Normal Inferior Vena Cava:
Caliber Changes Observed by Dynamic Ultrasound

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A review of the literature revealed conflicting reports on the physiologic variations of the caliber of the normal inferior vena cava as seen by sonography. In this study, 25 normal volunteers were examined using dynamic scanning, and the upper parts of their inferior vena cavas were observed for changes during various phases of respiration as well as Valsalva maneuver. Optimum distension and, therefore, optimum visualization of the inferior vena cava were achieved after simple breath holding or at end expiration. Inspiration and Valsalva maneuver decreased the size of this vessel in most subjects, making it difficult to see.

Respiratory variations in the sonographic appearance of the normal inferior vena cava have been described by many authors [1-7]. A review of this information yields conflicting results. Most authors feel that the normal inferior vena cava will diminish with inspiration, although the opposite has been stated as well. Disagreement is also found regarding the response of the inferior vena cava to expiration and breath holding. All have stated that Valsalva maneuver will enlarge the inferior vena cava and should therefore allow the best visualization of this structure on sonography (table 1).

In an effort to determine when the inferior vena cava is at its greatest caliber, dynamic ultrasound scanning was used. The inferior vena cavas of normal subjects were observed throughout the respiratory cycle and during Valsalva maneuver. In some volunteers simultaneous thoracic and abdominal pressure recordings were made during sonography to further substantiate the findings.

Subjects and Methods

Twenty-five volunteers were selected at random from the hospital staff. None had a history of cardiothoracic or abdominal disease. The 10 women and 15 men were aged 23-38 years. All examinations were performed on an Aloca Echo Camera SSD-202.

Primarily the retrohepatic part of the inferior vena cava was studied. The changes in diameter of the inferior vena cava were evaluated in each patient relative to his or her baseline during quiet breathing. Actual measurements in centimeters were not recorded. The upper part of the inferior vena cava was chosen because it was easily demonstrated in most subjects [8]. Constant anatomic landmarks (e.g., diaphragm, liver, portal vein) allowed about the same part of the inferior vena cava to be evaluated in each subject if changes in the relative positions of these structures with respiratory movements were taken into account.

Every patient was initially observed through several respiratory cycles just by watching the inferior vena cava on the ultrasonic monitor. Then stop-action pictures were exposed

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at end inspiration, end expiration, and while the breath was being held after a deep inspiration. Pictures were also made of the inferior vena cava with Valsalva after a deep breath. In those patients whose inferior vena cavas did not diminish with Valsalva after deep inspiration, a final picture was taken after Valsalva maneuver, after a half inspiration. Valsalva maneuver was defined as forced expiration against a closed glottis [9] and our subjects contracted abdominal and thoracic musculature. This entire process was repeated twice in each subject to insure that there was consistency to the responses of each individual.

In six volunteers, transthoracic and abdominal pressure measurements were made simultaneously with the dynamic scanning of the inferior vena cava. This was done by inserting catheters attached to pressure transducers into the esophagus and rectum. The images of the pressure curves were electronically combined with those of the inferior vena cava and viewed at the same time on a television screen, and were recorded on videotape. This was done on a smaller group of subjects to assure that our stop-action pictures which depended on visual observation of the subjects corresponded to the proper phase of respiration. The pressure readings were not measured but merely referred to a resting baseline in each subject.

TABLE 1: **Variations in Sonographic Appearance of Normal Inferior Vena Cava**

Reference	Response of Vena Cava to:			
	Inspiration	Expiration	Valsalva	Holding Breath
Bartrum and Crow [1]	0	0	+	−
Goldberg et al. [2]	−	−	+	0
Hassani [3]	+	+	+	0
Holm et al. [4]	−	0	+	0
Leopold [5]	0	0	+	+
Taylor [6]	−	0	0	0
Weill and Maurat [7]	+ −	+ −	0	+

Note.— − = Decreased diameter of inferior vena cava; + = increased diameter of inferior vena cava; 0 = not discussed by author.

