Optimal sequence for magnetic resonance cholangiopancreatography

Hiroshi KANZAKI, Soichi AKATA, Taizo OZUKI, Kimihiko ABE

Department of Radiology, Tokyo Medical University

ABSTRACT

Magnetic resonance cholangiopancreatography (MRCP) has attracted attention as a useful examination for abnormalities of the pancreaticobiliary system, because it is a simple procedure. Since there are few detailed reports on optimal sequences for MRCP, we attempted to clarify the topic.

The magnetic resonance imaging (MRI) equipment we used was a 1.0 Tesla super-conductive type. A fast spin echo (16 echo train) was used, and the echo space was set at 17 msec. TE was changed from 17 msec to 272 msec in 17 msec increments. TR was changed from 1,000 msec to 9,000 msec by 1,000 msec increments. Bile juice which had been collected from the PTCD tube of a patient with common bile duct cancer, was put in a test tube of 10 mm internal diameter. Saline was used as a substitute for pancreatic juice, because collection of pancreatic juice was difficult. Fat was used for contrast. Each signal intensity inside the test tube was measured and evaluated. We attempted to evaluate the signal of gastric juice by adding blueberry juice, making use of its manganese ion (Mn	extsuperscript{2+}).

With longer TR, the signal intensities of bile and pancreas juice increased. As TE became longer, the signal intensities of bile and pancreas juice decreased slightly, while that of fat decreased much more. In MRCP, it is necessary to set up a long TE to increase the relative signal intensity difference of fat in bile and pancreas juice. The signal intensity of gastric juice was made to disappear by the addition of blueberry juice diluted to a ratio of 1:3.

Ultrasound (US) and computed tomography (CT) are currently the modalities of choice for diagnosis of abnormalities of the pancreaticobiliary system. Invasive techniques such as percutaneous transhepatic cholangiography (PTC) or endoscopic retrograde cholangiopancreatography (ERCP) can demonstrate the whole pancreaticobiliary system as a projection image in different planes, which is useful in the establishment of the relationship between the biliary branches and the obstruction site or in the depiction of main pancreatic ductal dilatation, sometimes described as a "string of pearls". If a projection image comparable with PTC and ERCP could be obtained non-invasively, the precise location of the obstruction and its relation to the biliary tree or main pancreatic ductal dilatation could be depicted without later performance of PTC or ERCP. For patients with obstructive jaundice, the non-invasive method to obtain the projection image of bile ducts is scintigraphy	extsuperscript{3}. However this method is not effective in patients with severe jaundice and does not provide sufficient image quality for planning biliary drainage and surgery.

Due to physiological movement clinical magnetic resonance (MR) applications for abdominal organs did not develop as rapidly as MR imaging of other organs. However, with recent cutting-edge hardware technologies such as high performance gradient systems and phased-array capability as well as software innovations,
scan times have been further reduced to make breath-hold imaging clinically viable. The recent development of the fast spin echo sequence has dramatically shortened the time for T2-weighted image acquisition.

MR cholangiopancreatography (MRCP) is an exciting new application of MR imaging that combines the advantages of projectional and cross-sectional imaging techniques in the diagnosis of various obstructive and non-obstructive pancreaticobiliary diseases. It is a rapidly evolving non-invasive imaging modality that produces images without the need for intravenous contrast administration. The MRCP technique may allow the selection of those patients with obstructive lesions that require therapeutic ERCP intervention and may have the potential to reduce the need for diagnostic ERCP examinations. Incomplete MRCP imaging may create confusion regarding pancreaticobiliary anatomy or disease. However, there are few detailed reports on the optimal sequence of MRCP.

The purpose of our study was to determine the optimal sequence for MRCP. We also evaluated the usefulness of blueberry juice for MRCP in decreasing the gastric juice signal through the effect of the manganese ion ($\text{Mn}^{2+}$).

**MATERIALS AND METHODS**

We constructed a phantom. A test tube of 10 mm internal diameter was fixed in agar gel to avoid susceptibility artifacts. Bile juice, fat and saline were put in the test tube. Three different concentrations of blueberry juice (MAGNEBERRY; Meiji Milk Products, Tokyo) were also put in the test tube. Bile juice, which was light greenish yellow, was collected from the PCTD tube of a 58-year-old man with common bile duct cancer. Physiological saline was used as a substitute for pancreatic juice, because the collection of the pancreas juice was difficult. Three different concentrations of blueberry juice were used to obtain 0.01 mg/mL, 0.02 mg/mL, and 0.03 mg/mL, manganese ion ($\text{Mn}^{2+}$) respectively.

