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ORIGINAL ARTICLE

Non-Contrast Enhanced Magnetic Resonance Venography Using the Fast Imaging Employing Steady-State Acquisition (FIESTA) Pulse Sequence in Preoperative Evaluation of Liver Donors: Can it Replace CT Venography?

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ABSTRACT

Background: Liver transplantation has now become the preferred treatment for patients with liver failure. Pre-operative assessment of hepatic/portal vein anatomy of donors is necessary for which CT venography is most commonly used but it exposes the donors to huge radiation burden. To avoid this, non-contrast MR venography is the most preferred alternative for evaluation of veins.

Objective: To determine diagnostic yield of magnetic resonance venography using Fast Imaging Employing Steady-State Acquisition (FIESTA) pulse sequence in comparison to computed tomography venography for the determination of portal/hepatic venous anatomy of potential liver donors.

Methods: Retrospective study was conducted in which the venous phase CT scan and FIESTA (b-SSFP) sequence of 50 potential liver donors between 01-07-2021 and 30-11-2021 were reviewed. The hepatic and portal venous anatomy was reviewed. The assessment comprised the type of portal venous anatomy, the number of prominent tributaries from segment VIII and V of liver having diameter of 4mm or more emptying into the middle hepatic vein and the total number of accessory inferior right hepatic veins from segment VI and VII emptying into inferior vena cava (IVC).

Results: With 100% sensitivity and specificity, the FIESTA sequence precisely identified the portal vein anatomy, total number of accessory inferior right hepatic veins, and the total number of 4 mm thick tributaries from segment V and VIII draining into middle hepatic vein

Conclusion: We propose that magnetic resonance venography using FIESTA sequence can be used instead of CT venography to determine hepatic and portal vein anatomy of liver donors.

Key Words: FIESTA, CT venography, Liver donors, Accessory inferior right hepatic vein, Portal vein, Middle hepatic vein tributaries

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Received: 01.01.2023, Revised: 13.06.2023,
Accepted: 16.06.2023

How to cite this article: Hussain H, Rafique MS, Kundi S, Malik T, Bilal B, Khan K. Non-contrast enhanced magnetic resonance venography using the Fast Imaging Employing Steady-State Acquisition (FIESTA) pulse sequence in preoperative evaluation of liver donors: can it replace CT Venography?.J Shalamar Med Dent Coll. 2023; 4(1): 30-36. doi: 10.53685/jshmdc.v4i1.140

Doi:https://doi.org/10.53685/jshmdc.v4i1.140

INTRODUCTION

Living donor liver transplantation (LDLT) has now become the preferred treatment of choice for patients with acute liver failure or chronic liver disease and Barcelona Clinic Liver Cancer (BCLC) stage-A hepatocellular carcinomas (HCC).[1] LDLT is an exceptionally tough surgical procedure and one of the difficult tasks is to restore the portal venous (PV) and hepatic venous (HV) outflow tract.[2]

Determination of hepatic vascular anatomy prior to transplant is mandatory. The criterion for

determining hepatic vascular anatomy is conventional catheter angiography, however it is an invasive technique with concerns of endothelial damage and bleed.[3] It has since been largely supplanted by non - invasive imaging methods like CT/MR angiography.[3]

Currently, CT venography (CTV) is the most frequently employed imaging tool for assessing hepatic and portal venous anatomy.[4] However, every measure should be taken to prevent unnecessary risk to donor during the preoperative imaging screening. Excessive radiation exposure by CT and nephrotoxic effect of CT iodinated contrast media should be kept to the minimum.

For this reason, non-contrast MR venography (MRV) using balanced steady state free precession (b-SSFP) pulse sequence is the most preferred alternative for evaluation of veins.[5,6] This b-SSFP pulse sequence is a recent application in the domain of vascular imaging.[6] To the best of our knowledge, only one study in literature has looked into the effectiveness of this sequence for identifying HV and PV anatomy in liver donors prior to LDLT.[7] This retrospective analysis has the aim of comparing the diagnostic performance of fast imaging employing steady-state acquisition (FIESTA) using the b-SSFP pulse sequence of MRV in comparison to CTV for assessment of HV and PV anatomy of liver donors in pre-operative period.

METHODS

Institutional review board (IRB) approval (Reference no: PKLI-IRB/AP/008) was obtained before beginning this retrospective study. The study was carried out at the Radiology Department of Pakistan Kidney and Liver Institute and Research Center, Lahore (PKLI & RC). It was a comparative, cross-sectional study. Given that this is a retrospective study, the necessity to seek informed consent was waived. We evaluated 50 consecutive potential liver donor candidates between 18 to 44 years of age, who underwent protocol multiphasic CT abdomen for liver volumetry and magnetic resonance cholangiopancreatography (MRCP) examinations prior to liver transplant from July 2021 to November 2021. The study included all potential liver donor candidates who came for preoperative examination prior to liver transplant surgery irrespective of age and gender. Individuals who had claustrophobia and who had metallic devices inside them, were not included in the study.

