

# Mn-DPDP Enhanced T1-weighted Magnetic Resonance Cholangiography: Usefulness in the Diagnosis and Roadmap for the Treatment of Intrahepatic Choledocholithiasis<sup>1</sup>

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**Purpose:** To assess the preliminary findings of Mn-enhanced T1-weighted MR cholangiography for the evaluation of intrahepatic choledocholithiasis.

**Materials and Methods:** Seven patients with recurrent pyogenic cholangitis underwent conventional heavily T2-weighted and manganese-enhanced T1-weighted MR cholangiography. For the former, the two reviewers focused on intrahepatic ductal dilatation, calculi, and stricture; and for the latter, ductal enhancement.

**Results:** In seven patients, 13 diseased segments were depicted and intrahepatic bile ductal dilatation was present in all 13 of these in all seven patients. Calculi were present in eight segments in six patients, and stricture in four segments in three patients. Of the 13 diseased segmental ducts, six were seen at manganese-enhanced imaging to be filled with contrast material, suggesting a functioning bile duct.

**Conclusion:** Combined T2-weighted and mangafodipir trisodium-enhanced T1-weighted MR cholangiography provides both anatomic detail and functional detail of the biliary system. Combined MR cholangiography is useful for the evaluation of intrahepatic choledocholithiasis, demonstrating the stricture and function of the segmental ducts involved.

**Index words :** Bile ducts, calculi

Cholangitis

Magnetic resonance (MR), cholangiopancreatography

Heavily T2-weighted magnetic resonance (MR) cholangiography is a noninvasive modality that has been proven accurate in the diagnosis of bile duct obstruction and choledocholithiasis (1, 2). Previous reports concerning the usefulness of MR cholangiography for the assessment of intrahepatic choledocholithiasis have focused on the presence of intrahepatic ductal dilatation, stricture, and calculi (3, 4). However, heavily T2-

weighted MR cholangiography cannot reflect biliary dynamics.

Mangafodipir trisodium is a safe and approved hepatocyte-selective T1-weighted MR contrast agent, eliminated through the biliary system, and can therefore, in theory, be used as a biliary contrast agent during T1-weighted MR imaging (5 - 8). To our knowledge, however, the potential role of this agent in the evaluation of in-

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trahepatic choledocholithiasis has not been reported.

The purpose of this prospective and preliminary study was to evaluate the combined use of mangafodipir trisodium-enhanced T1-weighted and conventional heavily T2-weighted MR cholangiography in patients with intrahepatic choledocholithiasis.

## Materials and Methods

### Patient Population

Between September 2002 and September 2003, seven patients with intrahepatic choledocholithiasis [M:F=5:2; age, 35 - 81 (mean, 58) years] were prospectively examined using MR cholangiography. All seven had symptoms of acute cholangitis (abdominal pain, fever, or jaundice) at the time of admission. Five had experienced recurrent attacks on more than three occasions and the remaining two had had recurrent attacks twice. Three of the seven underwent surgery and in two, choledochoscopy was also performed.

### Imaging Studies

Patients were asked to fast for a minimum of six hours. For MR cholangiography, a 1.5-T superconducting unit (Magnetom Vision; Siemens Medical Systems, Erlangen, Germany) and a phased-array torso coil were used. Routine MR cholangiographic sequences were performed using a half-Fourier rapid acquisition with relaxation enhancement (RARE) sequence, with breath-hold (TR/effective TE, infinite/95 msec; flip angle, 1500; matrix, 240 × 256; field of view, 300 - 350 mm). Sequential multisection acquisition (slice thickness, 3 - 5 mm; imaging time, 18 seconds) followed by multiplanar reformatting techniques and a single thick-slab technique (50 - 70 mm section thickness) were used, and oblique coronal or sagittal images usually obtained. After the patients were removed from the magnet, an IV injection of mangafodipir trisodium (Mn DPDP; Teslascan, Nycomed Amersham, Oslo, Norway) at a standard dose of 5  $\mu$ mole/kg (0.5 ml/kg; maximum dose, 50 ml) was slowly injected for 2 - 3 ml/min, followed by a 10 ml saline flush. Between 30 and 60 min after injection, 3D T1-weighted fat-saturated volumetric interpolated breath-hold images (TR/TE, 4.2/1.6; flip angle, 120; matrix 205 × 256; field of view, 300 - 350 mm; and 24 partitions interpolated to 48 slices with a thickness of 1.3 mm) were obtained. All MR cholangiograms were reviewed at the console by an abdominal radiologist before the patient was removed from the magnet. A study

was terminated when mangafodipir trisodium was clearly seen to fill the extrahepatic duct.

