European Journal of Radiology 81 (2012) e513–e518

Contents lists available at ScienceDirect

European Journal of Radiology

journal homepage: www.elsevier.com/locate/ejrad

Clinical usefulness of free-breathing navigator-triggered 3D MRCP in non-cooperative patients: Comparison with conventional breath-hold 2D MRCP

Jung Hoon Kim [a,*], Seong Sook Hong [b], Hyo Won Eun [c], Joon Koo Han [a], Byung Ihn Choi [a]

[a] Department of Radiology and Institute of Radiation Medicine, Seoul National University College of Medicine, 101 Daehang-no, Chongno-gu, Seoul 110-744, Republic of Korea
[b] Department of Radiology, Soonchunhyang University Hospital, 657 Hannam-Dong, Youngsan-Ku, Seoul 140-743, Republic of Korea
[c] Health Promotion Center, Asan Medical Center, University of Ulsan, 388-1 Poongnap-dong, Songpa-gu, Seoul 138-736, Republic of Korea

ARTICLE INFO

Article history:
Received 27 March 2011
Accepted 1 June 2011

Keywords:
Magnetic resonance cholangiopancreaticography
Bile duct
Pancreatic duct
Image quality
Prospective acquisition correction technique (PACE)

ABSTRACT

Purpose: To assess the clinical usefulness of free-breathing 3D MRCP in non-cooperative patients compared conventional breath-hold 2D MRCP.
Materials and methods: We performed FB navigator-triggered 3D MRCP using prospective acquisition correction and BH 2D MRCP in 48 consecutive, non-cooperative patients among 772 patients. Thirteen patients had malignant obstruction. Two radiologists independently graded the likelihood of a malignant obstruction, the overall image quality, and the visibility of ten, individual anatomic segments of both the biliary and pancreatic duct in each sequence. The area under the ROC curve and the repeated measures analyses of variance with multiple comparisons were used for the comparison. The κ statistics were used for interobserver agreement.
Result: The diagnostic performance for detecting malignancy was significantly higher on FB MRCP ($A_z = 0.962$) than on either BH SS-RARE ($A_z = 0.820$, $P < 0.0185$) or MS-HASTE MRCP ($A_z = 0.816$, $P < 0.0067$). Interobserver agreement was excellent for FB MRCP ($\kappa = 0.889$) and fair for both BH SS-RARE ($\kappa = 0.578$) and MS-HASTE MRCP ($\kappa = 0.49$). FB MRCP had a significantly higher technical quality than BH MRCP ($P < 0.001$). FB MRCP was seen to have statistically better visibility of peripheral IHD, right main IHD, CHD, cystic duct, and CBD than BH MRCP ($P < 0.001$). FB MRCP and BH SS-RARE MRCP had statistically better visibility of both the left main IHD and pancreatic duct than did BH MS-HASTE MRCP ($P < 0.001$).
Conclusion: FB 3D MRCP is useful for non-cooperative patients in whom conventional BH 2D methods cannot be used successfully.

1. Introduction

MR cholangiopancreatography (MRCP) is a noninvasive imaging technique that provides detailed information regarding the anatomy and pathology of the pancreaticobiliary tree. Heavily T2-weighted sequences with long echo times clearly depict fluid-filled compartments, thus providing excellent image contrast by almost complete suppression of the background [1,2]. Respiratory motion artifacts constitute one of the major problems in MRCP imaging. Although a variety of imaging techniques have been used for MRCP, breath-hold (BH) techniques have been applied in order to overcome this limitation [3–5].

There has recently been a significant increase in the number of non-cooperative patients in hospitals because of the rapidly increasing number of older adults [6]. In non-cooperative patients, it is very difficult to perform optimal image studies and it can be impossible to perform diagnostic studies. Despite recent technical developments, the shortest acquisition times are generally still too long in order to obtain high diagnostic quality MRCP images in non-cooperative patients.

