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ORIGINAL ARTICLE

Do Respiratory Maneuvers affect the Hepatic Vein Waveforms and Maximum Velocity?

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ABSTRACT

Aim: To assess the effect of respiratory maneuvers on hepatic vein waveforms and flow velocity in patients without liver or cardiac disease.
Methods: This prospective cross-sectional study was conducted in the Radiology Department of Pakistan Kidney and Liver Institute and Research Center, Lahore (PKLI & RC) after approval from Institutional Review Board (IRB). The sample size of 70 patients was selected using the WHO sample size calculator, after applying the inclusion and exclusion criteria. Doppler waveforms and maximum velocities (Vmax) of the middle hepatic vein were recorded during normal respiration, after quiet expiration, and following breath-hold after deep inspiration. The waveforms were classified as triphasic, biphasic, or monophasic.
Results: The maximum velocities (Vmax) during normal respiration, after quiet expiration, and following deep inspiration were 26.67±9.41, 24.08±6.77 and 19.31±.61 respectively. During normal breathing, the middle hepatic vein waveforms were triphasic, biphasic and monophasic in 80%, 6%, and 14% of the patients respectively. After quiet expiration, these percentages were 82%, 4% & 14% respectively and following breath-hold after deep inspiration, these percentages were 41%, 14% and 45%, respectively ($p<0.05$).
Conclusion: The hepatic venous velocities were lower after deep inspiration. Their waveforms showed significant change from triphasic pattern to monophasic pattern following deep inspiration. Therefore, the respiratory variations must be considered during hepatic vein Doppler ultrasound assessment.
Keywords MeSH: Hepatic veins, velocities, waveforms, inspiration, expiration.

INTRODUCTION

Duplex ultrasound is of utmost significance in hepatic evaluation[1]. The modality is cheap, free of ionizing radiation, readily available and the advantage of portable ultrasound enables the acquisition of vital information in the in-patient and the critically ill. Doppler ultrasound is of value in the diagnosis of hepatic venous outflow obstruction[2]. Hepatic vein stenosis and thrombosis are recognized complications of liver transplantation and are more frequently observed following living donor liver transplant[3]; a monophasic hepatic venous flow pattern suggests stenosis[4].

Normally, the hepatic veins show a triphasic pattern with cardiac pulsatility and respiratory variation or phasicity. The waveform can change in patients with hepatic or cardiac disorders[5].

The flow within the hepatic veins is mostly antegrade, that is, towards the heart and away from the liver. The is interspersed with very brief periods of retrograde flow. The changes in left heart pressure influence the systemic arteries, and the changes of right atrial pressure are transmitted to the hepatic veins. Increased pulsatility states include congestive heart failure and tricuspid regurgitation[6].

The factors altering the waveform of hepatic veins and their phasicity have been discussed before[7]. As it is known that the hepatic venous waveform is affected by both the cardiac cycle and the respiratory variations, great emphasis has to be laid on the timing and variations in breathing motion. It has been demonstrated that both inspiration and expiration can affect the hepatic venous waveform and velocities. The Valsalva maneuver also has an influence[8]; it can even reduce the pulsatility to the extent of nonphasicity or a monophasic pattern[9]. Therefore, the ideal hepatic venous waveform spectrum acquisition would be during a mid-inspiratory breath-hold. The pathologic causes of nonphasicity or a monophasic pattern include Budd-Chiari syndrome, hepatic cirrhosis, and hepatic venous outflow obstruction. With disease progression, pulsatility is also lost as the hepatic veins get compressed by liver parenchymal fibrosis and/or edema.

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Therefore, knowledge of the influence of normal respiratory variations upon hepatic venous waveform in health is essential to assess the hepatic vein during disease and following surgery since these responses of flow to normal respiratory variations must not be mistaken as being pathological.

