Doppler Study to Evaluate the Effect on Venous Flow of Decubitus

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Objectives: To determine the decubitus for sleep where venous return would have more forward velocity, the venous flow changes were traced in the Middle Hepatic Vein (MHV) of healthy adults in the right, left and supine recumbent positions by Doppler Sonography.

Methods: Total 330 MHV Doppler tracings including 110 for each of the studied decubital (right, left and supine) positions were obtained on 110 fasted healthy adults of both gender. Each MHV Doppler spectrums was analyzed for the magnitude of its forward and backward flow velocity components and then accordingly, the spectrum was scored into HV_0, HV_1 or HV_2 grades. The ratio of flow velocity components and caliber of MHV were also calculated. Statistical significant difference (S.S.D.) of the percentage of HV_0, HV_1 and HV_2 grades correlated with the studied recumbent positions were evaluated by the fisher's exact test while S.S.D. for velocity' variables of forward and backward flow velocity waves correlated with the studied decubital positions, age, gender, heart rate, weight, height, body mass index and martial status of the participants were estimated by the chi-square test.

Results: 100, 82 and 77 percent of MHV Doppler spectrums in right, left and supine recumbent positions respectively were found of grade Hvo. The result related to comparison of these waves and calibration of MHV in the studied decubital positions revealed that in the right decubitus: the forward flow velocity component (S) were of comparatively high and uniform amplitude along with > 1 S : D ratio; "a" wave (back flow velocity) comparatively was of smaller amplitude and calibration of MHV was only here < 10 mm (i.e. normal). The Statistical significant difference (S.S.D.) evaluated for HV_0, HV_1 and HV_2 grades percentage correlated with the studied decubital positions except of right recumbent were highly significant ($p < 0.005$). The S.S.D. of ratios of forward and backward velocities' variables correlated with the studied decubital positions except of right recumbent were of also significant ($p < 0.001$). The S.S.D. of the velocity variables in relation to age, gender, heart rate, height, weight, body mass index and marital status of the subjects in all studied recumbent positions were not significant.

Conclusions: Among the right, left and supine decubital positions of healthy adults, it is the right decubitus where venous return to the heart is more and maximum because its all multiphasic MHV spectrums are characterized with: the comparatively more high forward velocity flow wave; low velocity of back flow wave and calibration of MHV < 10 mm (normal size.

Abbreviations: MHV - Middle hepatic vein, S.S.D. - Statistical Significant Difference.

Introduction

We all lie down in different recumbent positions while asleep. So awareness about the influence on blood flow back to the heart of decubiti is very valuable for us when important known adverse sequences of less venous flow are stagnation of venous blood, venous thrombosis, oedema, ascities, varicosity ultimately leading to failure of brain, kidney, liver, heart, lungs even death [1].

The venous flow is primarily generated by contraction of skeletal muscles in the limbs during exercise, respiratory-inspiration, Sympathetic activation of veins and venous valves [etc]. These factors are called as venous pumps[2]. The turbulence (pulsatility) in the venous flow which has also influence on venous flow is created by pressure changes due to contraction and relaxation of muscle of right atrium[3]. Sakai K *et al.* (1984) traced this pulsatility in the venous flow as multiphasic oscillations by Doppler sonography[4]. Abdu-Yousef[1] (1990) demonstrated that the multiphasic Doppler spectrum in the normal hepatic vein consists of large antegrade systolic (S) and diastolic (D) and small retrograde "v", "a", and rarely "c" waves (figure # 1).

The venous flow in human also being variably affected by the pull of earth (gravity) with respect to the posture e.g., when a person is in upright posture, tendency of gravity to reverse or stop venous return in lower limb is greatest, diminishing superiorly and virtually absent above the heart, where gravity acts with venous return, not against. Similarly in right decubitus, this hydrostatic force assists venous return towards right atrium because right atrium in that position is lower than the central venous flow while inverse effect happens in left decubitus where the right atrium attains higher altitude than the central venous return (Figure # 2 & 3)[5].

Thus one can hypothesize that different recumbent positions have variable influence on the venous return due to gravity and to our knowledge, the effect of different decubiti on venous flow has not been demonstrated in healthy people with Doppler ultrasound (D/S). The purpose of this study therefore was to observe and trace the effect of supine, right and left lateral decubitus on venous flow in healthy population with D/S.