The MRI equipment used was a 1.0 Tesla superconductivity type MAGNEX 100X (Shimadzu Corporation, Kyoto). The echo space (16-echo train) was set at 17 msec with a fast spin echo (FSE). A head coil was used. Four slices of the axial image of the test tube were obtained by using a 10 mm interleaved gapless multiscan. The field of view (FOV) was 25 cm and the matrix was $256 \times 240$. The signal intensity inside each test tube was measured using a region of interest (ROI) of 0.64 cm$^2$. The mean signal intensity of 4 slices was calculated, and used for comparison.

Two kinds of experiments, changing TR or TE, were done to determine the most optimal sequence. To evaluate changes of TE, two kinds of TR, 6,000 msec and 9,000 msec were used. The TE was varied from 17 msec to 272 msec in 17 msec increment by changing the echo center with the 16-echo train. To evaluate the changes of TR, two kinds of TE, 204 msec and 255 msec, were used. TR was changed from 1,000 msec to 9,000 msec in 1,000 msec increments.

**RESULTS**

1) Evaluation of changes in TR

With longer TR, the signal intensities of bile juice increased, resembling exponential function curves at both TE 204 msec and 255 msec (Fig-1a). At a TE of 255 msec, the signal intensity of TR at 9,000 msec was 4.53 times that of TR at 1,000 msec. Approximation curves are shown in Figure-1b. The numerical formula

![Image](image-url)
Fig. 1b: Changes in TR

At longer TR, the signal intensities of bile juice and saline increased, resembling exponential function curves, and the signal intensities of fat increased slightly, resembling linear function curves, at both a TE of 204 msec and 255 msec.

2) Evaluation for change TE

At longer TE settings, signal intensities of bile juice decreased slightly at both TR 6,000 msec and TR 9,000 msec (Fig-2a), resembling linear function curves. The signal intensity at TE 272 msec decreased in comparison with a TE of 17 msec by 89% under both conditions of TR 6,000 msec and TR 9,000 msec. Approximation curves as shown in Figure-2b. The numerical formula is:

\[
y = -78.332x + 11,389 \quad (\text{TR} = 9,000 \text{ msec})
\]
\[
y = -61.95x + 9,763 \quad (\text{TR} = 6,000 \text{ msec})
\]

The signal intensities of saline decreased slightly with longer TE settings, as in the case of bile juice (Fig-2a). At both TR 6,000 msec and 9,000 msec, the signal intensity at TE 272 msec decreased about 90% respectively compared to at TE 17 msec. These rates of decrease were similar to that in bile juice, resembling linear function curves. Approximation curves are shown in Figure-2b, and the numerical formula is:

\[
y = -79.809x + 10,490 \quad (\text{TR} = 9,000 \text{ msec})
\]
\[
y = -67.526x + 8975.6 \quad (\text{TR} = 6,000 \text{ msec})
\]

The signal intensity of saline was low in comparison with that of bile juice at all TEs. At both TR 9,000 msec and 6,000 msec, the average signal intensity of saline at all TEs was 91% lower than that of bile juice.

At longer TE settings, the signal intensity of fat decreased much more than bile juice and saline. The pattern of the decreasing curve resembled an exponential function. Approximation curves are shown in Figure-
At longer TE settings, signal intensities of bile juice and saline decreased slightly, resembling linear function curves, and the signal intensity of fat decreased much more than bile juice and saline. The pattern of the decreasing curve resembled an exponential function.

At TE 272 msec, the signal intensity was 10% that at TE 17 msec for both TR 6,000 msec and 9,000 msec. The signal intensities of noise were low and did not change at all, even when TE was made to change.

3) Evaluation of the usefulness of blueberry juice

When setting longer TR values, the signal intensity of each of three concentrations (0.03, 0.02, and 0.01 mg/mL) of blueberry juice was found to increase slightly at TE 255 msec (Fig 3a). With 0.01 mg/mL, the signal intensity at TR = 9,000 msec was 1.40 times that of TR = 1,000 msec (0.02 mg/mL = 1.44 times, 0.03 mg/mL = 1.26 times). They showed similar increase rates as fat, resembling linear function curves (Fig 3b). On the other
hand, because signal intensities of bile juice and saline increased exponentially, the signal intensity difference of blueberry juice increased for bile and saline with longer TR settings.

At longer TE settings, the signal intensity of each of the three concentrations of blueberry juice decreased much more than bile juice and saline at TR 9,000 msec (Fig.4a). With 0.01 mg/mL, the signal intensity of TE=272 msec was 11% of that of TE=17 msec (0.02 mg/mL=3%, 0.03 mg/mL=9%). The decreasing curves were exponential, like fat (Fig.4b). The signal intensities of bile juice and saline decreased slightly, which showed linear curves. At longer TE, the signal intensity difference of blueberry juice increased for both bile juice and saline.

