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Normal Variation in Hepatic Venous Doppler Waveform Post Living Donor Liver Transplant

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Abstract

Background: Due to the lack of cadaveric livers, particularly in our part of the world, living donor liver transplantation (LDLT) is commonly being performed. Graft failure and the outcome of surgery are most commonly impacted by vascular complications, including thrombosis and stenosis. Ultrasonography (US), including doppler assessment, has emerged as the initial imaging modality of choice for early detection and follow-up screening of vascular complications.
Methodology: This is a retrospective cohort study. It was conducted at Pakistan Kidney and Liver Institute and Research Centre (PKLI) from 01/07/2021 to 31/12/2021. All adult patients above 16 years of age who underwent LDLT were included. Doppler waveform of the hepatic vein was documented intraoperatively and then for 5 consecutive days. Subsequent scans were performed at 2 weeks, 4 months, and 6 months after transplant. Statistical analysis was performed on SPSS version 20.
Results: Ninety one patients included in the study, the minimum age was 17 years and the maximum age was 73 years. The mean age was calculated to be 45 years. About 79% were males and 21% were females. All patients had hepatofugal flow. The hepatic venous waveforms were quite variable, mostly fluctuating between triphasic and biphasic waveforms.
Conclusion: A whole spectrum of waveforms was noted, of which the triphasic pattern was most common. Both biphasic and monophasic patterns were also encountered and were of no predictive value in terms of significant impact on clinical outcomes.
Keywords: Living donor living transplant (LDLT), Doppler ultrasound, Hepatic vein.

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Introduction

In recent years Living donor liver transplantation (LDLT) has been accepted as a viable treatment option for adults and paediatric patients suffering from end-stage and congenital hepatobiliary diseases, particularly in countries where deceased donors are not available or the waiting lists for orthotopic liver transplantation are too long for critically ill patients.[1] Right lobes, including segments 5-8 are most commonly implanted, whilst extended right lobes, including segments 4-8, are needed for larger recipients to ensure adequate hepatic volume. A left lobe transplant alone is insufficient to sustain life in a normal adult.[2] Recent research reports promising outcomes of LDLT backed by immunosuppressive therapy, with 1-year patient and graft survival rates of 90% and 88% respectively[3], and a 5-year survival rate of approximately 75%.[4]

The most common complication resulting in graft failure following the procedure is vascular complications.[5] Furthermore, the reported incidence of vascular complications is higher following LDLT due to the more intricate nature of vascular anastomoses. The reported incidence of vascular complications following liver transplant in adults varies from 8-15%[6] and can go as high as 20% in cases of LDLT.[7]

The early detection of vascular complications is crucial as timely treatment minimizes graft ischemia and reduces irreversible liver damage. Ultrasound including doppler evaluation is now used as the initial imaging modality of choice for the early detection of vascular complications.[8] However, interpreting Doppler waveforms can be tricky if one is not familiar with normal

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variations of waveforms which are often noted in absence of complications.[9]

Intraoperative ultrasound is an integral component of transplant surgery and furnishes the surgeon with real-time information pertaining to the integrity of vascular anastomoses and graft hemodynamics. This technique minimizes post-procedural vascular complications that may require retransplantation to be performed.[10] Doppler assessment is also the imaging technique of choice to evaluate early and late surgical complications. The timing and frequency of doppler screening vary from a single examination on the postoperative day or every 12 hours daily or alternate-day examinations for 14 d, or daily until discharge.[11]

Material and Methods

Institutional Review Board approval was obtained before commencing the study. This is a retrospective cohort study. It was carried out at Pakistan Kidney and Liver Institute and Research Centre (PKLI) from 01/02/2021 to 31/12/2021. It included all adult patients over 16 years of age who underwent LDLT. All patients with vascular complications, patients who failed to show up at the 2 weeks, 4 months, and 6 months follow up ultrasound and those having hemodynamic complications like shock and shock-like states were excluded. Triplex Doppler ultrasound of the recipients was performed intraoperatively and then postoperatively for 5 consecutive days. Follow-up scans were performed at 2 weeks, 4 months, and 6 months after surgery. All scans were performed on either the GE Logiq S8 or GE Logiq P7 ultrasound machines. Hepatic vein waveforms were documented (Figure 1). Statistical analysis was performed using SPSS version 20. Qualitative data like Hepatic vein waveform was analyzed as frequency and percentages.

