insertion) and 5 were of type IX (anterior crossing of CHD by cystic duct with posterior insertion). Familiarity with these variants is important prior to laparoscopic cholecystectomy due to the risk of injury to the cystic and hepatic ducts. In comparison with conventional MRI sequences 3D MRCP showed consistently better visibility of the cystic duct insertion showing a statistically significant p-value of <0.05 (0.03).
Fig. 4: Grading of the cystic duct insertion visibility on 3D MRCP and MRI

References: Dr. Bhavana Budigi, Bangalore/IN
Fig. 5: Type II- low junction of cystic duct insertion with CHD on MIP
References: VIMS&RC, VIMS&RC - Bangalore/IN
Fig. 6: Types of intrahepatic ductal confluence variations

Fig. 7: Frequency of the intrahepatic ductal confluence variants in this study population

*References:* Dr. Bhavana Budigi, Bangalore/IN
Fig. 8: Grading of the visibility of the intrahepatic ductal confluence variants on 3D MRCP and MRI

References: Dr. Bhavana Budigi, Bangalore/IN
**Fig. 9:** Triple confluence of ducts-Type II on 3D MRCP (FRFSE)

*References:* VIMS&RC, VIMS&RC - Bangalore/IN
Intrahepatic duct confluence variations were noted in 29 patients- most common variant

*Fig. 10: Type II - triple confluence of ducts on MIP*

**References:** VIMS&RC, VIMS&RC - Bangalore/IN

...type II (triple confluence of RPS, RAS, and LHD into the CHD) was seen in 15 patients,

type IIIA (RPS drains into LHD) in 5 patients, type IIIB (RPS drains into CHD) in 3

patients, type IIIC (RPS drains into cystic duct) in 1 patient, type IVA (RAS drains into

CHD) in 3 patients, type IVB (RAS drains into RHD) in 1 patient and an unclassified

aberrant drainage of an accessory duct into proximal CBD was seen in 1 patient and was

classified as type VII. The type II variant at the level of the confluence becomes crucial

in patients being considered as potential donors for right hepatic lobe transplantation.
Intrahepatic biliary duct confluence variations were consistently better visualized on 3D MRCP sequences as compared to conventional MRI showing statistical significance with a p-value of <0.05 (0.04).

Fig. 11: Types of Choledochal cysts

Fig. 12: Frequency of the types of choledochal cysts
References: Dr. Bhavana Budigi, Bangalore/IN
Fig. 13: Grading of the visibility of choledochal cysts on 3D MRCP and MRI

References: Dr. Bhavana Budigi, Bangalore/IN

Fig. 14: Type IV A choledochal cyst on coronal T2W BTFE MRI sequence

References: VIMS&RC, VIMS&RC - Bangalore/IN
**Fig. 15:** Type IV A choledochal cyst on 3D MRCP (FRFSE)

**References:** VIMS&RC, VIMS&RC - Bangalore/IN
Fig. 16: Type IV A choledochal cyst on MIP

References: VIMS&RC, VIMS&RC - Bangalore/IN
Fig. 17: Type I A choledochal cyst on MIP

*References:* VIMS&RC, VIMS&RC - Bangalore/IN

Of the 7 patients with choledochal cysts, 6 were of the type I variety - three IA, one IB, two IC and one was of the IVA type. Choledochal cysts were well delineated in both conventional and 3D MRCP sequences, with a statistical significant p-value of <0.05 (0.00).
Pancreatic divisum was delineated on both 3D MRCP and conventional MRI, however, 3D MRCP showed better delineation than MRI in both cases. Dorsal and ventral pancreatic ducts in both cases of pancreatic divisum were clearly demonstrated on 3D MRCP with a grade 1 (well delineated) visibility of the ducts. Conventional MRI sequences showed grade 2 visibility (fairly well delineated) of the ducts. No statistical significance could be computed for pancreatic divisum as the variables for MRI were a constant owing to the small sample size.