The free-breathing (FB), navigator-triggered, prospective acquisition correction technique (PACE) has recently been used to obtain high-quality MRCP images. This technique obtains images by correcting for respiratory motion during free breathing using a navigator echo which directly monitors respiration in real time. The superiority of FB navigator-triggered 3D MRCP to conventional BH 2D MRCP has already been reported [7–10], however, there has been no prospective report to prove this superiority by comparing the FB 3D MRCP with BH 2D MRCP in non-cooperative patients. Therefore, in this study we prospectively compare the image

Abbreviations: MRCP, MR cholangiopancreatography; FB, free-breathing; BH, breath-hold; 3D, three-dimensional; 2D, two-dimensional; TSE, turbo spin echo; SS-RARE, single-slab rapid acquisition with relaxation enhancement; MS-HASTE, multislice half-Fourier single-shot TSE; PACE, prospective acquisition correction technique; ROC, receiver operating characteristic curve; A_z, the area under the ROC; IHD, intra hepatic duct; CHD, common hepatic duct.

* Corresponding author. Tel.: +82 2 709 9396; fax: +82 2 795 3928.
E-mail address: Jhkim2008@gmail.com (J.H. Kim).

0720-048X/$ – see front matter © 2011 Elsevier Ireland Ltd. All rights reserved.
doi:10.1016/j.ejrad.2011.06.004

Table 1
Sequence parameters on MR cholangiopancreatography.

Sequence	TR (ms)	TE (ms)	Flip angle (°)	ETL	TA (s)	FS	Matrix ($N_{phase} \times N_{frequency}$)	No. of slices	ST (mm)
BH SS-RARE	–	1100	150	256	3	Yes	256 × 256	1 × 6	40–80
BH MS-HASTE	1100	87	150	218	18	Yes	218 × 256	15	4
FB 3D MRCP	1700	674	180	180	254–368	Yes	384 × 384	40	1.5

Note: TR, repetition time; TE, echo time; ETL, echo train length; TA, acquisition time; FS, fat saturation; ST, slice thickness; BH SS-RARE, breath hold single-slab rapid acquisition with relaxation enhancement; MS-HASTE, multislice half-Fourier single-shot TSE; FB 3D MRCP, free-breathing three-dimensional MRCP.

quality and diagnostic capability of FB navigator-triggered 3D MRCP with BH 2D MRCP in non-cooperative patients.

2. Materials and methods

2.1. Patients

This prospective study was approved by our institutional review board. Informed consent was obtained from all patients or their guardians before they were evaluated using MRCP. A total of 772 patients were referred for MRCP examination at our institution between June 2004 and January 2007. During this period, we performed MRCP examinations in 48, consecutive, non-cooperative patients (17 male and 31 female patients; mean age, 71 years; range, 62–83 years) who could not hold their breath. A non-cooperative patient is a patient who is unable to hold his/her breath according to our requirements during an MR examination. This was determined by the radiologist currently assigned to the MRI unit. Non-cooperative patients included those with impaired mental status ($n = 35$), dyspnea ($n = 12$), and hearing loss ($n = 1$). In patients with impaired mental status, we checked the mini-mental state examination (MMSE) obtained in the patient's hospital ward. Impaired mental status specifically refers to dementia ($n = 20$) and other conditions that decrease the MMSE to a score of less than 15 [11]. Among our 48 patients, 13 had malignant bile duct obstruction including pancreatic cancer ($n = 6$), cholangiocarcinoma ($n = 5$), and gallbladder cancer ($n = 2$). Thirty-five patients had benign disease including a gallbladder or biliary stone ($n = 15$), pancreatitis ($n = 5$), benign dilatation of the pancreatic duct ($n = 3$), and benign dilatation of the bile duct ($n = 12$).