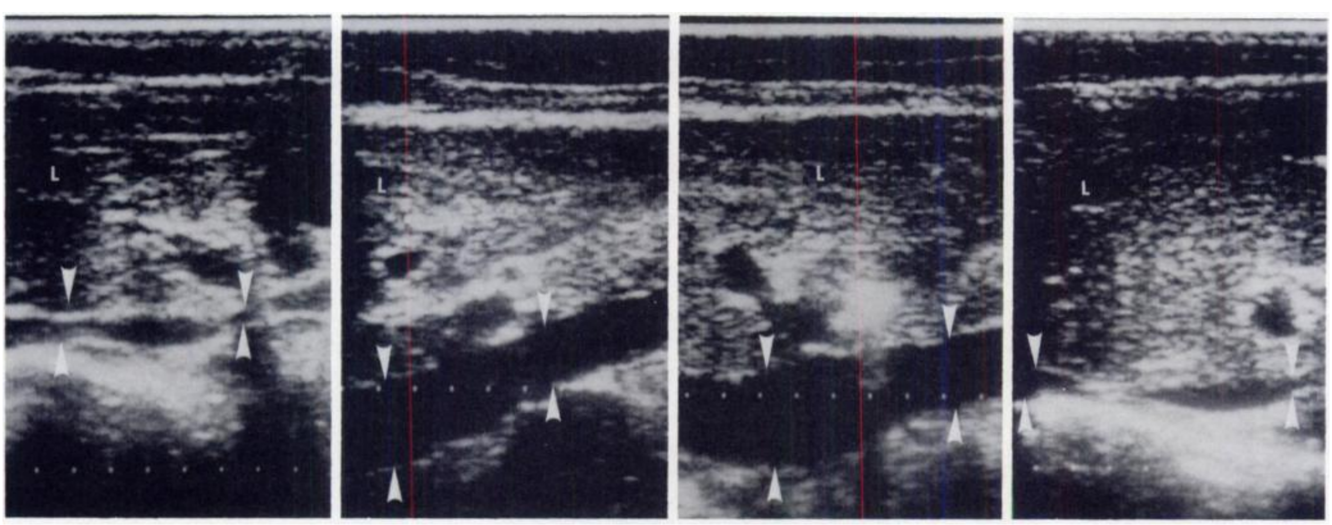
TABLE 2: **Normal Inferior Vena Cava: Caliber Changes Observed by Ultrasound**

Phase of Respiration	Caliber of Inferior Vena Cava No. Patients (n = 25)		
	Increased	Decreased	No Change
Inspiration	0	25	0
End expiration	25	0	0
Breath held after full inspiration	25	0	0
Valsalva maneuver:			
After full inspiration:			
Men (n = 15)	0	15	0
Women (n = 10)	0	5	5
Subtotal	0	20	5
After half inspiration	0	25	0

Results

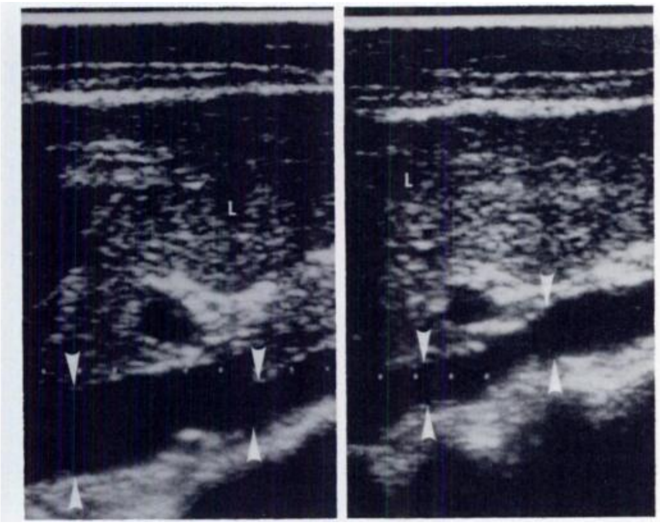
Our findings are summarized in table 2. During inspiration, the inferior vena cava decreased in caliber (anteroposterior position) in every patient (fig. 1A). The decrease was quite varied and depended on the individual patient. Many showed almost complete collapse of the vessel. In addition, the way in which inspiration was performed led to marked variation; sniffing or rapid inspiration caused a quick and marked decrease of the vessel size.