Table 2: Statistical analysis of the anatomical variants

<table>
<thead>
<tr>
<th>ANATOMICAL VARIANT</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cystic duct insertion</td>
<td>.038</td>
</tr>
<tr>
<td>Intrahepatic duct confluence variation</td>
<td>.044</td>
</tr>
<tr>
<td>Choledochal cysts</td>
<td>.000</td>
</tr>
<tr>
<td>Pancreatic divisum</td>
<td>-</td>
</tr>
</tbody>
</table>
Summary:

- Anatomical variants in decreasing order of visibility:
  
  § Intrahepatic duct confluence - MIP > 3D > MRI (coronal T2W BTFE)
  
  § Cystic duct insertion variants - 3D > MIP > MRI (coronal T2W BTFE)
  
  § Choledochal cysts - 3D/MIP = MRI
  
  § Pancreatic divisum - 3D > MIP > MRI. Ducts and their drainage are best seen on 3D.

**TABLE 3: Intraluminal filling defects**

<table>
<thead>
<tr>
<th>S.NO</th>
<th>FINAL DIAGNOSIS</th>
<th>NO. OF PATIENTS</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Pneumobilia</td>
<td>2</td>
</tr>
<tr>
<td>2</td>
<td>Gallbladder polyps</td>
<td>2</td>
</tr>
<tr>
<td>3</td>
<td>Cholelithiasis</td>
<td>20</td>
</tr>
<tr>
<td>4</td>
<td>Choledocholithiasis</td>
<td>12</td>
</tr>
<tr>
<td>5</td>
<td>Hepatolithiasis</td>
<td>4</td>
</tr>
<tr>
<td>6</td>
<td>CBD stent</td>
<td>2</td>
</tr>
<tr>
<td>7</td>
<td>Gallbladder carcinoma</td>
<td>4</td>
</tr>
<tr>
<td>8</td>
<td>Stump carcinoma with intra ductal spread</td>
<td>1</td>
</tr>
<tr>
<td>9</td>
<td>Cholangiocarcinoma - Polypoidal type</td>
<td>1</td>
</tr>
</tbody>
</table>

48 patients showed evidence of intraluminal filling defects. MIP failed to delineate 22 cases (24.4%) with intraluminal filling defects. There were 3 cases that were false positively visualized on MIP, 5 that were false positively visualized on ultrasonography, 2 that were false positively visualized on 3D MRCP. 2 cases of gallbladder polyps were not detected on conventional MRI, 3D MRCP and MIP, however there were detected on ultrasonography. 1 case of Cholelithiasis was not detected on MRI, MRCP and MIP; however it was detected on ultrasonography. 1 case of Cholelithiasis was detected on both conventional MRI and ultrasonography; however, it was not detected on 3D MRCP and MIP.
In MIP, most of the intraluminal filling defects (38 cases-79.1% patients) have not been visualized, owing to the MIP reconstruction artifact. Due to partial volume effect and limited spatial resolution of the MIP reconstructed images, MIP tends to completely obscure small filling defects and poorly delineate the visualized defects, which does not enable the reader to interpret the nature of the filling defect. Hence, correlation with source images is of prime importance in order to avoid missing key findings. False positive intraluminal filling defects were detected in 2 cases on 3D MRCP and 4 cases on MIP.

**Fig. 19:** Choledocholithiasis on 3D MRCP
Fig. 20: Choledocholithiasis not visualized on MIP

References: VIMS&RC, VIMS&RC - Bangalore/IN
**Fig. 21:** Choledocholithiasis on coronal T2W BTFE

**References:** VIMS&RC, VIMS&RC - Bangalore/IN
Fig. 22: Choledocholithiasis poorly delineated on MIP

References: VIMS&RC, VIMS&RC - Bangalore/IN
Fig. 23: Choledocholithiasis, cholelithiasis and hepatolithiasis on 3D MRCP (FRFSE)

References: VIMS&RC, VIMS&RC - Bangalore/IN
Fig. 24: Choledocholithiasis, cholelithiasis and hepatolithiasis on MIP

References: VIMS&RC, VIMS&RC - Bangalore/IN
Fig. 25: Ventrally displaced pneumobilia on T2W TSE axial image

References: VIMS&RC, VIMS&RC - Bangalore/IN
**Fig. 26:** poorly delineated pneumobilia mimicking calculus in the left hepatic duct on 3D MRCP (FRFSE)

