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A Study on Parallel Imaging for the Improvement of Sharpness in MRCP for Liver Transplantation

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Abstract

In order to evaluate hepatobiliary in MRCP of liver donors, accurately, this study attempted to look into the availability of the parallel imaging technique for the enhancement of sharpness along with the reduction of the time of examination of the liver donors. From July 2014 through August 2014, MRCP was conducted with six patients and seven normal volunteers, and the sharpness of the pancreaticobiliary duct was evaluated. Of them, 11 were male and two were female, and their age distribution was between 21 and 67 (average age 39.15±6.53 years old). As the equipment used for the examination, GE Signa Excite HDxt 1.5T (Signa HDxt, GE Healthcare, Milwaukee, WI, USA) and 8ch phased array torso coil (GE Healthcare) were used. With the images obtained using FSE pulse sequences, parts with strong linearity in the liver duct, bile duct and pancreatic duct were selected using Image J(version. 1.49h, Wayne Rasband, National Institutes of Health, USA) with ROI. It was 0.4264±0.1227[lp/mm] on average in the image applying the parallel imaging technique, which was higher than 0.2672±0.1085 [lp/mm] on average in the image not applying it, and the result of a paired t-test of 50% MTF curve of sharpness evaluation was statistically very significant (t=12.929, p=0.000). The application of the parallel image technique in MRCP of donors for liver transplantation shortens the time of patient examination and enhances the sharpness of the image of the pancreaticobiliary, and it is judged that it can maximize the accuracy of diagnosis and the efficiency of the MRCP.

Keywords: *MRCP, Sharpness, Parallel Imaging, Image J*

1. Introduction

Liver transplantation is a treatment of liver diseases such as end-stage liver disease or hepatocellular carcinoma, which extracts the liver from a brain-death patient and normal person and transplants it to the target patient. However, in countries where organ donations are socially not common, partial liver transplantation through living liver donors, rather than organ transplantation through brain-death patients, is increasing([1], Figure 1). Anatomically, the liver is divided into the right lobe and left lobe, which is located in the abdominal cavity under the diaphragm, at the right part of the abdomen. Gallbladder is an organ that stores and condenses bile produced in the liver, which is in the shape of an empty eggplant, located in the middle of the lower part of the liver. Cystic Duct (CD) forms Common Bile Duct (CBD) combined with Common Hepatic Duct (CHD). Pancreas is a digestive gland that has both an exocrine organ and an endocrine organ, which is located in the left side of the duodenum behind the stomach, consisting of three parts: the head, body and tail, and Pancreatic Duct (PD), the secretary duct of the digestive enzymes of the pancreas is running horizontally through the center of the pancreas to connect to the duodenum [2].

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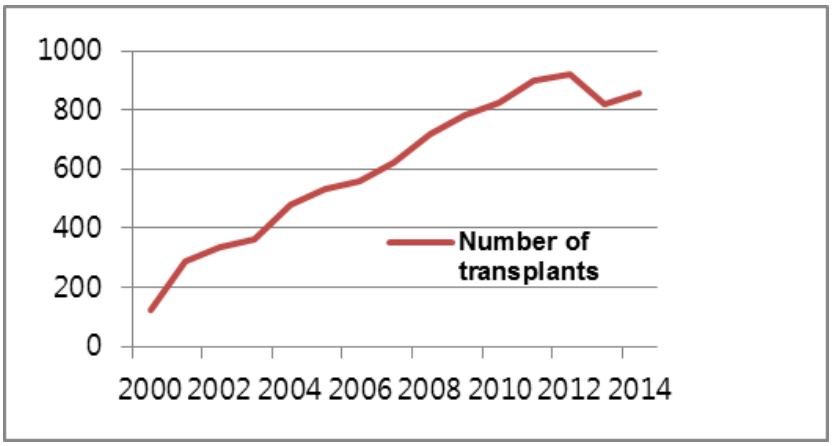

Figure 1. Liver Transplants 2000 to 2014, adapted from Korean Network of Organ Sharing, www.konos.go.kr/.