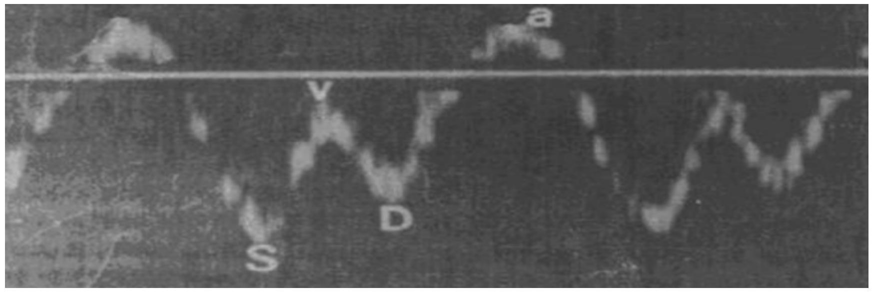

Figure 1: *Doppler sonogram of hepatic vein in healthy adult by Abdu-Yousef.*

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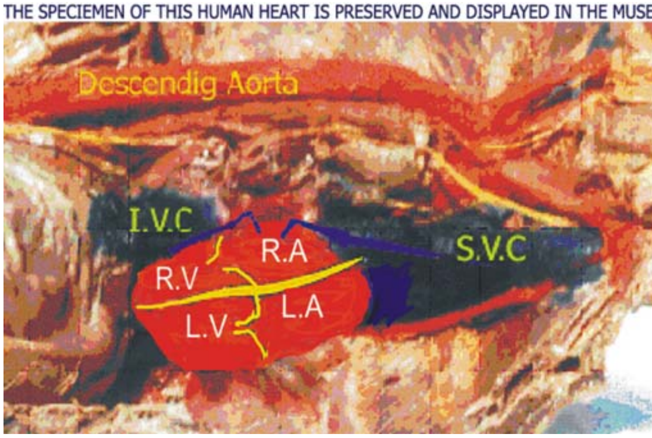


Figure 2: *In Left Decubitus, Right Atrium has raised level than SVC and IVC, so Venous Return is opposed by Gravity in that lying.*

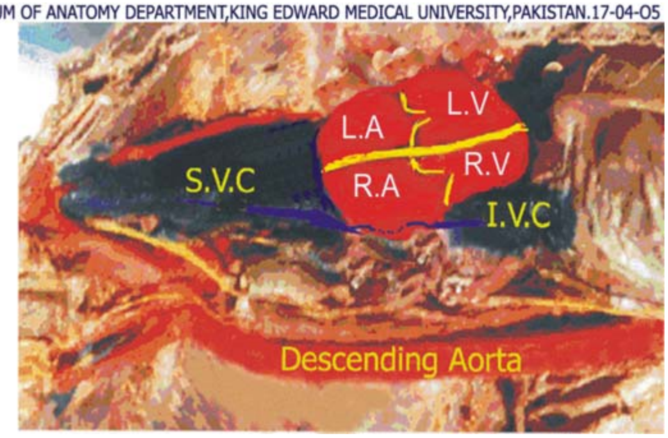


Figure 3: *In Right Decubitus, Right Atrium has lower level than SVC and IVC, so Venous Return is assisted by Gravity in that lying.*

Subject and Methods

Subjects

Out of two hundreds, only one hundred and ten volunteers (fifty five male and fifty five female) were enrolled. They were neither thin nor obese and had no history of thoraco-abdominal surgery, neurological, musculoskeletal, respiretory, hepatic or cardiovascular diseases etc. Their mean age was 31±4.8 years old (range 25 – 50 years old). Their mean weight was 60.2 ± 9.7kg (range 47 – 90 kg) and their mean height was 1.65 ± 0.07 m (range 1.44 – 1.79 m). Their body mass index (weight / [height] ^{2}) was 20.7 ± 1.9 (range 18.2 – 25). Their mean heart rate per minute was 72 ± 3 (range 75 – 85) their name, residence, contact number and martial status (45 bachelor and 75 married) of participants were recorded. Participants were explained all the procedures and their consents were obtained.

Equipment

All measurements were obtained by the same Radiologist using a B-K Medical 2102 (Hawk Analogic Company U.S.A.) sonographic system with real time B mode imaging coupled with pulsed Doppler, M Mode and color coded Doppler and with 3.5 MHz broad bandwidth sector electronic probe. The wall filter setting was kept at its lowest available value (50 Hz) and the pulse repetition frequency was adjusted manually to its's lowest setting without aliasing. The axial size of pulsed Doppler sample volume was kept in 3 – 5 mm range. The Doppler angle of incidence always used was less than 60º.