Expiration led to expansion of the inferior vena cava in all volunteers (fig. 1B). Suspending respiration after maximum inspiration also caused enlargement of the inferior vena cava in all subjects (fig. 1C), often to the greatest caliber observed. However, this was not constant and some patients showed maximum dilatation at end expiration. These differences were seldom striking.



A B C D

Fig. 1.—One patient. **A**, Longitudinal sonogram during inspiration. Inferior vena cava *(arrowheads)*. L = liver. **B**, Longitudinal sonogram at end expiration. Distended inferior vena cava *(arrowheads)*. **C**, Longitudinal sonogram with breath held after deep inspiration. Vena cava *(arrowheads)* in most distended state. **D**, Longitudinal sonogram during Valsalva maneuver. Typical response with inferior vena cava *(arrowheads)* in almost completely collapsed state.



A B

Fig. 2.—**A**, Longitudinal sonogram in woman. Inferior vena cava *(arrowheads)* in distended state after Valsalva maneuver, after full inspiration. **B**, Longitudinal sonogram with Valsalva maneuver after half inspiration. Inferior vena cava *(arrowheads)* decreased in size.

Two different responses were noted after Valsalva. In most subjects (15 of 15 men and 5 of 10 women) the inferior vena cava diminished (fig. 1D). The collapse was gradual, but often so marked that the inferior vena cava was reduced to a thin line. The subjects were asked to hold their breath for a short time after inspiration to allow reexpansion of the inferior vena cava before beginning the Valsalva. In this way it was certain our findings were not merely the result of inspiratory collapse being maintained. Five of the 10 women showed no decrease of the inferior vena cava with Valsalva. This latter response was never observed in a man, yet was seen in 50% of the women.

In the women whose inferior vena cavas did not diminish with Valsalva after a deep breath, a repeat Valsalva was performed after half inspiration. With this, all the women had decrease of the inferior vena cava (fig. 2).

Discussion

Optimum visualization of the inferior vena cava is important as a vascular sonographic landmark within the abdomen because of its close anatomic relationship with many other structures [10]. Aside from its value as a sonographic landmark, it is affected by several pathologic processes; such as right-sided heart failure [7], extension of tumor into its lumen [11], or displacement by masses in adjacent areas [12].

We have evaluated the anteroposterior diameter of the normal inferior vena cava in supine subjects during respiration with dynamic scanning. Changes in caliber are attributed to variations in blood flowing through the inferior vena cava in accordance with the respiratory and cardiac cycles [6]. In inspiration, blood is literally sucked into the chest by negative pressure, causing the vessel to collapse. Flow is high but pressure is reduced. During expiration and breath holding, these are reversed, causing ballooning of the inferior vena cava. With Valsalva maneuver, another factor seems to be at work: abdominal pressure. It is stated that even with persistent Valsalva, blood will flow into the chest as venous pressure rises [9]. In most people, the abdominal pressure is apparently sufficient to force blood out of the inferior vena cava and into the thorax. This collapse of the inferior vena cava with Valsalva is the opposite of what occurs in the jugular veins, where distension is the rule. The neck veins are, however, superficial and are not subjected to the high pressures generated in the abdomen.

It is not certain why some of the women were unable to collapse the inferior vena cava after Valsalva maneuver, after deep inspiration. They were all able to do so, however, if Valsalva was performed after only half a breath was taken. Body habitus seemed to play no role. Possibly it had to do with the way in which the abdominal muscles were contracted. One must always consider that regardless of how explicit directions are about performance of the Valsalva maneuver, there will be wide variation in the actual response. Some people will exert more force, others may or may not contract thoracic or abdominal muscles in the same manner. These problems do make a "standard" Valsalva maneuver difficult to achieve in all patients.

In our subjects, the best way to achieve maximum distension and therefore maximum visualization of the inferior vena cava was simply by holding the breath after inspiration. In some patients, maximum distension will occur at end expiration; however, the difference in distension in these two states was often small. More importantly, the vena cava will be small in all subjects during inspiration and in 80% during Valsalva. Therefore, we do not recommend scanning at these times if optimal visualization of the inferior vena cava is desired.

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