In conducting in-vivo liver transplantation using the right lobe, which takes up over 60% of hepatic content, the problem that should be considered first is the assurance of the liver donors' safety. For the donors' safety and the prevention of liver dysfunction in the liver recipient after the transplantation, the accurate anatomical structure of the donors and liver recipients' hepato-biliary tract should be understood through imaging screening [1]. Endoscopic Retrograde Cholangio Pancreatography (ERCP) is an examination using endoscope and radiation, in which an endoscope is inserted through to the duodenum, a contrast medium is injected to the bile duct and pancreatic duct through the duodenal papilla, to observe the region with a disease on the bile duct and pancreatic duct. Traditionally, though recognized as an optimal standard technique for the diagnosis and treatment of pancreatobiliary diseases, ERCP is invasive, subject to radiation exposure, and has a risk of the occurrence of complications. Recently, as Magnetic Resonance Imaging (MRI) has come to have proper Contrast to Noise Ratio (CNR) and Signal to Noise Ratio (SNR) to detect lesions and identify the range of the lesions for pathologic diagnosis and treatment planning with the dramatic development of hardware and software, and the time for obtaining images has been shortened, the domains of MRI diagnosis are expanding [3]. Especially, Magnetic Resonance Cholangio-Pancreatography (MRCP) provides high diagnostic images of the pancreaticobiliary duct, combining the merits of projection image and sectional image by imaging bile in the pancreaticobiliary duct with the T2 weighted image technique at a high signal intensity, optimizing signal differences between the surrounding tissues. As compared to ERCP, MRCP has a merit that it can obtain images with the non-invasive method without using radiation and contrast medium. In addition, as compared to ultrasound and ERCP, it has lower dependence on the examiner, and can show anatomical diversity with the surrounding organs as well as closed pancreaticobiliary duct, so studies of the accuracy or availability of diagnosis are actively carried out [4].

However, abdominal examination should be given while breathing is stopped, so various protocols of shortening scanning time are used. Of them, the parallel imaging technique is a technique using many received coils to obtain data, unlike the existing method using a single received coil, which is used to reduce the time of examination and enhance spatial resolution [5]. As preceding research, in their study of 3D T2 MRCP using the parallel imaging technique, Zhang *et al.*, reported that better quality MRCP image could be obtained as compared to existing 2D image [6]. Therefore, this paper attempted to study the availability of the parallel imaging technique for the enhancement of the sharpness of images of the hepatobiliary in MRCP of liver donors.

2. Materials and Methods

2.1. Subjects and MRCP Imaging Technique

MRCP was conducted with six patients who visited our hospital between August 2014 and February 2015 and seven normal volunteers, and the sharpness of the pancreaticobiliary duct was evaluated. Of them, 11 were male and 2 were female, and regarding their age distribution was between 21 and 67 (average age 39.15±16.53 years old), (Table 1). As for the equipment used in this test, GE Signa Excite HDxt 1.5T (Signa HDxt, GE Healthcare, Milwaukee, WI, USA) and 8ch phased array torso coil (GE Healthcare) were used. Image parameters were as follows: Sequence; thick-slab fast spin echo, TR; 2240ms, TE; 800ms Matrix size; 480256, FOV; 230mm, and Slice thickness; 50mm.

Table 1. Population Characteristics

Characteristics	Values
Sample (n)	
patient	6 (46%)
normal volunteer	7 (54%)
Sex (n)	
male	11 (85%)
female	2 (15%)
Mean age (years)	39.15 ± 16.53
Height (cm)	170.08 ± 6.42
Weight (kg)	66.23 ± 10.82

2.2. Testing Method and Image Measurement

For examination, in order to minimize the movement by breathing, using a respiratory gaiting technique, in the condition of breathing hold, an image (asset factor = 2) applying parallel image technique and an image not applying it were obtained (Figure 2). The slice of the examination was put in the ampullar of vater, the tip of CBD; thick slab was set by 15; and 360 radial scanning was made.

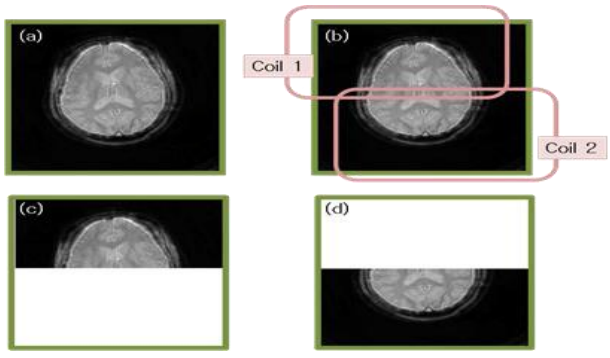

Figure 2. Data Acquired from each Coil Element goes into Reconstruction of Whole Image

With the obtained image, a plot profile was measured after setting up a Region of Interest (ROI) in a DICOM image using Image J (version. 1.49h, Wayne Rasband, National Institutes of Health, USA). Multiple ROIs were measured by selecting parts with strong linearity in the HD, bile duct and PD to calculate the average (Figure 3).