2.2. MR cholangiopancreatography

MRCP was performed on a 1.5-T MR system (Magnetom Sonata Maestro, Siemens Medical Solutions). A circular, polarized, phased-array body coil with 12 elements was used as the radiofrequency receiver. We did not use oral contrast. To localize the biliary and pancreatic ductal system, we performed an axial T2-weighted half-Fourier single-shot TSE sequence (repetition time, 800; echo time, 63 ms; flip angle, 150°; 7-mm slice thickness; 20 slice number) and an axial fat suppression T1-weighted fast low-angle shot (FLASH) sequence (repetition time, 159 ms; echo time, 2.6 ms; flip angle, 120°; 7 mm slice thickness; 20 slice number). The MRCP protocol was composed of BH 2D single-slab rapid acquisition with relaxation enhancement (BH SS-RARE), BH 2D multislice half-Fourier single-shot turbo spin echo (BH MS-HASTE), and a FB navigator-triggered 3D turbo spin echo (TSE) using PACE. The navigator echoes of a gradient-echo FLASH sequence continuously acquired a coronal 2D image to monitor the movement of the right diaphragm using the following parameters: flip angle, 3° and TR/TE, 150 ms. Data of the end-expiratory phase were gathered via navigator-triggering. The acquisition time, which depended on the patient's respiration cycle, was recorded in order to calculate the mean acquisition time. The slabs of a BH SS-RARE MRCP were obtained at various angles, i.e. coronal, axial, and oblique planes, that allowed optimal visualization of the bile ducts, and there was an average of six, thick-slab acquisitions per patient. BH MS-HASTE and FB 3D MRCP were then obtained in the coronal and oblique planes. Each breath-hold examination was performed during a single breath-hold. BHMS-HASTE and FB 3D MRCP were reconstructed using the maximum intensity projection (MIP) algorithm. The acquisition MRCP parameters are listed in Table 1.

2.3. Image interpretation

The MRCP was analyzed by two radiologists with 6 years of clinical experience in abdominal MR imaging. The reviewers were blinded to patient identification, clinical histories, final results, and other imaging findings. MRCP images were independently evaluated in random order on picture archiving and communication system monitors and during separate viewing sessions that were at least 1 week apart. The reconstructed image data set

Table 2
The visibility of ten individual segments of the biliary tree and pancreatic duct in each MRCP sequence.

	FB 3D MRCP	BH SS-RARE	BH MS-HASTE	*P*-Value
Bile duct				
c-RHD	2.82 ± 0.38	2.45 ± 0.59	2.32 ± 0.51	$^{*}P < 0.001$, $^{**}P < 0.001$, $^{***}P = 0.253$
p-RHD	2.31 ± 0.64	1.54 ± 0.73	1.54 ± 0.71	$^{*}P < 0.001$, $^{**}P < 0.001$, $^{***}P = 0.722$
c-LHD	2.85 ± 0.35	2.49 ± 0.58	2.31 ± 0.54	$^{*}P < 0.001$, $^{**}P < 0.001$, $^{***}P = 0.157$
p-LHD	2.21 ± 0.69	1.53 ± 0.73	1.50 ± 0.69	$^{*}P < 0.001$, $^{**}P < 0.001$, $^{***}P = 0.433$
CHD	2.94 ± 0.24	2.69 ± 0.52	2.57 ± 0.53	$^{*}P < 0.001$, $^{**}P < 0.001$, $^{***}P = 0.262$
CD	2.35 ± 0.63	1.50 ± 0.66	1.53 ± 0.56	$^{*}P < 0.001$, $^{**}P < 0.001$, $^{***}P = 0.425$
CBD	2.91 ± 0.29	2.53 ± 0.61	2.56 ± 0.57	$^{*}P < 0.001$, $^{**}P < 0.001$, $^{***}P = 0.413$
Pancreatic duct				
P-Head	2.74 ± 0.48	2.39 ± 0.71	2.09 ± 0.74	$^{*}P = 0.075$, $^{**}P < 0.001$, $^{***}P < 0.01$
P-Body	2.70 ± 0.58	2.39 ± 0.77	1.92 ± 0.77	$^{*}P = 0.091$, $^{**}P < 0.001$, $^{***}P < 0.01$
P-Tail	2.60 ± 0.70	2.17 ± 0.80	1.71 ± 0.73	$^{*}P = 0.125$, $^{**}P < 0.001$, $^{***}P < 0.01$

Note: Values are expressed as mean ± S.D. C, central; p, peripheral.
* *P*-Value between FB MRCP and SS MRCP.
** *P*-Value between FB MRCP and MS MRCP.
*** *P*-Value between SS MRCP and MS MRCP.