Study Protocol

The study was conducted at the Radiology Deptt. Mayo Hospital, KEMU and Abdullah Ultrasound Centre since Feb. 2004 to Aug. 2006. The volunteers had fasted for last eight hours before undergoing experimentation. Skin area of right sub-costal and intercostal spaces alongwith epigastric area were shaved and cleaned. Using longitudinal or tranvese approach, the small Doppler gate was positioned over the central part of the MHV at least 1-2 cm distal from its opening into inferior vena cava. On each volunteer after lying of 15, 30 & 45 minutes in supine, right and left decubital positions, angle independent Color and power Doppler images of the Middle hepatic venous flow in full inspiration after holding breath were traced of at least 6 sec. on the film. Simultaneously after angle correction, these Doppler spectrums were analyzed for maximum systolic velocity (S), maximum diastolic velocity (D), v-wave velocity (v) and a-wave velocity (a). Caliber variations of MHV were also measured using M mode. The hepatic parenchyma and hepatic vasculature, the gallbladder, the periportal area, kidneys, pancreas, para-aortic space, spleen, and the peritoneal space were also evaluated with gray scale ultrsonography in each case.

On basis of HV scoring classification of Bolondi L *et.al.* (1991)' MHV Doppler spectrums of each subject in right, left and supine recumbent positions after lying of 15, 30 and 45 minutes were scored into HV_0, HV_1 and HV_2.

The magnitude of the antegrade "S" and "D" and retrograde "v" and "a" flow velocities and S/D, a/S, a/D, v/S and v/D ratios of each MHV Doppler spectrum traced in right, left and supine recumbent positions after lying of 15, 30 and 45 minutes as well as the mean caliber variations ± standard deviation of MHV were determined.

Statistical analysis

The fisher's exact test for pair data was used to evaluate the percentage of HV_0, HV_1 and HV_2 pulsatility patterns traced in MHV of the volunteers related to their supine, right and left lateral positions. The chi-square test (SPSS for Windows, version 13 statistical package) was used to evaluate the correlation of velocities' variables (of S, D, a waves) with the decubital positions, age, gender, heart rate, weight, height, body mass iindex and martial status of the participants. A *P*- value of less than .05 was considered significant.

Result

Doppler Observations:

i) Venous Flow pulsatility Patterns

In right decubitus after lying intervals of different durations, each MHV Doppler spectrum (image of an oscillation) was found to be composed of two large waves above the baseline termed antegrade "S and D" waves followed by one small wave below the baseline termed retrograde "a" wave (Spectrums # 1, table # 1). These typical multiphasic oscillations displaying triphasic pusatility were given score HV_0 on having standard amplitudes of its waves.

In supine and left decubital positions, atypical multiphasic (70%), biphasic (20%) and monophasic (10%) pulsatility oscillations in the MHV were observed. Increased duration of lying in these recumbent positions resulted 2 – 4% increase of biphasic and monophasic pulsatility oscillations at the cost of the multiphasic pulsatility oscillations. Each multiphasic oscillation here contrary to that in right decubitus, was found to be made of four instead of three waves i.e. two antegrade flow waves "S" & "D" and two retrograde components "a" and "v" . This multiphasic was howere also scored HV_0 because of having amplitudes near to the standard recommended by L Bolondi *et.al* (1991)[6]. The biphasic pusatility oscillations observed in the study was made of "S" & "D" waves and scored HV_1. The monophasic waveform was found to made of single flattened forward pulse with no "S" & "D" discrimination and scored HV_2. (Table # 1 Spectrum #,2 & 3,4 and 5).

ii) Magnitude of Venous Forward flow velocity waves

In Right Decubitus

The velocity of antegrade systolic component was 26 ± 02cm/sec. that was 6 ± 01 cm/sec. > that of antegrade Diastolic component. Their S:D ratio was 1.3 ± 01. Neither the velocity nor S:D ratio of these components were affected by the increased duration of lying in this decubitus. (Spectrums # 2 & 3 and table # 2).