All the abdominal CT scans were carried out in a supine position using a 128 slice multi-detector CT scanner (GE Revolution Evo) after injecting 2 ml/kg of iodinated contrast media (Ultravist 370 mgI/mL) at a rate 5.5 ml per second via a power injector system. In all patients a non-contrast, early arterial phase at 20 seconds, portal venous phase (PVP) at 35-40 seconds and hepatic venous phase (HVP) at 60-65 seconds were acquired. The upper abdomen was scanned in the non-enhanced, early arterial and PVP phases, and the whole abdomen and pelvis were scanned in the HVP.

MRCP scans were all done while the patient was supine using the 1.5 Tesla MR equipment (GE Healthcare Signa Voyager) using a 16-channel body coil combined with a posterior spine coil. Patients were asked to refrain from deep breathing throughout the scan and to fast for four to six hours prior the study.

Several routine pulse sequences were acquired including axial/coronal T2-weighted SS-FSE, axial/coronal FIESTA, axial dual echo, radial T2 SSFSE and 3D axial/coronal MRCP RT. Our parameters for acquiring FIESTA sequence were as follows: 70° flip angle, 3.9-ms TR, 1.7-ms TE, 83.33 kHz bandwidth, 37-cm field of view, 1.7 x 1.7-pixel size, and 5-mm thickness with 5-mm overlap. The axial FIESTA images included 32 slices with a mean acquisition period of around 20 seconds.

Both the HV and PV anatomy was assessed on the venous phase CT scan and FIESTA images acquired during MRCP examination by two independent consultant radiologists having more than 5 years of experience in hepatobiliary

imaging using a workstation (GE Advantage windows workstation).

To minimize memory bias, the images were analyzed in a separate session 2 months following the database scan. The evaluation included the PV anatomy and its variants based on Cheng's classification, number of accessory IRHV draining independently into IVC regardless of their diameter and the number of prominent tributaries from segment V and VIII of liver having diameter of 4 mm or more draining directly into MHV. CTV phase images were first assessed, and then FIESTA images were studied to see if CTV data provided additional information regarding the venous anatomy as observed on FIESTA images.

Statistical Analysis

Data was recorded on Excel sheet and subsequently exported to the Statistical package for Social Sciences (SPSS) version 25 for statistical analysis. Numerical variables were measured as mean and standard deviations, whereas categorical variables were expressed as frequencies and percentages. Sensitivity and specificity were calculated. Pearson's Chi-square test was employed for comparison of both methods. A p-value of 0.05 or less was regarded statistically significant.

RESULTS

The 50 candidates selected for preoperative liver donor evaluation had a age between 18-44 years. Among them, 29 (58%) were males and 21 (42%) females. (Table 1). Among these 50 individuals, 18 candidates ultimately underwent donor hepatectomy (10 males, 8 females).

Portal venous anatomy

Based on Cheng's classification, three types of PV anatomy were identified using CTV as the reference standard. Conventional portal venous anatomy (type I-classic ramification) was seen in 45 of 50 individuals (90%) while variant PV anatomy was seen in 5 of 50 individuals (10%). Among them, 1 (2%) had trifurcation (type II) of the main portal vein and 4 (8%) had early origin of the right posterior portal vein from the main portal vein (type III). FIESTA accurately identified the PV anatomy and its variant in all donors with 100% sensitivity and specificity. (Table 2)

Accessory inferior right hepatic veins (IRHV)

No accessory IRHV was detected in 34 of 50 cases (68%) whereas 16 cases (32%) had accessory hepatic veins. Among them, 10 (20%) had one IRHV, 5 (10%) had two IRHVs and 1 (2%) had three IRHVs. FIESTA accurately detected all these veins as well with 100% sensitivity and specificity. (Table 2)

V5 and V8

There were four V5/V8 tributaries in 1 (2%) case, three in 11 (22%) cases, two in 26(52%), and one in 12(24%) cases detected with CTV. FIESTA again accurately identified all the tributaries of middle hepatic vein (MHV) for all 50 donors with 100% sensitivity and specificity. (Table 2).