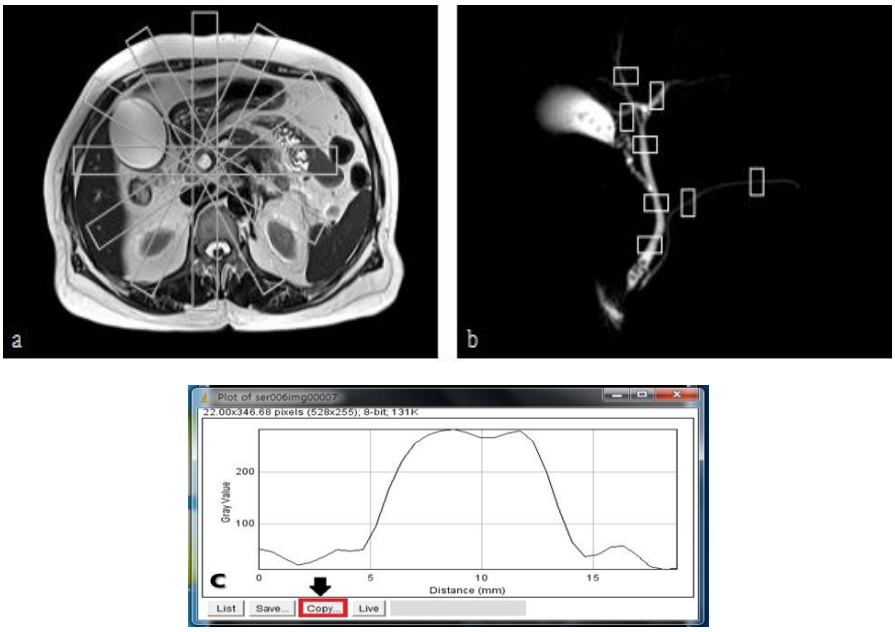

Figure 3. Scan Range (a), ROI Localization (b) and Plot Profile(c).

2.3. Measuring Modulation Transfer Function (MTF)

Modulation Transfer Function (MTF) was used for image analysis. With the measured ROI, after the transform process of differential-FFT (fast Fourier transform, Fig .4), MTF graph was obtained with FFT transform data using OriginPro(version 9.0, OriginLab Corp, Northampton, MA, USA), and the image applying the parallel imaging technique and the image not applying it were compared and evaluated.

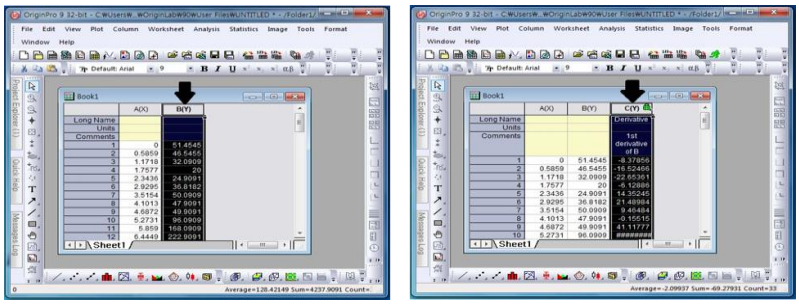

Figure 4. The Transform Process of Differential-FFT from the Main Menu

MTF is a frequency transfer function expressing the original information faithfully when the detector's input signal transforms into an output signal through the system, which can evaluate sharpness and spatial resolution of images obtained with film/screen method and digital method. Sharpness is defined as an ability to show the boundary of an image, clearly, and spatial resolution, as an ability to separate small neighboring objects. Resolving power is expressed in spatial frequency, which is usually shown in the number of the line pairs per mm (lp/mm) [7]. As sharpness in the final MTF curve measured using OriginPro, 50% MTF curve was chosen(Figure 5), and as resolution, a value closest to 10% MTF curve were chosen to make a quantitative evaluation. This paper compared the sharpness of spatial resolution using MTF in diagnosing a disease that requires resolution using 50% MTF curve value. The preceding research proposed that the evaluation of high

spaces like fracture in computer radiographic image could increase the accuracy of diagnosis [8].

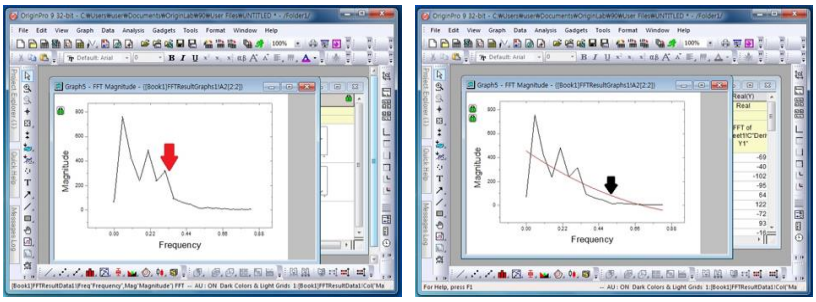

Figure 5. The MTF Curve Obtained from Differential-FFT

2.4. Statistics Analysis

The measured data were shown in frequency (%) and average ± standard deviation, using SPSS version 22.0 (SPSS, Chicago, IL, USA), and using a paired t-test, the statistical significance of the sharpness of the image applying parallel imaging technique and the image not applying it. Significance level (α) of less than 0.05 was considered statistically significant.