In supine and left decubiti

Unlike to right decubitus, in these recumbent positions, antegrade diastolic > than antegrade systolic. Here, The velocity of antegrade Diastolic component was 22.6 ± 04cm/sec. that was 4.5 ± 01 cm/sec. greater than that of the antegrade systolic component. The S.D ratio of these components was less than that in right decubitus by value of 0.54 ± 0.3.The increased duration of lying in these recumbent positions accelerated the velocity of diastolic component but retarded / reduced to that of systolic component along with the value of S.D ratio. (The (Spectrum # 1, 2 & 3 and table # 2).

iii) Magnitude of Venous Reversal flow velocity waves

The reversal flow velocity wave of multiphasic spectrums traced in right decubitus was "a" while in left and supine, two reversal flow velocity waves were found i.e. "v" and "a". In right decubitus, the velocity of "a" was -9 ± 0.2 cm/sec which was less than that in left and supine by -8 ± 0.1cm/sec. the value of a/S and a/D in right decubitus were 0.34 ± 0.1 and 0.45± 0.2 which were less than to those in left and supine by 0.46± 01 and 31± 02. The increased duration of lying in the right decubitus did not affect on the velocity of "a" alongwith it's value of a/S and a/D while it accelerated / enhanced to "a" in left and supine alongwith adverse effect on their value of a/S and a/D. (Spectra # 1,2,3 & Table # 2).

iv) Magnitude of Caliber of MHV

The caliber of MHV remained same and was 8 ± 02 mm in right decubitus after all intervals of lying followed in the present study. The caliber of MHV was greater in left and supine from that in right decubitus by value of 2.54 ± 0.34 mm and increased with increased duration of lying. (Spectra # 1,2,3 & Table # 2).

Statistical Evaluation

The level of significant difference evaluated was $p < 0.005$ between HV_0, HV_1 and HV_2 pulsatility patterns traced in MHV of the subjects while lying in supine and left while its value was $p < 0.1$ in right decubitus position. Significant difference was $p < 0.001$ between velocities' variables of S, D, and a waves correlated with supine and left but its value was $p < 0.1$ related with right recumbent position of the subjects. The level of significant difference observed between velocities' variables of S, D, and a waves correlated with age, gender, heart rate, height, weight, body mass index and marital status of the subjects was $p < 0.1$.

Discussions

Doppler sonography was chosen for the present study because it is considered a well established non-invasive method for rapid, comprehensive, and accurate detection of magnitude and direction of venous blood flow particularly in portal system[7]. Determination of the central venous flow directly from inferior vena cava by Doppler sonography has limitations as insonation angle to sample volume of I.V.C adversely alter the pulse Doppler waveform and provide erroneous information[8]. Middle hepatic vein (MHV) was selected in this study to determine changes of venous flow i.e. technically having no problem of insonation angle because of its anatomical course, easily approachable in different decubitus by the beam transducer of the ultrasound apparatus, nearest location to and draining it's venous blood directly into the inferior vena cava (I.V.C) seems to reflect almost the central venous flow.

Moreover the significant change in the forward and reversal flow velocity components of MHV Doppler spectrum in healthy adult just with change of decubitus along with diverse influence of increased duration of lying created great curiosity in the researchers of this study to search the truth by this study in this regards.

Table 1: *The decubiti and their associated Doppler spectral waveform patterns observed in middle hepatic vein of healthy people (n = 110).*

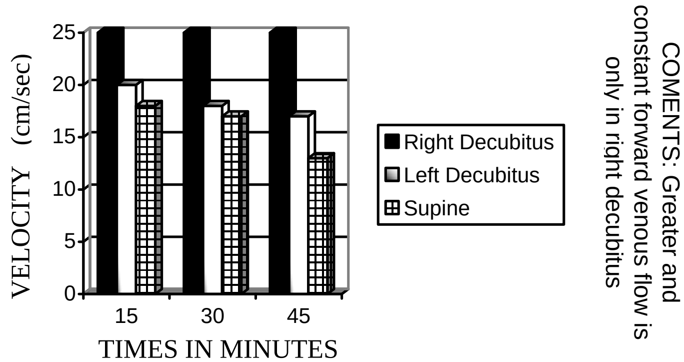
Minutes of Lying	Decubitus	Percentage Grading in respect of HV_O score			Analysis
		HV_O (Triphasic waveform)	HV_1 (Biphasic waveform)	HV_2 Monophasic waveform	
15	Right	110 (100%)	0 (0%)	0 (0%)	In right decubitus, only 100 % typical Triphasic Doppler sonograpgic spectrum of middle hepatic vein was observed.
	Left	84 (76.5%)	15 (13.5%)	11 (10%)	
	Supine	83 (75.5%)	18 (16%)	9 (8.50%)	
30	Right	110 (100%)	0 (0%)	0 (0%)	
	Left	82 (75.5%)	16 (14.50%)	12 (11%)	
	Supine	76 (70%)	22 (20%)	12 (10%)	
45	Right	110 (100%)	0 (0%)	0 (0%)	
	Left	80 (72.72%)	17 (15.45%)	13 (11.82%)	
	Supine	73 (66.36%)	22 (20%)	15 (13. 64%)	