Figure 1 part A shows A) Axial CTV image shows a large accessory inferior hepatic vein IRHV (white arrow) from segment VI entering the inferior vena cava separately from right hepatic vein. Part B shows Axial FIESTA image of the liver of same patient acquired during MRCP also shows the same large accessory inferior hepatic vein IRHV(white arrow) entering the inferior vena cava. Figure 2 part A shows Axial image from a contrast enhanced CT in venous phase through the liver demonstrates a thick segment VIII tributary (white arrow) of MHV. Part B shows Axial FIESTA image of the liver acquired during MRCP of same patient also shows the same thick segment VIII tributary of

Table 1: Demographics of the patients included in the study

Characteristic		
Age (Years)	mean±SD	26.80±7.82
Gender	Male n (%)	29(58%)
	Females n (%)	21(42%)

Table 2: Diagnostic performance of Fast imaging employing steady-state acquisition (FIESTA) in comparison to CTV

Portal vein anatomy	CTV (n)	FIESTA	p-value
Type I	45	45/45 (100 %)	
Type II	1	1/1 (100 %)	
Type III	4	4/4 (100%)	
Total	50	50/50 (100%)	<0.05
Accessory IRHV			
0	34	34/34 (100%)	
1	10	10/10 (100%)	
2	5	5/5(100%)	
3	1	1/1 (100%)	
Total	50	50/50 (100%)	<0.05
V5 and V8			
1	12	12/12 (100%)	
2	26	26/26 (100%)	
3	11	11/11 (100%)	
4	1	1/1 (100%)	
Total	50	50/50 (100%)	<0.05

Pearson Chi-Square test was applied; p-value < 0.05 is considered statistically significant

Abbreviations: CTV= CT venography; **FIESTA**= Fast imaging employing steady-state acquisition; **IRHV**= Inferior right hepatic vein; **V5**= tributary of middle hepatic vein supplying segment V; **V8**= tributary of middle hepatic vein supplying segment VIII MHV.

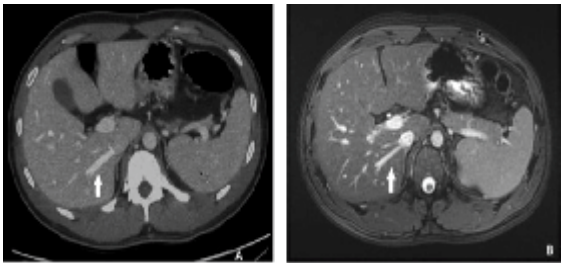

Figure 1: A = Axial CTV image and B = Axial FIESTA, image of 28-year-old male who is a potential Liver donor

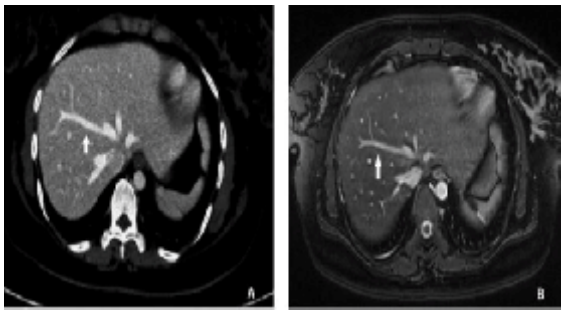

Figure 2: = Axial CTV image and B = Axial FIESTA, image of 30-year-old female who is a potential Liver donor

DISCUSSION

Fast imaging employing steady-state acquisition (FIESTA) is an MRI technique developed by GE Healthcare that uses a b-SSFP pulse sequence.[8] It is a two-dimensional gradient-echo technique that uses much shorter repetition time (TR) to shorten the scanning period without suffering from severe signal loss or signal to noise ratio (SNR) penalty.[9] There are number of technical benefits to this sequence. First, it is a non-contrast study. Second, this sequence is ultrafast, with a maximum scanning period of about 10–12 seconds only in one breath hold. Third, this acquisition produces good results even in the presence of rapidly moving blood and is insensitive to flow void artifacts. So, in nutshell, the FIESTA sequence main benefits include insensitivity to flow void artifacts, crisp edge definition, fast acquisition, high SNR, and motion insensitivity.[9,10]

On FIESTA image, the contrast is not exclusively T1- or T2-weighted. It is instead governed by the tissues' T2-T1 ratio. So, fat and fluid (which have differing T1 and T2 signals but a comparable T2-T1 ratio) are frequently bright while muscles are dark.[8,9] For this reason, this sequence was initially employed in cardiac and coronary artery evaluation with a more recent use in imaging of internal auditory canal, the breast, fetus and also in small bowel enteroclysis and MR colonography.[8,9] The FIESTA sequence also appears to offer an accurate assessment of the vascular anatomy due to its bright blood effect property (i.e. blood has a higher signal intensity that is unrelated to flow or contrast injection).[6] In our institution we have included FIESTA sequence to regular abdominal MRI imaging. It produces high SNR from blood.[6] As a result, major vascular structures like veins can be clearly seen without just depending on postcontrast acquisition.