**DISCUSSION**

It is necessary for MRCP to depict the bile and
pancreas juice at high signal intensities, and other components at low signal intensities. Because bile and pancreas juice are fluids, they have a long T2 compared with surrounding organs. We thought a heavy T2 weighted image would be required to depict static water component in vivo at high signal intensity. Moreover fat should be kept at a low signal intensity for MRCP, because it blocks the signal intensity of static water\(^{[10]}\). Bone and muscle were not obstacles, because they have few protons (H\(^+\)) and have low signal intensity. Floating protons in blood vessels have low signal intensity, since they do not stay in the image plane long enough to experience both radio-frequency pulses. So blood flow is not an obstacle for MRCP.

As mentioned earlier, with longer TR settings, the signal intensity of bile and pancreas juice increased remarkably and exponentially, while that of fat increased slightly in a linear fashion. Thus, for MRCP, TR should be set longer to show the signal intensity of bile and pancreas juice more clearly. Furthermore,
with longer TE, the signal intensities of bile and pancreas juice decreased slightly in a linear pattern, while that of fat decreased much more than bile and pancreas juice, exponentially. Therefore, MRCP would be more clear with longer TE and longer TR sequences.

Gastric juice is also an obstacle in MRCP, like fat, because it is a static fluid located near the pancreaticobiliary system. Blueberry juice has a low signal intensity because it contains the manganese ion (Mn⁺⁺). We hoped we could make the gastric juice signal disappear by using blueberry juice above a certain concentration. As a result, when long TR and long TE sequences were set up, even a one-third concentration of blueberry juice usually showed low signal intensity. Blueberry juice can be used routinely in MRCP as a natural, safe, and inexpensive negative contrast agent with high efficacy.

CONCLUSION

We examined the optimal sequence of MRCP using fast spin echo. The signal intensities of bile and pancreas juice increased with longer TR. Moreover, with longer TE setting, the signal intensity of bile and pancreas juice decreased slightly, while that of fat, which blocks MRCP, decreased much more. The biggest difference of signal intensity of fat for bile and pancreas juice was shown at longer TR and longer TE sequences. The signal intensity of gastric juice was made to disappear by concentration of 1/3 blueberry juice. Blueberry juice may be used routinely in MRCP studies as a natural, safe, and inexpensive negative contrast agent with high efficacy.

ACKNOWLEDGMENTS

We thank Prof. J.P. Barron of the International Medical Communications Center of Tokyo Medical University for reviewing the manuscript in English.

REFERENCES

9) Lomas DJ, Bearcroft PW, Gimson AE: MR cholangiopancreatography; prospective comparison of a breath-hold 2D projection technique with diagnostic ERCP. Eur Radiol 9: 1411-1417, 1999
14) Henkelman RM: Why fat is bright in RARE and fast spin-echo imaging. JMRI 2: 533-540, 1992
Magnetic resonance cholangiopancreatography (MRCP) の至適撮影条件の検討

神崎 博 赤田 壮市
小槻 泰三 阿部 公彦
東京医科大学放射線医学教室

【要旨】一般的に膵胆道系の異常の診断には超音波検査や CT を用いるのが第 1 選択である。引き続き侵襲的ではあるが percutaneous transhepatic cholangiography (PTC) や内視鏡を用いた endoscopic retrograde cholangiopancreatography (ERCP) が精査のために用いられる。近年 MRI を用いた magnetic resonance cholangiopancreatography (MRCP) が膵胆道系の異常の診断に使用されてきている。MRCP は簡便で非侵襲的であるが、その最適撮影条件を詳細に検討した報告は少ない。そこで我々は胆汁・生理的食塩水・ラードを内径 10 mm の試験管に入れて 1.0 Tesla 超伝導型 MRI 装置にて撮影し、その信号強度から MRCP の至適撮影条件を検討した。(胆汁は十分量の採取が困難なため生理的食塩水にて代用した)。

TR は 1,000 から 9,000 msec まで 1,000 msec 毎に変化させ、TE は 17 から 272 msec まで 17 msec 毎に変化させた。さらに 3 種の濃度のブレーメージュースの信号値も測定し、ブレーメージュースが MRCP の障害となる胃液の信号を低下させることができるか否か検討も加えた。

結果として、TR が長くなるにつれて胆汁と生理的食塩水の信号値は指数関数的に上昇したが脂肪の信号値はわずかに直線状に上昇したものであった。また TE が長くなるにつれて胆汁と生理的食塩水の信号値は直線状に若干低下したが、脂肪の信号値は指数関数的に著しく低下した。胆汁と胃液の信号値を上昇させ、かつ MRCP の障害となる脂肪との信号値差を大きくするためには TR, TE とともに長く設定することが最適な条件と考えられた。またブレーメージュースは通常服用する濃度の 1/3 でも胃液の信号を消失させることができた。

<Key words> Magnetic resonance cholangiopancreatography (MRCP), 至適撮影条件, pancreaticobiliary system