Table 2: *Influence of Decubiti on Diameter and means of velocities variables of Doppler spectral waveform components observed in middle hepatic vein (MHV) of healthy people (n = 100).*

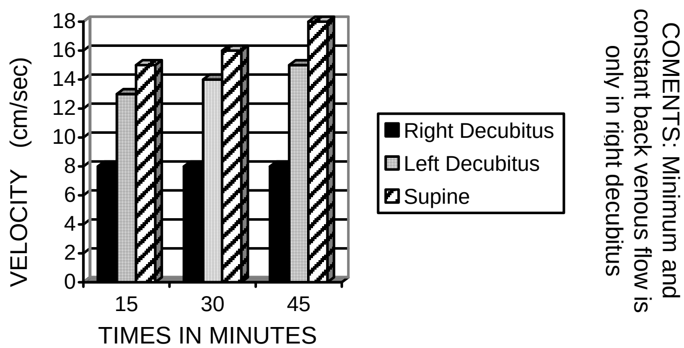
Minutes of Laying	Decubitus	Variables										Remarks
		Caliber of MHV (mm)		Maximum systolic velocity (cm/sec.)		Maximum Diastolic velocity (cm/sec.)		"a" velocity (cm/sec.)		S.D		
		Observed (Mean± Sd)	Normal Range	Observed (Mean± Sd)	Normal Range	Observed (Mean± Sd)	Normal Range	Observed (Mean± Sd)	Normal range	Observed (Mean± Sd)	Normal Range	
15	Right	8 ± 01	7 - 10	26 ± 02	22 - 47	20 ± 01	12 - 42	-9 ± 02	-9 - -12	1.3 ± 01	0-9 - 1.5	Velocities of Antegrade and Retrograde components of normal limit are only in Right Decubitus .
	Left	11 ± 01		20 ± 01		22 ± 02		-13 ± 01		1.0 ± 02		
	Supine	10 ± 01		18 ± 01		20 ± 01		-15 ± 02		0,9 ± 01		
30	Right	8 ± 01		26 ± 02		20 ± 02		-9 ± 01		1.3 ± 03		
	Left	12 ± 01		18 ± 02		25 ± 01		-14 ± 02		0.7 ± 0-1		
	Supine	11 ± 01		17 ± 01		21 ± 03		-16 ± 02		0.8 ± 02		
45	Right	8 ± 01		26 ± 02		20 ± 02		-9 ± 01		1.3 ± 01		
	Left	13 ± 01		17 ± o2		26 ± 01		-15 ± 02		0.6 ± 01		
	Supine	12 ± 01		13 ± 03		22 ± 02		-18 ± 01		0.6 ± 03		

i)"S" and "D" waves of the Spectrum

The first wave of an oscillation below baseline in the venous Doppler spectrum is due to a drop in pressure in right atrium though caused by right atrial relaxation(atrial Diastole) and movement of tricuspid annulus towards cardiac apex while ventricle systole has no role for it's creation directly, but conventionally still it is named antegrade systolic wave, symbolized by "S" just because of the simultaneous systole of the ventricle happening during this phase. The 2nd. Wave of the oscillation below the baseline in the spectrum is because of the negative pressure created in right atrium due to opening of tricuspid valve and flowing of blood from the right atrium. Simultaneous diastole of right ventricle is also happening during this phase so this wave is termed Diastolic wave, short named by "D". Clinically the high amplitudes within certain limit of these antegrade waves (S & D) are considering the sign of good venous return as expressing more hepatopetal flow [9]. In the present study of healthy adult, comparative high amplitude of these waves was found in right decubitus in comparison that in left and supine. The reason of this variation may be the positional change of right atrium of human heart with change of the recumbent position in reference to the surface of earth (Figure # 2 & 3). So in right recumbent position, gravity assist the forward venous flow velocity into the right atrium and causes comparatively high amplitude of "S" and "D" waves of the venous flow Doppler spectrum in this recumbent position. The magnitude of venous return towards the right atrium can be also assessed from the S: D ratio of antegrade waves velocity components and value is >01 for an ideal venous return [10]. Abu – yousaf[1] measured the value of S:D ratio in hepatic veins of healthy subjects was 1.3 ± .02 similar to that we found in healthy subjects in right decubitus but its value measured by us in left and supine positions was < 01 marking right decubitus best one for the excellent return of venous among different recumbent positions.