### Image Analysis

All MR cholangiographic images were reviewed on a PACS workstation by two abdominal radiologists, who reached a consensus. The focus of all image analysis was to identify intrahepatic ductal dilatation and stricture, intrahepatic and common duct calculi, and coexistent parenchymal abnormalities such as parenchymal atrophy, abscess, biloma, and cancer. Obstruction was defined as 'complete' when manganese-enhanced T1-weighted MR cholangiography showed that contrast agent had not filled the intrahepatic duct, and as 'partial' when contrast-filling of the duct was depicted, even though this appeared at T2-weighted image to contain strictures or calculi.

Findings regarding the distribution of intrahepatic abnormalities were based on a classification of the liver's internal lobation and segmentation (four segments: left lateral, left medial, right anterior, and right posterior). Intrahepatic ductal dilatation was diagnosed when the diameter of a duct was greater than 3mm, and stricture was diagnosed when the focal caliber of any segment had changed. Calculi were considered present when a signal void was identified within the bile duct in at least two different projections.

## Results

The findings of MR cholangiography are summarized in Table 1.

According to the findings of conventional T2-weighted MR cholangiography, seven patients had 13 diseased segments. Intrahepatic bile ductal dilatation was present in all 13 segments in seven patients, intrahepatic bile ductal calculi in eight segments in six patients (Figs. 1, 2), and stricture in four segments in three patients (Fig. 2). Of the 13 diseased segmental ducts thus revealed, six were filled with contrast material at manganese-enhanced imaging, suggesting a functioning bile duct (Fig. 2). The remaining seven, on the other hand, were not filled, suggesting a non-functioning bile duct (Fig. 1).

Three of the seven patients underwent left lateral segmentectomy. And all three pathologic specimens obtained revealed multiple intrahepatic duct stones and severe proliferative fibrosis of bile duct walls. Two patients underwent choledochoscopy, involving successful stone extraction, and the remaining two were treated

conservatively.

## Discussion

Mangafodipir trisodium is a paramagnetic contrast agent originally designed for liver imaging. It consists of manganese bound to DPDP, is taken up by functioning hepatocytes, and is primarily excreted via bile into the feces (5 - 8). Because manganese is a paramagnetic metal ion, it acts mainly during T1, resulting in T1 shortening, though also during T2, resulting in T2 shortening (5 - 8). Enhanced liver and functioning bile ducts therefore show higher signal intensity on T1-weighted images and lower signal intensity on T2-weighted images (5 - 8). The signal intensity of bile ducts that are obstructed or otherwise not functioning due to stasis, however, may

not be affected: biliary stasis in the setting of strictures or stones reduces the excretion of biliary manganese (5). This characteristic property of mangafodipir trisodium-enhanced MR cholangiography could, in theory, be used as a noninvasive imaging tool in the evaluation of biliary dynamics (5).

The management of symptomatic intrahepatic choledocholithiasis is difficult and remains far from satisfactory (9), though during the last decade has improved; this is due to the systemic approach adopted, advances in hepatobiliary imaging, the availability of flexible choledochoscopy, the application of stone-fragmentation technology, and innovative approaches to biliary tract surgery. To achieve the optimal result, a combination of all these various treatment modalities, applied selectively, is required (10); the choices made depend on