METHODOLOGY

This prospective cross-sectional study was conducted in the Radiology Department of Pakistan Kidney and Liver Institute and Research Center, Lahore (PKLI & RC). After approval from the Institutional Review Board (IRB), 70 patients including 30 female and 40 male patients, age range of 18-62 years and a mean age of 33 years, were enrolled in the study using WHO sample size calculator, from June 1, 2021, to June 30, 2021, that is, a duration of 1 month. Patients of all ages and genders coming to the radiology department for an ultrasound abdomen were included. Patients with known liver or cardiac disease, patients with deranged liver function tests, patients with echogenic parenchyma indicating a fatty liver, and patients with coarse hepatic parenchyma on ultrasound were excluded.

The ultrasound was performed on GE Logiq P8 machines using a curved transducer with the patient lying comfortably in a supine position. The findings on these scans were evaluated and verified by a consultant with greater than 10-years' experience in Doppler ultrasound.

During the hepatic B-mode ultrasound, focal hepatic lesions were carefully excluded. During normal respiration, after silent expiration, and during a breath-hold after deep intake, the Doppler waveforms and maximum velocities (Vmax) of the middle hepatic vein were recorded. The tracings were obtained for at least 2 respiratory cycles. The measurements were obtained at 3 cm from the inferior vena cava to avoid the influence of its waveform upon the middle hepatic vein. The waveforms were classified as triphasic, biphasic, or monophasic. Statistical analysis was done on SPSS version 20. Kruskal-Wallis H test was applied to see the effect of respiratory maneuvers on hepatic venous flow pattern, and a p-value of less than 0.05 was considered statistically significant.

RESULTS

The maximum velocities (Vmax) during normal respiration, after quiet expiration, and following deep inspiration were 26.67±9.41, 24.0±6.77, and 19.31±6.61 respectively. During normal breathing, the middle hepatic vein waveforms were triphasic, biphasic, and monophasic in 80%, 6% and 14% of the patients respectively. After quiet expiration, these percentages were 82%, 4%, and 14%, respectively. However, assessment following breath-hold after deep inspiration revealed percentages of 41%, 14% and 45%, respectively (Table 1).

Thus, the waveforms were quite similar during normal respiration and after quiet expiration. However, when evaluated after a breath-hold following deep inspiration, a triphasic flow pattern was observed in significantly fewer patients; biphasic and monophasic patterns were dominant in a larger number of patients particularly the monophasic pattern. In other words, it can be said that following breath-hold after deep inspiration, triphasic pattern in hepatic veins of most patients changed into a monophasic pattern, that is, loss of phasicity ($p<0.05$)

The Vmax during normal respiration was higher than quiet expiration and that after quiet expiration was higher than after deep inspiration ($p<0.05$) (Figures 1 and 2).

Table 1: Effect of respiratory maneuvers on hepatic vein waveform.

Respiratory Maneuver	**Waveforms**		
	Triphasic	**Biphasic**	**Monophasic**
Normal Respiration	80 (56%)	6(4%)	14(10%)
Expiration	82 (57%)	4(3%)	14(10%)
Breath hold after inspiration	41(29%)	14(10%)	45(31%)

Figure 1: Hepatic vein waveform and velocity with normal respiration *(left)* and after quiet expiration *(right):* On both the occasions the waveform is triphasic, with slight decrease in Vmax after quiet expiration (from 42.5 cm/s to 40.7 cm/s)

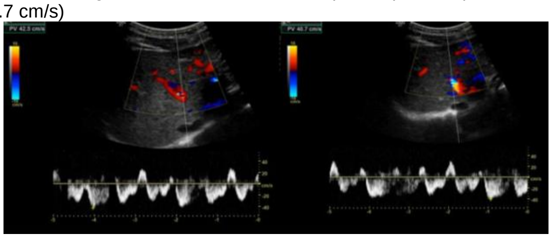
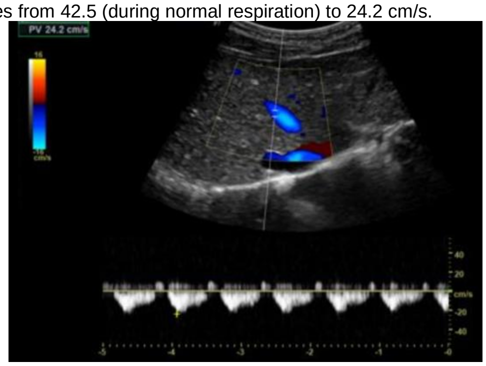


Figure 2: Hepatic vein waveform and velocity after deep inspiration: A change in waveform from triphasic to biphasic is registered. The Vmax also decreases from 42.5 (during normal respiration) to 24.2 cm/s.