Results

The inclusion criteria were met by 91 patients. The mean patient age was 45 years, with a minimum age of 17 years and maximum age of 73 years. Of these recipients, 79% were males and 21% were females. The hepatic vein waveform included triphasic, biphasic, and monophasic patterns. The triphasic pattern remained the dominant pattern, though its prevalence reduced gradually from 86% to 57% from intra-operative assessment to the 6 months scan. The biphasic pattern was the second most common waveform and its prevalence increased from 14% to 43% from intra-operative assessment to the 6 months scan. No cases of monophasic pattern were encountered intraoperatively and at 4 months or later. There was a steady surge of monophasic flow pattern from day 4 onwards and this peaked at 2 weeks. The 2-week follow-up also marked the peak surge of the biphasic flow pattern and the greatest dip in the otherwise dominant triphasic flow pattern (Figure 2).

Table I: Waveform pattern distribution intraoperatively and then on days 1, 2, 3, 4, 5, 2 weeks, 4 months, and 6 months.

	Hepatic vein waveform %		
	Triphasic	**Biphasic**	**Monophasic**
Day 0	86	14	0
Day 1	73	24	3
Day 2	85	14	1
Day 3	78	22	0
Day 4	70	25	5
Day 5	65	21	14
2 weeks	32	46	22
4 months	68	32	0
6 months	57	43	0

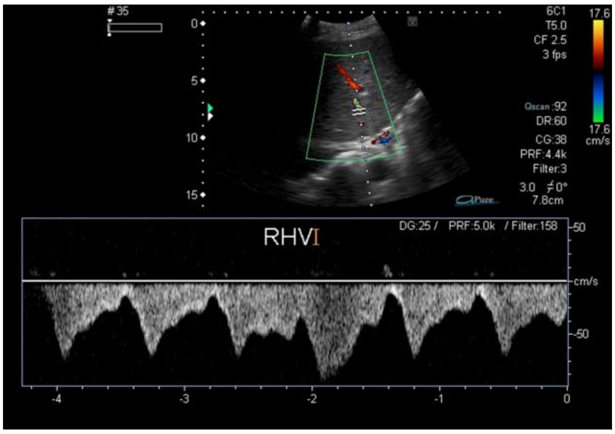
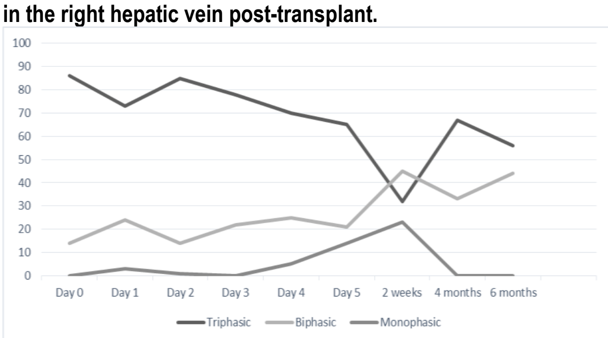


Figure 1 Triphasic waveform with hepatofugal flow documented in the right hepatic vein post-transplant.



Discussion

The shape of the hepatic vein spectral Doppler waveform is primarily determined by pressure changes in the right atrium. Anything increasing the right atrial pressure will cause an upward sloping of the wave and conversely, anything reducing the right atrial pressure will cause downward sloping of the wave. Majority of the hepatic venous flow is antegrade from the liver and toward the heart. Consequently, it is also away from the transducer and is therefore projected below the baseline.[12] There are four described components of the normal periodic hepatic vein waveform. The "a wave" coincides with right atrial contraction. This creates a pressure gradient favoring a minor degree of retrograde flow into the hepatic veins. This minor reversal of flow manifests on doppler as a small wave above the baseline. This is followed by the "S wave". As ventricular systole commences, ventricular contraction causes traction on the tricuspid annulus that in turn leads to stretching of the right atrium. The resulting drop in pressure creates a gradient for anterograde flow from the hepatic veins, most pronounced at mid-systole.