3. Results

The result of a paired t-test on 50% MTF curve for sharpness evaluation was statistically very significant (t=12.929, p=0.000), and the average of the image applying parallel imaging technique was 0.4264±0.1227 [lp/mm], higher than the average, 0.2672±0.1085 [lp/mm] of the image not applying the parallel imaging technique (Table 2, Figure 6).

Table 2. Comparison of Mean ± SD with Asset Factor and Without Asset Factor in 50% MTF Curve

No.	Without asset factor (50% MTF lp/mm)		With asset factor(=2) (50% MTF lp/mm)	
	Mean	SD	Mean	SD
1	0.3259	0.1297	0.5289	0.1058
2	0.2775	0.0628	0.5029	0.0937
3	0.3939	0.1123	0.4966	0.0873
4	0.2687	0.0669	0.2983	0.0982
5	0.2798	0.0908	0.5248	0.0687
6	0.2609	0.0915	0.3925	0.1281
7	0.2299	0.0591	0.4250	0.1834
8	0.2170	0.0881	0.4188	0.1247
9	0.3922	0.1051	0.5386	0.0978
10	0.2076	0.1607	0.3767	0.1590
11	0.2581	0.1989	0.3902	0.1763
12	0.2131	0.1562	0.3438	0.1370
13	0.1491	0.0879	0.3060	0.1351
Mean	0.2672	0.1085	0.4264	0.1227

Values are the average ± standard deviation.
SD: standard deviation, *MTF*: modulation transfer function.

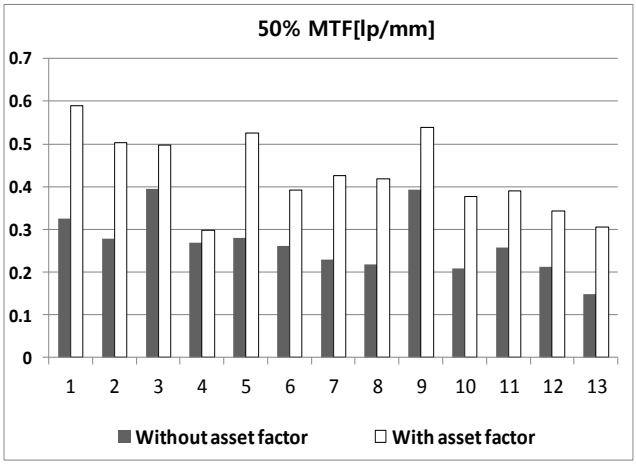

Figure 6. Comparison with and without Asset Image of 50% MTF

In qualitative evaluation with the naked eye, the images (Figures 7 b and d), to which the parallel image technique was applied, overall, showed high sharpness, and especially, in right liver duct (arrow), left liver duct (star) and arrowhead of the pancreatic duct, they showed longer and more accurate running than the images (Figures 7 a and c), to which the parallel image technique was not applied.

Figure 7. Thick-slab MRCP Images: without Asset Factor (a, c) and with Asset Factor (b, d). Right Hepatic Duct (arrow), Left Hepatic Duct (star), Tail Portion of Pancreatic Duct (arrowhead)

4. Discussion

Liver transplantation is settled as the only treatment method from which full recovery of patients in end-stage of liver disease can be expected [9]. The initial liver transplantation started with cadaveric donor liver transplantation, but with the rapid increase of the number of patients who need liver transplantation, countries where organ donations have not been socially common could not cope with the demands, so gradually, partial liver transplantation through living liver donors' donations (living-related liver

transplantation) came to cover the place. Like this, as the number of living liver donors increased, donors' post-operative safety assurance emerged as an important problem. In liver transplantation, the most important problems are volume and hepatic veins. However, in liver transplantation, approach to liver transplant may differ depending on the shape of the liver biliary tree, and especially, there is a research result that the biliary tree complication is the most common and difficult to treat after adult-to-adult partial liver transplantation, so there was a report that more attention should be paid to the accurate understanding of the structure of hepatobiliary [10].