**References:** VIMS&RC, VIMS&RC - Bangalore/IN
Table 4: Statistical analysis of the results of visibility of intraluminal filling defects

<table>
<thead>
<tr>
<th></th>
<th>Sensitivity</th>
<th>Specificity</th>
<th>PPV</th>
<th>NPV</th>
<th>Accuracy</th>
</tr>
</thead>
<tbody>
<tr>
<td>MRI</td>
<td>93.62%</td>
<td>100%</td>
<td>100%</td>
<td>91.42%</td>
<td>96.20%</td>
</tr>
<tr>
<td>3D MRCP</td>
<td>85.71%</td>
<td>93.75%</td>
<td>95.45%</td>
<td>81.08%</td>
<td>88.88%</td>
</tr>
</tbody>
</table>

Fig. 27: Ill defined pneumobilia on MIP

References: VIMS&RC, VIMS&RC - Bangalore/IN
Table 5: Causes of biliary tract obstruction.

<table>
<thead>
<tr>
<th>Location</th>
<th>Number of cases</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Benign stricture</strong></td>
<td></td>
</tr>
<tr>
<td><strong>Location</strong></td>
<td><strong>Number of cases</strong></td>
</tr>
<tr>
<td>Distal CBD</td>
<td>5</td>
</tr>
<tr>
<td>Proximal CBD</td>
<td>1</td>
</tr>
<tr>
<td>Mid CBD</td>
<td>1</td>
</tr>
<tr>
<td>CHD</td>
<td>2</td>
</tr>
<tr>
<td>Aberrant RPS</td>
<td>1</td>
</tr>
<tr>
<td>Periampullary</td>
<td>1</td>
</tr>
<tr>
<td>IHBR- primary sclerosing cholangitis</td>
<td>1</td>
</tr>
<tr>
<td><strong>Malignant stricture</strong></td>
<td></td>
</tr>
<tr>
<td><strong>Location</strong></td>
<td><strong>Number of cases</strong></td>
</tr>
<tr>
<td>Cholangiocarcinoma (proximal CBD)</td>
<td>2</td>
</tr>
<tr>
<td>Periampullary (distal CBD)</td>
<td>9</td>
</tr>
<tr>
<td>GIST (distal CBD)</td>
<td>1</td>
</tr>
<tr>
<td>Gallbladder carcinoma (CHD)</td>
<td>2</td>
</tr>
<tr>
<td>Stump malignancy</td>
<td>1</td>
</tr>
<tr>
<td>Pancreatic head carcinoma (distal CBD)</td>
<td>1</td>
</tr>
<tr>
<td>Cholangiocarcinoma (hilar)</td>
<td>2</td>
</tr>
<tr>
<td>Cholangiocarcinoma (CHD)</td>
<td>2</td>
</tr>
<tr>
<td><strong>Choledocholithiasis</strong></td>
<td></td>
</tr>
<tr>
<td><strong>Location</strong></td>
<td><strong>Number of cases</strong></td>
</tr>
<tr>
<td>Distal CBD</td>
<td>6</td>
</tr>
<tr>
<td>Proximal CBD</td>
<td>4</td>
</tr>
<tr>
<td>Cystic duct calculi</td>
<td>2</td>
</tr>
</tbody>
</table>
**Fig. 28:** case of GIST medial to the second part of duodenum seen causing distal obstruction of CBD causing proximal dilatation on coronal T2W BTFE

**References:** VIMS&RC, VIMS&RC - Bangalore/IN
Fig. 29: GIST as seen on T2W TSE axial images.

References: VIMS&RC, VIMS&RC - Bangalore/IN
**Fig. 30:** Distal CBD stricture in the same case of GIST as above presenting as a smooth tapering stricture on MIP

**References:** VIMS&RC, VIMS&RC - Bangalore/IN
Fig. 31: Cholangiocarcinoma seen as intraluminal filling defect on coronal T2W BTFE

References: VIMS&RC, VIMS&RC - Bangalore/IN
Fig. 32: Cholangiocarcinoma seen as a CHD stricture on MIP. Intraluminal filling defect could not be appreciated.