Typically, this forms the highest velocity deflection seen in the waveform. This is then followed by the "v wave" of atrial overfilling. As blood distends the right atrium, flow from the hepatic veins slows, resulting in the s wave returning to the baseline. During the process, if the atrium fills to capacity, a small amount of flow can "recoil" backward resulting in a v wave that rises above the baseline. Finally, the "D wave" coincides with opening of the tricuspid valve. This results in the overall flow of blood away from the liver and the waveform again plunges back down below the baseline.[13]

Ensuring integrity of the hepatic venous anastomoses by doppler assessment is vital as there is no collateral pathway for blood to leave the liver and failure of adequate venous drainage may lead to congestion and life-threatening graft dysfunction.[14] Hepatic venous complications after cadaveric transplant have an incidence ranging from 1%-6% and this almost doubles for LDLT.[15] HV outflow obstruction can occur intraoperatively due to suboptimal surgical technique or graft torsion. Postoperatively this can happen due to compressive effects from graft regeneration, luminal narrowing caused by intimal hyperplasia, or fibrosis at the anastomosis.[16] Loss of the triphasic pattern and absent retrograde flow is thought to reflect increased stiffness of the hepatic parenchyma around the hepatic veins and had a 98.4% negative predicted value for venous obstruction.[17] Furthermore, a persistent triphasic pattern on doppler evaluation can exclude the possibility of substantial stenosis.[16] However, it is also documented that monophasic waveforms alone are not specific for hepatic outflow obstruction and associated dampening of the flow velocities usually accompany the loss of various components of the triphasic pattern.[18]

A whole spectrum of waveforms can be encountered in the postoperative period without associated vascular complications. Therefore, radiologists should be careful in labeling patients as having hepatic outflow obstruction on the basis of waveform alone. The distribution of waveforms we encountered, spanning from triphasic to biphasic, is comparable with the study of Sanyal et al.[19] The hepatic venous waveforms were quite variable, mostly fluctuating between biphasic and triphasic waveforms. Triphasic waveforms in combination with normal hepatic arterial and portal venous indices ruled out vascular complications. The biphasic and monophasic patterns were of no predictive value as there was no associated vascular, biliary, clinical, or biochemical abnormality. During the first 2 days, we had a steady dominant triphasic pattern followed by a biphasic pattern hovering close to 85% and 14% respectively. We did not encounter a monophasic pattern intraoperatively. Thereafter there was a continuous decline in the triphasic pattern and a gradual increase in the biphasic pattern. Eventually, at the 6-month follow-up scan, the gap had narrowed, and though the triphasic pattern remained dominant it accounted for 57% of the flow pattern as opposed to the biphasic pattern which accounted for 43%. Interestingly there was a sharp surge in the biphasic pattern at the 2-week follow-up scan, where it accounted for 46% of the flow pattern and it was the same time the monophasic pattern peaked at 22% and the triphasic pattern plummeted to 32%. Subsequently, we did not encounter the monophasic pattern on the 4-month and 6-month follow-ups. It is unclear what caused this anomaly of distribution at the 2 weeks follow-up and we will continue to collect further data to establish if this indeed is a point of adaptation resulting in an unusual waveform pattern distribution. Interobserver variance might have contributed to a certain degree.

Conclusion

The hepatic venous waveforms are quite variable, mostly fluctuating between triphasic and biphasic waveforms. Whereas triphasic waveforms in combination with normal hepatic arterial and portal venous indices ruled out vascular complications, a biphasic or monophasic pattern was of no predictive value. They were seen in some patients at 2 weeks following transplant who had no other vascular, biliary, clinical, or biochemical abnormality to suggest hepatic venous outflow obstruction.

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