According to preceding research, Hiroshige *et al.*, reported that it is important to understand the anatomical structure of blood vessels in the liver and bile duct in the donors and recipients accurately before transplantation through imaging screening for the donors' safety and the prevention of liver dysfunction after the transplantation [11]. MRCP technology has improved since it was first known by Dooms *et al*. In 1986, and currently, MRCP is used to provide quality diagnostic images for the pancreaticobiliary duct by imaging the bile in the pancreaticobiliary duct with high signal intensity. Till now, in clinics, direct cholangiography like ERCP has been carried out. However, ERCP is an invasive examination, and unless the contrast medium injected into the biliary tract is well discharged, it may cause complication like cholangitis, and if there is biliary duct stricture, the cholecystography of the upper part of the stricture may not be possible. Also, it has demerits that it is not adapted to pediatric patients with acute pancreatitis or cholangitis and that general anesthesia must be given [12]. MRCP is spreading fast, currently, replacing the role of diagnostic ERCP.

The merits of MRCP, above all, include the following: it is non-invasive; the overall cholecystography is possible even if that on the upper biliary tract is difficult in ERCP; it does not have complication like cholangitis. In addition, it can provide quality projection images and sectional images of pancreaticobiliary without injecting a contrast medium into the biliary tract and can evaluate lesions in the regions inside the entire liver and outside the bile duct. Moreover, it has other merits that its dependence on the examiner is low, and exposure to radiation can be avoided [14]. Till now, many studies have made comparisons between MRCP and ERCP. Kaltenthaler *et al.*, reported that the accuracy of examination and the patient's preference were higher in MRCP than ERCP, and that it would be more useful in clinical and economic aspects [15]. Andrew et al. stated that the accuracy of MRCP was so excellent that it could replace ERCP in diagnosing hepatobiliary; the dependency on the examiner is low; and especially, it is an examination with high efficiency in imaging the closed hepatobiliary [16].

In the late 1980s, as reconstruction algorithms using a complex coil were introduced, with the signal measurement through the parallel arrangement of the coil, parallel image technique began. Later, as various parallel image techniques were introduced, Signal-to-Noise Ratio (SNR) is used to obtain images in a sufficiently high magnetic field or reduce the time to obtain the images. The parallel image technique is used to reduce the scan time or improve the resolution, but an additional SNR loss may occur depending on the position of the coil arrangement [17]. In preceding research, Takayuki et al. noted that by using ASSET technique in MRCP using Respiratory-Triggered 3D-Fast Relaxation Fast Spin Echo (FRFSE) MRCP can obtain more clinical information on the pancreaticobiliary as compared to 2D-Single Shot Fast Spin Echo (SSFSE) MRCP [18]. As a quantitative evaluation method for the sharpness of CT and X-ray images, mostly, MTF is used. According to the existing reports, the influences of proper parameter values of images on the image quality in the clinics have been suggested as objective criteria for characteristic evaluation using MTF [19]. However, the sharpness of images was qualitatively evaluated in MRI using hydrogen in many cases, but there have not been many studies using quantitative evaluation.

Therefore, this study was conducted to look into the clinical availability of quantitative evaluation using MTF curve in the field of MRI along with the parallel image technique,

by comparing the MTF curve of an MRCP image applying the parallel image technique and that not applying it. The plot profile of the MRCP image obtained was Image J, MTF curve was calculated using OriginPro. Then, spatial frequency value close to 0.5 was measured, and the sharpness of two images was compared and analyzed. The average value of the image applying a parallel imaging technique was 0.4264±0.1227 [lp/mm], which was 0.1592 [lp/mm] higher than the average value of the image not applying the parallel imaging technique, 0.2672±0.1085 [lp/mm] (t=12.929, p=0.000). Thus, when the spatial frequency values of the two images were compared and analyzed, it is found that the sharpness of the image applying the parallel image technique is higher. Also, as in Figs. 3. b and d, in qualitative evaluation with the naked eye, the image applying the parallel image technique overall, showed an aspect of high sharpness, and especially, it showed longer, more accurate running in the image applying the parallel image technique than that not applying the technique in the right liver duct, left liver duct and arrowhead of the pancreatic duct, and it was found that it was consistent with the result of quantitative evaluation using MTF curve.

This paper has a limitation of a lack of subjects, but it can be compensated by evaluating the sharpness only instead of lesions.

5. Conclusion

In conclusion, it is judged that the application of a parallel image technique in MRCP of donors for liver transplantation shortens the time of examination of patients and enhancing the sharpness of hepato-pancreatobiliary images, which can maximize the accuracy of examination of patients and the efficiency of MRCP test. Also, based on the results of this study, a quantitative evaluation method applying MTF would be useful in the field of MRI and it should be theoretically established through continuous research in the future.

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