DISCUSSION

Hepatic Doppler ultrasound adds valuable information about hepatic function[10]. It has a pivotal role in hepatic evaluation. Hepatic venous flow is governed by respiratory variations, cardiac function especially pressure changes in the right atrium, hepatic parenchymal compliance, intra-thoracic and intra-abdominal pressure. The normal hepatic vein Doppler waveform is triphasic which comprises two antegrade peaks toward the heart and one retrograde flow peak towards the liver in healthy individuals[11]. The antegrade flow is displayed below the baseline and comprises four waves: "a", "S", "v" and "D" which correspond to different phases of the cardiac cycle[12].

The precise interpretation of the hepatic venous duplex ultrasound findings is vital because it indicates cardiac and hepatic physiology changes. Liver parenchymal disease can change the hepatic vein compliance owing to their thin walls[13]. A monophasic waveform of the hepatic veins suggests severe liver dysfunction and is associated with severe portal hypertension[14]. The hepatic vein pulsatility not only is a reflection of pressure changes in the right atrium but is also an indicator of hepatic parenchymal compliance. Thus, liver diseases that alter the compliance will also decrease hepatic vein pulsatility. This changed waveform is proportional to the degree of hepatic fibrosis and hepatocyte regenerative process that may compress the hepatic veins[15].

Teichgraber et al. studied the hepatic venous flow in healthy subjects during full inspiration, mid-inspiration, and expiration in left, middle, and right hepatic veins separately. They reported an increase in hepatic venous velocity following inspiration as well as decreased pulsatility (a transition to monophasic or biphasic pattern from the normal triphasic). These conclusions are in keeping with our findings. Another study conducted by the same author deduced that hepatic venous velocity not only increased following expiration but also decreased during inspiration compared to mid-inspiration. In addition, they also suggested that food intake and exercise did not influence the waveform patterns but exercise did cause increased hepatic venous velocities[16].

Another study performed by Altinkaya et al. revealed results similar to ours whereby, the maximum hepatic venous velocities were higher during normal breathing compared to quiet expiration and higher after quiet expiration compared with end inspiration. Fewer patients had a triphasic hepatic venous flow pattern at end inspiration than normal respiration and quiet expiration, also in agreement with our observations. However, this change from triphasic pattern to monophasic and biphasic was more pronounced in our study as shown by the percentages[17].

Variability of hepatic vein Doppler tracings was reported in 7 out of 75 healthy individuals by Shapiro et al who also concluded that respiratory maneuvers do affect these tracings[18].

A research by Bolondi et al., who enrolled 65 healthy individuals in their control arm, reported that all of them had a triphasic hepatic venous flow[19]. Dietrich et al. investigated 75 healthy subjects in their control group and inferred that only 12 of these had monophasic patterns which were thought to be due to a fatty liver depicted by an increased hepatic echogenicity. Thus, alteration in the hepatic waveform can be considered a sign of at least some degree of hepatic function derangement. Even though the results of these investigators are different from ours, it is important to emphasize that they did not study the influence of respiratory variations on the hepatic waveforms and did not analyze the hepatic vein velocities.

Our study had two limitations. First, to exclude the presence of any cardiac disease, we relied on clinical history though a better approach would have been to have echocardiography to rule out cardiac abnormalities. Second, we recorded the middle hepatic vein Doppler tracings which may have been slightly different for left and right hepatic veins owing to differing liver mass around them.

CONCLUSION

The different respiratory maneuvers significantly affect the hepatic venous velocities and waveforms even in healthy adults. Thus, these variations must be considered during hepatic vein Doppler ultrasound assessment, and sampling of hepatic vein flow should not be performed following deep inspiration.

Conflict of interest: Nil

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