References: VIMS&RC, VIMS&RC - Bangalore/IN

Grade 1 visibility of Level of obstruction was seen on 3D MRCP in 43 cases (47.8%), on MIP in 36 cases (40%), on conventional MRI in 27 cases (30%). Level of obstruction could not be visualized in 2 cases (2.2%) on MIP - 1 case of pneumobilia and 1 case of impacted cystic duct calculus.

Grade 1 visibility of cause of obstruction was seen in 27 cases (30%) on conventional MRI sequences, 15 cases (16.7%) on 3D MRCP, and 7 cases (7.8%) on MIP. Cause of obstruction was not visualized in 20 cases (22.2%) on 3D MRCP, 29 cases (32.2%) on MIP and 0 cases on conventional MRI sequences.

Table 6: Statistical analysis of the results of visibility of biliary tract obstruction
<table>
<thead>
<tr>
<th></th>
<th>SENSITIVITY</th>
<th>SPECIFICITY</th>
<th>PPV</th>
<th>NPV</th>
<th>ACCURACY</th>
</tr>
</thead>
<tbody>
<tr>
<td>MRI</td>
<td>95.56%</td>
<td>85.11%</td>
<td>86.00%</td>
<td>95.24%</td>
<td>90.20%</td>
</tr>
<tr>
<td>3D MRCP</td>
<td>93.33%</td>
<td>72.34%</td>
<td>76.36%</td>
<td>91.89%</td>
<td>82.60%</td>
</tr>
<tr>
<td>MIP</td>
<td>71.11%</td>
<td>93.62%</td>
<td>91.42%</td>
<td>77.19%</td>
<td>82.60%</td>
</tr>
</tbody>
</table>

**LIMITATIONS OF THIS STUDY:**

1. Small sample size has attributed to the lack of statistical significance in the visibility of Main pancreatic duct and in the visibility of pancreatic divisum.
2. MIP has shown higher specificity inaccurately in both intraluminal filling defects and biliary tract obstruction, as MIP has a very low sensitivity in detecting intraluminal filling defects and this has translated into a higher true negative rate and vice versa, resulting in a false positive specificity value. However, it was included in this study to stress on the MIP reconstruction artifacts.
Fig. 1: Frequency of anatomical variants in this study population

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Fig. 2: Types of cystic duct insertion variations

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**Fig. 3:** Frequency of the cystic duct insertion variants

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Fig. 18: Grading of visibility of pancreatic divisum on 3D MRCP and MRI
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Conclusion

In conclusion, the invaluable addition of conventional MRI images to MRCP must be considered in the interpretation of normal biliary tract anatomy and in the case of pathologies. MRCP remains the mainstay for a non-invasive evaluation of the biliary tract and adequate knowledge in the application of different sequences in each pathology helps in accurate diagnosis.

In this study, MRCP proved superior to MRI in the visualization of the biliary tract segments. Although MRI may provide adequate delineation, MRCP has proved superior in technical quality and has shown statistical significance. Anatomical variants are being reported with an alarmingly reduced frequency in everyday reporting by radiologists worldwide. The importance of anatomical variants in patients requiring surgery has been highlighted in many studies, and for this reason the frequency of anatomical variants and their delineation has been studied. MRCP showed consistently better quality in the visibility of the cystic duct insertion variations and intrahepatic duct confluence variants and pancreatic divisum, whereas choledochal cysts were equally well delineated on both conventional MRI and MRCP.

In the diagnosis of intraluminal filling defects, both MRI and MRCP showed good sensitivity and specificity. However, MRI showed better specificity as MRCP failed to differentiate air from stones and failed to delineate malignancy in a few cases.

In the diagnosis of biliary tract obstruction, conventional MRI and MRCP showed good delineation of the level of obstruction, however the cause of obstruction, especially in the case of malignancy causing extrinsic compression, conventional MRI proved superior to MRCP.

ACKNOWLEDGEMENTS

I would like to take this opportunity to thank my guide, Dr. Prachi Kala, Professor, Dr. Ram Prakash, HOD & Professor of the department and Dr. Rohini. A, Assistant Professor for their guidance and support.
References