Table 1. Radiologic Findings of Recurrent Pyogenic Cholangitis

No./Age/Sex	Location (Intrahepatic duct)	Findings at MR Cholangiography			
		Findings at T2- MRC (pre-contrast)	Contrast filling at Mn-T1- MRC (post-contrast)	Diagnosis on MRC (combined pre- & post-contrast)	Treatment
1/53/M	Left lateral duct	Dilatation, multiple calculi	No contrast filling in duct	Non-functioning duct	Conservative
	Right posterior duct	Multiple impacted calculi	No contrast filling in duct	Non-functioning duct	
	Right anterior duct	Dilatation, no calculi	Contrast filling in duct	Functioning duct	
2/51/M	Left lateral duct	Dilatation, multiple calculi	No contrast filling in duct	Non-functioning duct	Segmentectomy
	Right posterior duct	Dilatation, stricture, no calculi	No contrast filling in duct	Non-functioning duct	
	Right anterior duct	Dilatation, stricture, no calculi	Contrast filling in duct	Functioning duct	
3/47/F	Left lateral duct	Dilatation, multiple calculi	Contrast filling in duct	Functioning duct	Choledocoscope
	Right posterior duct	Dilatation, stricture, no calculi	Contrast filling in duct	Functioning duct	
	Right anterior duct	Dilatation, multiple calculi	Contrast filling in duct	Functioning duct	
4/81/F	Left lateral duct	Dilatation, multiple calculi	No contrast filling in duct	Non-functioning duct	Segmentectomy
	Right posterior duct	Dilatation, multiple calculi	No contrast filling in duct	Non-functioning duct	
	Right anterior duct	Dilatation, multiple calculi	No contrast filling in duct	Non-functioning duct	
5/35/M	Left lateral duct	Dilatation, multiple calculi	No contrast filling in duct	Non-functioning duct	Segmentectomy
	Right posterior duct	Dilatation, multiple calculi	No contrast filling in duct	Non-functioning duct	
	Right anterior duct	Dilatation, multiple calculi	No contrast filling in duct	Non-functioning duct	
6/60/M	Left lateral duct	Dilatation, multiple calculi	No contrast filling in duct	Non-functioning duct	Conservative
	Right posterior duct	Multiple impacted calculi	No contrast filling in duct	Non-functioning duct	
	Right anterior duct	Dilatation, stricture, no calculi	Contrast filling in duct	Functioning duct	

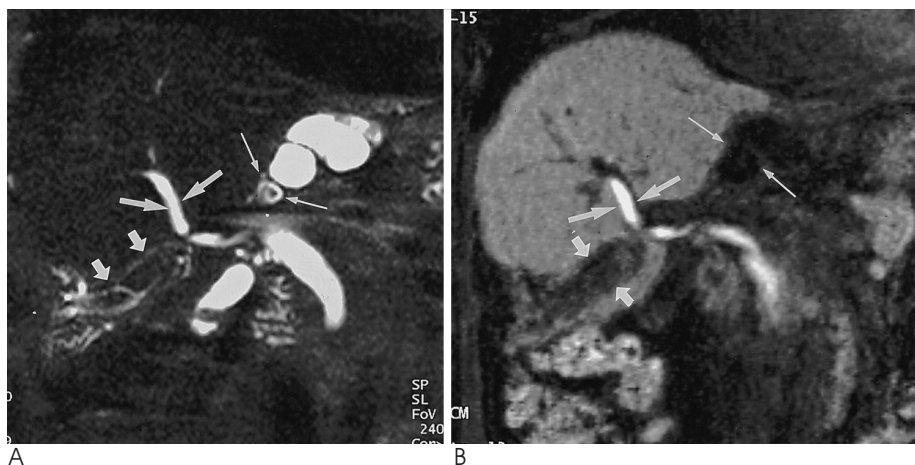


Fig. 1. Patient 1. (A) Coronal MR image obtained with a thin-section half-Fourier rapid acquisition with relaxation enhancement sequence (infinite/95 [effective], flip angle 150°) shows markedly dilated left duct with stone (thin arrows), impacted multiple stones in right posterior duct (short arrows), and slightly dilated right anterior duct without stone (thick arrows). (B) Coronal 3D volumetric interpolated T1-weighted gradient echo image (4.2/1.6, flip angle 12°) obtained at 30 minutes after injection of mangafodipir trisodium shows the enhanced right anterior duct (thick arrows) and common bile duct. Contrast was not filled in left (thin arrows) and right posterior duct (short arrows).

