Evaluation of the branching pattern of the intrahepatic bile ducts using 3D balanced turbo-field-echo (BTFE) MR sequence: comparison with drip infusion cholangiography with CT (DIC-CT)

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Aims and objectives

Few studies showed the utility of 3D BTFE sequence evaluating the branching patterns of the bile ducts and PV, though the sequence was developed several years ago and 2D BTFE sequence has been performed as a part of MRCP protocol in many clinics.

The purpose of this study was to evaluate the diagnostic ability of BTFE sequence regarding the anatomic relation between the right posterior bile duct and PV as compared with DIC-CT or MRCP.

For liver surgery, it is crucial to preoperatively examine the running course of the right posterior bile ducts to avoid postsurgical bile leakage and damage to the residual liver or graft in individual cases (1-4).

- The complex anatomy and variety of the bile duct and portal vein (PV).
- For living-donor liver transplantation, right lobe graft placement has become increasingly common (1, 3, 5). However, biliary complications (bile leakages in 13%, biliary strictures in 1.5%) were the most common (5).

MR cholangiopancreatography (MRCP) and drip infusion CT cholangiography (DIC-CT) play an important role.

- High-resolution images
- MRCP: #non-invasive without contrast media or radiation exposure (1, 2), #motion artifacts (body movement or irregular breathing) or pseudolesion artifacts compressed by the right hepatic artery, #heavily T2-w sequence not allowing visualization of concentrated or hemorrhagic bile duct (2, 6), #not depicting PV (1)
  #The sensitivity for recognizing variant was reported only 74% (4, 7).
- DIC-CT: #depicting PV and other structures on source images with few artifacts in short scan time. #the usefulness reported in previous reports (2, 6, 8-10). #Some disadvantages such as adverse reactions and poor visualization of bile ducts with hyperbilirubinemia (2, 11).

The 3D balanced turbo-field-echo (BTFE) sequence may enable clear depiction of the relationship between the bile ducts and PV without above-mentioned disadvantages of DIC-CT.

- More clearly depicting concentrated or hemorrhagic bile than conventional MRCP with a heavily T2-weighted imaging sequence (6, 12)
- Providing good visualization of PV and other structures (12).
Methods and materials

Study design and patients

• IRB approved. Informed consent was waived. The privacy was completely protected.
• Between March 2010 and December 2015.
• Eligibility criteria for entry: adult patients underwent MRCP and 3D BTFE on a Philips 1.5-T MR scanner and DIC-CT within 2 months without invasive treatment in between.
• The exclusion criteria: age <18 years; contraindications to MRI or contrast media; hyperbilirubinemia (serum bilirubin >2 ml/dl).
• Of these, 3 patients were excluded: the bile ducts not visualized on DIC-CT in 1, the confluence of the bile duct outside FOV on MR in 2.
• ⇒ 30 patients (12 men, 18 women, 65±12 years) analyzable.
• Their clinical diagnoses: cholelithiasis (n=8), intrahepatic cholangiocarcinoma (n=5), suspected choledocholithiasis (n=3), hepatocellular carcinoma (n=3), liver metastasis (n=3), cholecystitis (n=3), common bile duct cancer (n=2), suspected Mirizzi syndrome (n=1), suspected sclerosing cholangitis (n=1), and gallbladder cancer (n=1).

MRI and CT scanning

• MRI images: #1.5-T MR scanner (Intera; Philips Medical Systems, Eindhoven, The Netherlands), #with the diaphragmatic navigator-gated and fat suppression, #the scanning parameters in Table 1 on page 6, #acquisition time, slightly shorter on BTFE than MRCP depended on the patients’ respiratory rate, ranged 3-5 min.
• CT images: #multidetector-row helical CT; 120 kVp output; 1 mm-thickness, #the biliary contrast media, 100 ml of meglumine iotroxate (Biliscopin 50 mg/mL; Schering, Berlin, Germany) administered >30 minutes before scanning.
• 2mm-thick MPR images were created in axial and coronal orientations.

Image data analysis

• Fig. 1 on page 6 Classification of the anatomic relation between the right posterior bile duct and PV (supraportal/infraportal pattern, A-E subtypes), as previously reported (3).
  -Supraportal pattern: the right posterior bile duct (P) runs dorsally and cranially to the right or to the right anterior PV.
  -Type A: P joins the right anterior bile duct (A).
  -Type B: P drains into the confluence of A and left hepatic duct (LHD).
  -Type C: P enters LHD.
- Infraportal pattern: P runs ventrally and caudally to the right or the right anterior PV.
  - Type D: P joins A.
  - Type E: P enters the common hepatic duct.

- Visual evaluation: independently carried out by two radiologists, blinded to the clinical information. Three images each of DIC-CT, MRCP, and BTFE were evaluated at intervals of >2 weeks, using the paging method as previous study (1).
  The degree of confidence was graded with a 3-point scale: score 1, guess; score 2, half guess; score 3, sure. The degree of motion artifacts was graded with a 3-point scale: score 1, severe; score 2, moderate; score 3, no or mild.