Graph 1: *Durations of Lying in Three Recumbent Positions Has Different Influence on the Velocity of Forward Venous Flow Wave (S).*



Graph 2: *Durations of Lying in Three Recumbent Positions Has Different Influence on the Velocity of Back Venous Flow Wave (a).*

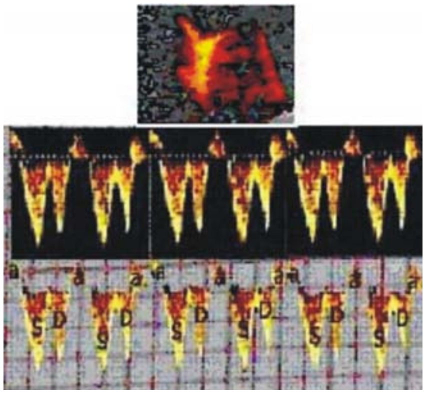
ii)"v" and "a" waves of the spectrum

A small wave between antegrade "S" and "D" waves in the venous Doppler spectrum is called "v". It is due to the elevated right atrial pressure resulted from overfilling against a closed tricuspid value. Sakai K *et al*. (1984)[4] *observed* the absence of "v" wave in hepatic vein spectrum of healthy subjects in the Doppler study. In the present study, this retrograde was found absent in the middle hepatic vein Doppler spectrum of healthy subjects while lying in right decubitus but was present when the healthy subjects were lying in left and supine recumbent positions revealing that the venous return is more opposed in these recumbent positions other than right decubitus.

Another small wave after antegrade "S" and "D" waves of the venous Doppler spectrum is called "a" .it due to the elevated right atrial pressure caused by right atrial contraction. Its magnitude -9 ± 02 cm/sec was observed by Shapiro *et al*. (2004)[11] in hepatic veins Doppler spectrum of healthy subjects which coincides with that "a" wave related to the present study MHV Doppler spectrum in healthy people while lying in the right decubitus. In the present study, the velocity of "a" observed in the MHV Doppler spectrum of healthy people in left and right decubitus was > to that observed by Shapiro *et al*. (2004)[11] proving that the venous reversal flow is more hepatofugal in these recumbent positions The further increase of the amplitude of "a" wave with increased duration of lying in left and supine position observed in the present study proves that venous return becomes further more hepatofugal with increased duration of lying in these recumbent positions.

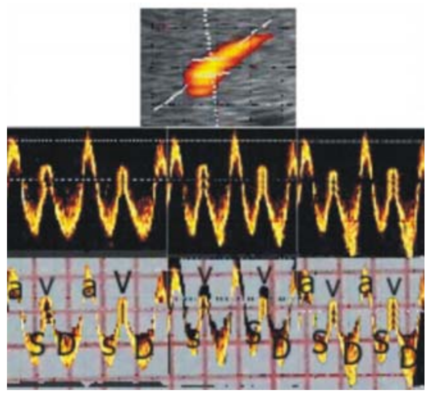
iii) Calibration of MHV

The normal calibration of hepatic veins in healthy adults measured by Doppler sonograpghy is 7 ± 02 mm and > to 10mm represent impedance in hepatic venous return[12]. In the present study, it was < 9 mm in right decubitus while > 10mm which increased further with increased duration of



A B C

Spectra 1: Characterizations of Triphasic Doppler sonographic spectrum of middle hepatic Vein observed in right decubitus after 30 (A), 60 (B) and 120 (C) minutes.