LDLT is a very challenging surgical operation. The right hepatic vein (RHV) is kept in the grafted liver during a right lobe LDLT (RL-LDLT) while the left hepatic vein (LHV) is

preserved in the grafted liver in left lobe LDLT (LL-LDLT).[11] The decision to preserve the middle hepatic vein (MHV) is made based on the individual's particular circumstances. The drainage of the segments IV, V and VIII is mainly by the MHV.[12] Therefore, the inclusion or exclusion of MHV with the graft and whether the MHV tributaries (V5, V8) should be reconstructed in the recipient is of importance.[13] Currently, MHV is frequently retained in the donor during RL-LDLT for the sake of donor safety.[14] Prior to surgery, it is also necessary to identify accessory inferior right hepatic veins (IRHV), since direct reimplantation of these veins in the inferior vena cava (IVC) by venoplasty may be necessary to improve the graft's venous outflow.[15] Hepatic venous congestion might arise in recipients following RL-LDLT without MHV if V5,V8 and IRHV are not properly reconstructed ultimately leading to graft malfunction with bad results.[16] Similarly knowledge of portal vein (PV) anatomy is important as the reconstruction of PV is required for graft survival as well.[17]

A careful and accurate preoperative evaluation of hepatic vessels is mandatory to reduce morbidity of both donor and recipient. The wellbeing of living donors should be given top consideration as they are healthy people and are willingly submitting to major surgery with potential adverse outcomes. It is important to minimize iatrogenic risk to healthy donors as much as possible. Routine CTV necessities the use of iodinated contrast agents and is also linked with excessive radiation exposure. As an alternative modality, we tried to exploit the utility of FIESTA pulse sequence in the determination of HV and PV anatomy in liver donors.

The most frequent variant of the hepatic venous system is the accessory IRHV, seen in upto 48% of general population.[18] It drains mainly posterior right hepatic lobe segments namely (segments VI and VII) directly into IVC18 (Fig. 1). To avoid hepatic congestion, accessory IRHV having a diameter of 5 mm or higher need to be anastomosed separately to the IVC.[18] Therefore, prior to surgery, it is crucial to identify these bigger accessory veins in all donors. In this study, a total of 23 accessory IRHV were detected with CTV. And FIESTA also accurately identified equal number of accessory IRHV joining IVC with 100% sensitivity and specificity. RL-LDLT without MHV is currently the standard method in adult patients in Asia.[19] Since, MHV is typically kept in the donor in view of donor safety, its thick tributaries draining segment V & VIII having diameter of 5 mm or more, need to be reconstructed to avoid graft congestion. (Fig.2) In our study, FIESTA identified all the 4 mm thick V5 and V8 tributaries of MHV with 100 % sensitivity and specificity.

Similarly, knowledge of PV anatomy is important as well. In 20–35% of population, PV variants are present.[20] Common variant patterns include the main PV trifurcation (type II) and the right posterior sectoral branch coming from the main PV (type III).[20] Preoperative detection of these anatomical variants is crucial since their unanticipated existence could be dangerous during right lobectomy. In our study, type II variant was seen in one (2%) and type III in 4 (8%) cases with CTV. FIESTA again accurately depicted all the PV variants with 100 % sensitivity and specificity. With this new technology (FIESTA), it is feasible to do preoperative assessments of PV and HV anatomy without causing injury or exposing liver donors to radiation.

Similar to our results, Carr et al. also reported 100% sensitivity and specificity of b-SSFP sequence in predicting HV and PV anatomy in potential liver donors prior to surgery.[7] Since there is only one study in the literature that has compared the effectiveness of CTV with balanced steady state free precession (b-SSFP) pulse sequence for evaluation of veins, so we cannot compare our study results with any other study.

There were few limitations to our study. First, we used CTV images as a reference standard, though surgical results would have been preferable. Second, it is a retrospective study. Third, special care is needed in MRCP while acquiring images especially with breath hold technique, otherwise abnormality can be missed.

CONCLUSION

The study determined the MRV FIESTA sequence efficacy in evaluating hepatic/portal venous anatomy, yielding images of top standard without the requirement for contrast agent. It's sensitivity and specificity were both similar to CTV. The significant features of this sequence are its quick acquisition and resistance to flow void artefacts. The FIESTA (b-SSFP) ultrafast pulse sequence has the potential to substitute for CT venography in the pre-surgical diagnostic work-up for liver donors for assessment of hepatic/portal vein anatomy. In this way we can reduce the radiation burden to the healthy young population.

Conflict of Interest:

All authors declared no conflict of interest.

Grant Support and Financial Disclosure:

No specific grant was taken for this research from any funding agency in the public, commercial or not-for-profit sectors.

Data Sharing Statement:

The data is available from the corresponding author upon request.

Contributors:

HH: Central Idea, interpretation, drafting the work

MSR: Drafting the work and revising it critically for important intellectual content.

SK: Data Collection, data entry.

TM: Review of the study, statistical analysis of data.

BB: Proofreading, contribution in the manuscript write-up.

KK: critical review, editing, proofreading

All authors approved the final version and signed the agreement to be accountable for all aspects of work.

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