Ultrasound in Med. & Biol., Vol. ■, No. ■, pp. 1–8, 2017

0301-5629/$ - see front matter

http://dx.doi.org/10.1016/j.ultrasmedbio.2017.07.018

● *Original Contribution*

# FEASIBILITY OF ULTRAFAST DOPPLER IN POST-OPERATIVE EVALUATION OF HEPATIC ARTERY IN RECIPIENTS FOLLOWING LIVER TRANSPLANTATION

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(*Received* 28 *October* 2016; *revised* 19 *June* 2017; *in final form* 22 *July* 2017)

**Abstract—To determine the feasibility of using UltraFast Doppler in post-operative evaluation of the hepatic artery (HA) after liver transplantation (LT), we evaluated 283 simultaneous conventional and UltraFast Doppler sessions in 126 recipients over a 2-mo period after LT, using an Aixplorer scanner The Doppler indexes of the HA (peak systolic velocity [PSV], end-diastolic velocity [EDV], resistive index [RI] and systolic acceleration time [SAT]) by retrospective analysis of retrieved waves from UltraFast Doppler clips were compared with those obtained by conventional spectral Doppler. Correlation, performance in diagnosing the pathologic wave, examination time and reproducibility were evaluated. The PSV, EDV, RI and SAT of spectral and UltraFast Doppler measurements exhibited excellent correlation with favorable diagnostic performance. During the bedside examination, the mean time spent for UltraFast clip storing was significantly shorter than that for conventional Doppler US measurements. Both conventional and UltraFast Doppler exhibited good to excellent inter-analysis consistency. In conclusion, compared with conventional spectral Doppler, UltraFast Doppler values correlated excellently and yielded acceptable pathologic wave diagnostic performance with reduced examination time at the bedside and excellent reproducibility. (E-mail: kimkw@amc.seoul.kr) © 2017 World Federation for Ultrasound in Medicine & Biology.**

*Key Words:* **UltraFast, Doppler, Liver transplantation, Hepatic artery.**

## INTRODUCTION

The use of liver transplantation (LT) as a final treatment for end-stage liver disease and acute liver failure is widespread and increasing. The major causes of morbidity and mortality after LT include rejection, general post-operative complications (*e.g.,* bleeding, infection), biliary complications and vascular complications, among which hepatic artery (HA) obstruction is the gravest. Timely diagnosis is of utmost importance for graft and patient outcomes because insufficient HA inflow may cause serious complications such as severe graft ischemia or failure, bile duct necrosis and bile leak and bile duct stricture (Kim et al. 2007; Pawlak et al. 2003; Settmacher et al. 2000; Tamsel et al. 2007; Wozney et al. 1986). Doppler ultrasound (US) is a primary surveillance method for detection of HA complications in recipients who have undergone LT (Dodd et al. 1994; Platt et al. 1997; Tamsel et al. 2007).

Two types of conventional Doppler modes are available: spectral analysis and color-coded flow imaging. Spectral Doppler provides outstanding temporal resolution and full flow quantification, but it is typically obtainable only at a single location or multiple locations along the same sample line. Color-coded flow imaging overcomes the limited spatial sampling of spectral analysis by sacrificing the observation time at any given location and spreading the US firings over the whole region of interest (ROI). The mean flow velocity and/or Doppler power information are accordingly displayed by overlaying a gray-scale image with a color-coded map at reduced frame rates (approximately a few hertz) (Boote 2003; Powis 1994). The recently introduced UltraFast US