- The diameter of the right posterior bile duct was calculated: intrahepatic biliary dilatation >3 mm based on a previous report (13).

**Statistical analysis**

- Wilcoxon signed-rank test and paired samples t-test.
- Kappa statistic: poor (#=0.00-0.20), slight (#=0.21-0.40), fair (#=0.41-0.60), moderate (#=0.61-0.80), excellent/perfect (#=0.81-1.00).
**Fig. 1:** Illustrations of the running course of the right posterior bile duct: supraportal/infraportal pattern, A-E subtypes.

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<table>
<thead>
<tr>
<th>Parameter</th>
<th>BTFE</th>
<th>MRCP</th>
</tr>
</thead>
<tbody>
<tr>
<td>Repetition time, ms</td>
<td>4.5</td>
<td>Infinite</td>
</tr>
<tr>
<td>Echo time, ms</td>
<td>2.2</td>
<td>650</td>
</tr>
<tr>
<td>Flip angle, degrees</td>
<td>90</td>
<td>90</td>
</tr>
<tr>
<td>TSE/TFE factor</td>
<td>256</td>
<td>105</td>
</tr>
<tr>
<td>Bandwidth</td>
<td>781</td>
<td>292</td>
</tr>
<tr>
<td>Field of view, mm</td>
<td>330</td>
<td>330</td>
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<tr>
<td>Matrix, mm</td>
<td>256</td>
<td>256</td>
</tr>
<tr>
<td>Slice/section thickness, mm</td>
<td>2.0/1.0 overlap</td>
<td>1.6/0.8 overlap</td>
</tr>
<tr>
<td>Number of signals averaged</td>
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<td>1</td>
</tr>
<tr>
<td>Sensitivity encoding factor</td>
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<td>2</td>
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</table>

TSE, turbo spin echo; TFE, turbo field echo.

**Table 1**: Imaging parameters for BTFE and MRCP

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Results

The diameter of the right posterior bile duct did not differ between DIC-CT and MR (2.7±1.5 and 2.5±1.3 mm).

5 patients (17%) were diagnosed with intrahepatic biliary dilatation.

The motion artifact scores were 3.0 ± 0, 2.7 ± 0.5, and 2.9 ± 0.2 for reader 1 and 3.0 ± 0, 2.6 ± 0.6, and 2.8 ± 0.4 for reader 2 on DIC-CT, MRCP, and BTFE, respectively: slightly more on BTFE than DIC-CT.

Table 2 on page 9: Patient numbers for each branching pattern (supraportal/infraportal type; types A-E) on DIC-CT, MRCP, and BTFE.

Table 3 on page 9: Concordance of diagnosed types between reader 1 and 2, and imaging modalities (# statistics).

- The diagnostic concordances between the two readers for DIC-CT and BTFE, and between DIC-CT and BTFE for both readers were moderate to perfect (#=0.66-1.00).
- For the supraportal or infraportal type, these diagnostic concordances were perfect (all κ=1.00).
- Conversely, the diagnostic concordances between the two readers for MRCP, and between DIC-CT and MRCP were poor to fair (#=-0.53-0.41).

Table 4 on page 10: Confidence scores for diagnosis of branching patterns.

- DIC-CT # BTFE > MRCP for both readers with excellent inter-rater reliability

Representative patients are presented in Fig. 2 on page 11 and Fig. 3 on page 12.
Table 2: Patient numbers for each branching pattern (supraportal or infraportal type; types A-E) on DIC-CT, MRCP, and BTFE (n=30)

<table>
<thead>
<tr>
<th>Type</th>
<th>Supraportal</th>
<th>Infraportal</th>
<th>A</th>
<th>B</th>
<th>C</th>
<th>D</th>
<th>E</th>
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<tbody>
<tr>
<td>Reader 1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>DIC-CT</td>
<td>28</td>
<td>2</td>
<td>21</td>
<td>6</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>MRCP</td>
<td>27</td>
<td>3</td>
<td>20</td>
<td>5</td>
<td>2</td>
<td>3</td>
<td>0</td>
</tr>
<tr>
<td>BTFE</td>
<td>28</td>
<td>2</td>
<td>19</td>
<td>8</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Reader 2</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>DIC-CT</td>
<td>28</td>
<td>2</td>
<td>21</td>
<td>6</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>MRCP</td>
<td>29</td>
<td>1</td>
<td>18</td>
<td>10</td>
<td>1</td>
<td>1</td>
<td>0</td>
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<tr>
<td>BTFE</td>
<td>28</td>
<td>2</td>
<td>20</td>
<td>7</td>
<td>1</td>
<td>1</td>
<td>1</td>
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</tbody>
</table>
**Table 3:** Concordance of diagnosed types between reader 1 and 2, and imaging modalities (# statistics)