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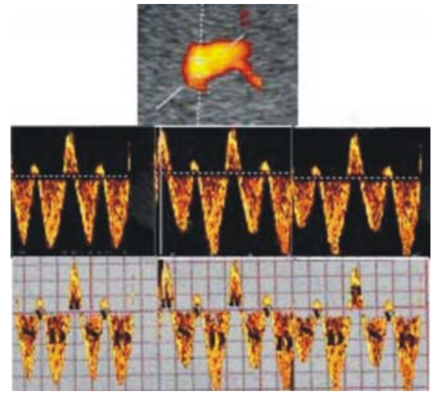
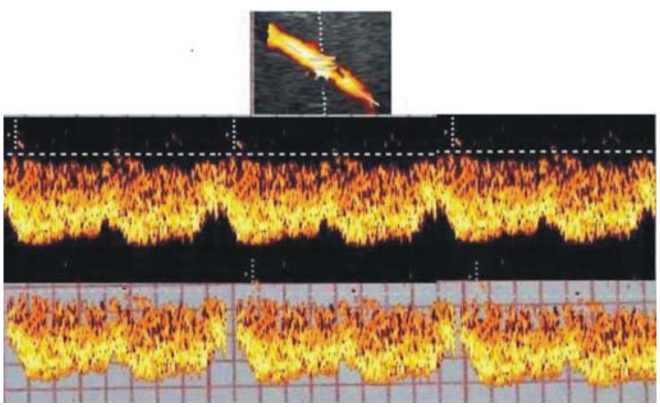
Spectra 2: Characterizations of Triphasic Doppler sonographic spectrum of middle hepatic Vein observed in left decubitus after 30 (A), 60 (B) and 120 (C) minutes.



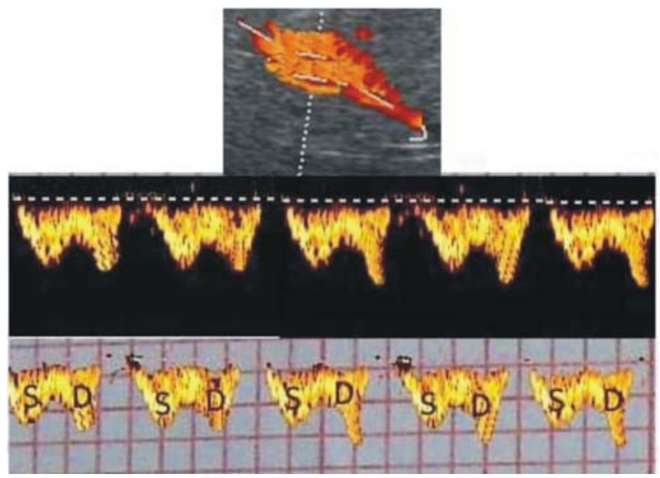
A B C

Spectra 3: Characterizations of Triphasic Doppler sonographic spectrum of middle hepatic Vein observed in Supine decubitus after 30 (A), 60 (B) and 120 (C) minutes.



A B C

Spectra 4: *Characterizations of Monophasic Doppler spectrum of middle hepatic Vein observed in Left decubitus after 30 (A), 60 (B) and 120 (C) minutes.*



A B C

Spectra 5: *Characterizations of Monophasic Doppler spectrum of middle hepatic Vein observed in Left decubitus after 30 (A), 60 (B) and 120 (C) minutes.*

lying in left and supine recumbent. It indicates that the hepatic venous flow is impeded and impedance is increased with increased duration of lying in left and supine recumbent positions.

iv) Hv Scoring

Bolondi[6] classified the hepatic vein Doppler spectrum into Hv_0, $Hv_1$and Hv_2 on characteristics of waves of the Doppler spectrum. He gives score Hv_0 to the multiphasic pattern looks like "W" with high amplitudes of "S" and "D" components, Hv_1 to biphasic waves pattern with low amplitudes of "S" and "D" and Hv_2 to monophasic pattern characterized by single wave of low amplitude. Hv_0 score is considered sign of excellent hepatic venous return. In this study, MHV Doppler spectrum achieved 100 % Hv_0 in right decubitus while < 80% in left and supine recumbent positions. It expresses that excellent hepatic venous return is in right decubitus.

Prone position was not chosen in the present study because a number of adverse effects of this position are cited by Roobobotton CA *et al.*, 2003. [13]. Morover the approach of MHV for Doppler spectrum is very difficult in prone position.

On the basis of findings of the present study, for healthy, right recumbent position is recommended while asleep.

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