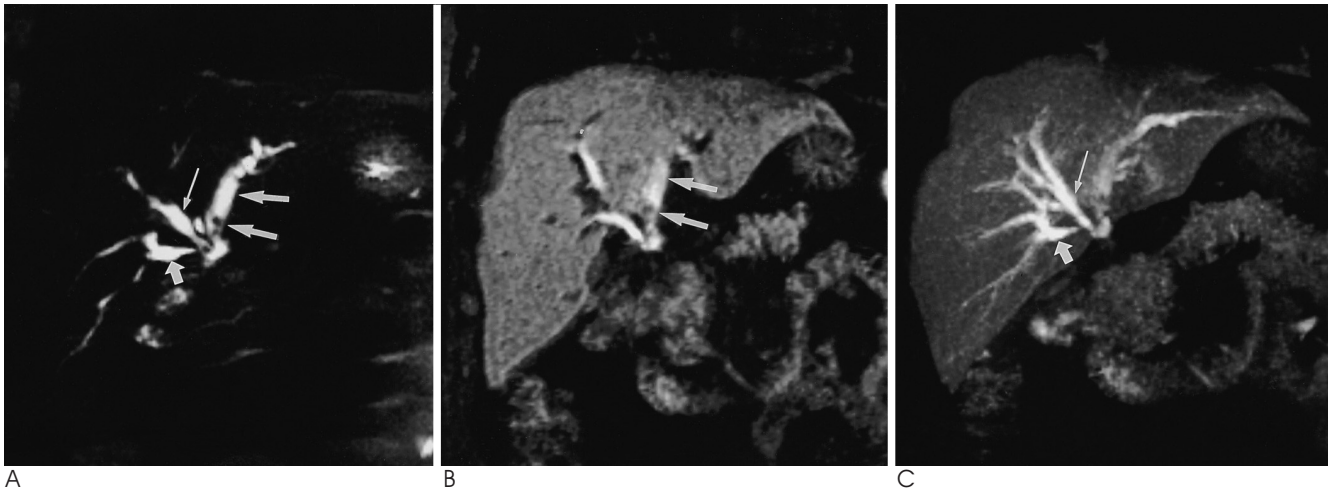


Fig. 2. Patient 4. (A) Serial coronal MR image obtained with a thin-section half-Fourier rapid acquisition with relaxation enhancement sequence (infinite/95 [effective], flip angle 150°) shows dilated left duct with stone (thick arrows), dilated right posterior duct without stone (thick, short arrow), and dilated right anterior duct with stone (thin arrow). (B) and (C) Serial coronal 3D volumetric interpolated T1-weighted gradient echo image (4.2/1.6, flip angle 12°) obtained at 30 minutes after injection of mangafodipir trisodium shows the enhanced all of the three ducts same as (A), suggesting functioning ducts.

the exact location and level of stones or stricture, the degree of stenosis or obstruction, the degree of destruction of the involved liver segment, and the presence of combined hepatic abscess or cholangiocellular carcinoma. It has recently been reported that for the accurate topographic evaluation of intrahepatic choledocholithiasis, MR cholangiography, since it is able to depict the entire biliary tree despite obstruction or stenosis, is superior to direct colangiography (3). There are, however, certain limitations regarding the use of conventional heavily T2-weighted MR cholangiography for the evaluation of degree of stenosis or obstruction, and the function of the involved bile duct and liver parenchyma. In our study, mangafodipir-enhanced T1-weighted MR cholangiography was able to provide functional information regarding involved bile ducts, the degree of stricture, and whether an involved duct was functioning, as well as relevant morphologic information. Combined Mn-DPDP-enhanced and conventional T2-weighted MR cholangiography, rather than conventional T2-weighted MR cholangiography alone, was, therefore, able to provide the further additional information required for decision as to treatment.

Our study suffers a number of limitations, one of which is the small number of cases. Another is that since mangafodipir-trisodium could not be used in patients with jaundice, our patient population was restricted to these with intrahepatic choledocholithiasis without jaundice. A third limitation is that we did not perform serial post-mangafodipir trisodium MR cholangiography.

It has been reported for the evaluation of liver parenchyma and bile duct, the optimal time is 15 - 20 minutes after injection, which roughly coincides with the hepatocyte and biliary tract phase of hepatobiliary scintigraphy (5 - 7). The presence of a non-functioning intrahepatic duct, as seen at mangafodipir-enhanced T1-weighted MR cholangiography, was therefore used to indicate the non-excretion of contrast material into that duct until 60 minutes had elapsed. A fourth limitation is that we were unable to obtain pathologic correlation of the findings of MR cholangiography.

In conclusion, T2-weighted and mangafodipir trisodium-enhanced T1-weighted MR cholangiography in combination depict both the anatomic and functional detail of the biliary system. For the evaluation of choledocholithiasis, mangafodipir trisodium-enhanced T1-weighted MR cholangiography is thus a useful supplement to the conventional heavily T2-weighted procedure.

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