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<table>
<thead>
<tr>
<th></th>
<th>Supra- or infra-portal</th>
<th>A-E types</th>
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<tr>
<td>Between Reader 1 and 2</td>
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<tr>
<td>DIC-CT</td>
<td>1.00</td>
<td>0.86</td>
</tr>
<tr>
<td>MRCP</td>
<td>-0.53</td>
<td>0.13</td>
</tr>
<tr>
<td>BTFE</td>
<td>1.00</td>
<td>0.80</td>
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<tr>
<td>Between imaging modalities for both readers</td>
<td></td>
<td></td>
</tr>
<tr>
<td>DIC-CT and MRCP</td>
<td>0.35/-0.05</td>
<td>0.33/0.41</td>
</tr>
<tr>
<td>DIC-CT and BTFE</td>
<td>1.00/1.00</td>
<td>0.87/0.66</td>
</tr>
<tr>
<td></td>
<td>Reader 1</td>
<td>Reader 2</td>
</tr>
<tr>
<td>----------------</td>
<td>----------</td>
<td>----------</td>
</tr>
<tr>
<td>DIC-CT</td>
<td>2.9 ± 0.3</td>
<td>2.9 ± 0.3</td>
</tr>
<tr>
<td>MRCP</td>
<td>2.4 ± 0.7</td>
<td>2.4 ± 0.8</td>
</tr>
<tr>
<td>BTFE</td>
<td>2.9 ± 0.3</td>
<td>2.8 ± 0.4</td>
</tr>
</tbody>
</table>

Data are expressed as mean ± standard deviation.

IRR, inter-rater reliability; n.s., not significant.

**Table 4**: Confidence scores for diagnosis of branching patterns

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**Fig. 2:** A case of the supraportal pattern type A. It was clearly depicted on both axial DIC-CT image (A) and BTFE image (B) that the right posterior bile duct (RPBD) ran cranially to the right anterior portal vein (RAPV) and joined the right anterior bile duct (RABD). MRCP images, including MIP (C), demonstrated only bile ducts and the anatomic relation between the RPBD and PV was unclear. RHD= right hepatic duct, RPV= right portal vein.

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**Fig. 3:** A case of the infraportal pattern type D. On coronal DIC-CT images (A: posterior slice, B: anterior slice), RPBD ran caudally to the RAPV and joined the RABD. Furthermore, coronal BTFE images (C: posterior slice, D: anterior slice) clearly showed these findings. In comparing MRCP MIP image (E) and MRCP MIP image in Figure 2C, it was difficult to identify the difference of the branching pattern (type A or D) without visualization of PV.

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Conclusion

Similar to DIC-CT, the 3D BTFE MR sequence had high diagnostic accuracy regarding the branching pattern of the intrahepatic bile duct, without contrast media or poor visualization according to hyperbilirubinemia. For the supraportal or infraportal type, the diagnostic accuracy of BTFE was considered 100%.

Discussion

• Despite some motion artifacts on BTFE, the confidence scores were high for both BTFE and DIC-CT.
• The diagnostic concordance was high between BTFE and DIC-CT, and between the two readers. For the supraportal or infraportal type, these diagnostic concordances were 100%.
• Considering the usefulness of DIC-CT reported previously (2, 6, 8-10) and 83% of patients with non-dilated bile duct, the diagnostic accuracy of BTFE was also thought to be high.
• In contrast, MRCP showed poor diagnostic concordance and low confidence scores.
• Variant PV anatomies were frequently associated with variant bile duct (1, 4). We did not evaluate in this study but the running course of PV was clearly visualized on BTFE images.
• Limitation: only 2 patients diagnosed as the infraportal type among 30 patients. The frequency of the infraportal type was reported to be 10-12% (1, 4), so more patients are required.

#Disadvantages of DIC-CT:

• Adverse reactions and poor visualization with hyperbilirubinemia.
• Even without hyperbilirubinemia, poor visualization of the bile ducts might be caused by liver dysfunction. We excluded one patient with no visualization of the bile duct.
• If the density of liver parenchyma decreased to the density of PV due to fatty liver, the visualization of PV may be poor.

#Disadvantages of MRCP:

• PV undepicted, so the relationship with the bile duct unknown and inferred from the shape of the right posterior bile duct. The diagnostic accuracy was low in our study, as previously reported (4, 7).
• Heavily T2-w used in MRCP may not allow visualization of concentrated or hemorrhagic bile duct (2, 6).
• Motion artifacts caused by irregular breathing, body movement.

#Using fat-suppressed 3D BTFE on 1.5-T MR.

• 3-T MR can obtain higher SNR than 1.5-T, though increasing banding artifacts, susceptibility-related artifacts, and specific absorption rate (14, 15). Consequently, fat-suppressed BTFE sequence in abdominal images has been performed primarily on a 1.5-T scanner in daily clinical practice.

• 2D BTFE sequence has been performed as a part of MRCP protocol in more clinics than 3D sequence because of short scan time allowing breath-hold scan. However, MPR images obtained by 3D BTFE enables detailed evaluation of branching pattern of bile duct and PV and other structures.
References