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scanners have changed the perspective of medical US imaging, including Doppler studies. Whereas conventional US imaging involves sequential medium insonification *via* focused beams and successive image line reconstruction, UltraFast imaging, which emerged with the advent of massive parallel computing (or processing) capabilities, transmits several tilted plane waves into the medium and coherently sums the backscattered echoes to reconstruct US images, leading to a marked increase in the frame rate (Bercoff et al. 2011). The high spatiotemporal resolution of UltraFast US acquisition facilitates the simultaneous, uninterrupted imaging and quantification of blood flow at every pixel within a ROI (UltraFast color box) at a high Doppler pulse repetition frequency, unlike conventional color Doppler acquisition (Bercoff et al. 2011; Tanter and Fink 2014). Therefore, a stored UltraFast Doppler clip contains information on both spectral analysis and color-coded flow imaging, and by the retrospective quantitative analysis of flow characteristics, Doppler US would be more easily applied in the clinical practice. By applying these advantages of UltraFast Doppler to the practice of post-operative Doppler study in LT recipients, it is possible to switch from an uncomfortable standing position in an intensive care unit environment to a comfortable environment in a reading room. For the outpatient department, deferring the time spent for simple measurements or turning them off to a separate workstation can be useful in operating an US machine. However, the premise that must be verified is whether the UltraFast Doppler can give enough information to be comparable to conventional spectral Doppler, and whether the information obtained from the conventional spectral Doppler is reproducible without being lost or distorted in the UltraFast Doppler. However, few clinical studies have validated the feasibility of UltraFast Doppler for HA evaluations in recipients who have undergone LT. Therefore, this study aimed to determine the feasibility of using UltraFast Doppler for post-operative HA evaluation in recipients who have undergone LT by comparing HA indexes obtained with UltraFast Doppler and conventional spectral Doppler in terms of correlation, performance in diagnosing the pathologic wave, examination time at the bedside and reproducibility.

## METHODS

### *Patients*

Our institutional review board approved this retrospective study and waived the informed patient consent requirement.

The study included 126 recipients who had undergone LT (mean age, 54.5 y ± 8.8; age range, 29–74 y) evaluated post-operatively at our US department for post-operative surveillance of vascular complications, using an Aixplorer US scanner (SuperSonic Imagine, Aix en Provence, France) between May and June 2016. The patients included 90 men (age range, 29–74 y; mean, 54.6 y ± 9.0) and 36 women (age range, 34–73 y; mean, 54.3 y ± 8.5). Sixty-eight were inpatients, and 58 were outpatients.

Twenty-three patients were recipients of deceased donor livers using a whole liver graft; the remaining 103 underwent living donor right lobe (n = 99), left lobe (n = 3) or dual-lobe LT (n = 1) LT. Indications for LT included hepatitis B-associated liver cirrhosis (n = 33), hepatocellular carcinoma (n = 44), alcoholic liver cirrhosis (n = 28), cryptogenic liver cirrhosis (n = 4), fulminant hepatitis (n = 3), autoimmune hepatitis-associated liver cirrhosis (n = 3), hepatitis C-associated liver cirrhosis (n = 2), primary sclerosing cholangitis (n = 2), malignant hemangioendothelioma (n = 1), combined hepatocellular and cholangiocellular carcinoma (n = 1), acute rejection (n = 1), non-cirrhotic portal fibrosis (n = 1), ischemic cholangiopathy (n = 1), Wilson's disease (n = 1) and polycystic liver disease (n = 1).

### *Doppler examination*

A total of 283 Doppler US sessions were performed in 126 patients (mean, 2.3 ± 1.8 per patient; range, 1–11). The mean intervals between LT and Doppler US were 17.4 ± 16.2 d (range, 2–88) and 1055 ± 1483.3 d (range, 42–6010) for inpatients and outpatients, respectively. All Doppler US examinations of HAs were performed on an Aixplorer scanner with a 1- to 6-MHz wideband convex transducer, by one of three radiology technicians with at least 3 y of clinical experience with Doppler US of recipients who had undergone LT. Patients were examined in the supine position with the right arm elevated (or abducted if necessary); right and left liver grafts were subjected to oblique intercostal scanning and transverse and sagittal subcostal scanning, respectively. After location of the hepatic hilum on gray-scale US, equipment settings, such as depth, focal zone and time-gain compensation, were optimized. Color and conventional spectral Doppler sonograms were subsequently obtained. On color Doppler imaging, the ROI size was adjusted to contain the targeted HA of the liver graft. Standard conventional spectral Doppler parameters were adjusted to the maximal gain without background noise and the lowest pulse repetition frequency without aliasing artifacts, and a 2- to 5-mm Doppler sample volume was obtained for optimal signal detection from the HA. The Doppler angle was corrected in parallel with the target vessel flow direction. The waveform was obtained for at least three consecutive heartbeats during short breath holding end-expiration.