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Continuous Flow from Inferior Vena Cava into the Right Atrium Predicts Normal Central Venous Pressure

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ABSTRACT

Background: Respiratory variation in Inferior Vena Cava (IVC) diameter is validated for estimation of Right Atrial Pressure (RAP) by echocardiogram. Although IVC flow into the Right Atrium (RA) can be appreciated in parasternal views, it is not routinely evaluated. We have observed an uninterrupted continuous wave (CW) Doppler flow signal from the IVC during sampling of the Tricuspid Regurgitation (TR) jet.
Objectives: The present study aimed to show that this uninterrupted signal was a surrogate for normal/low RAP.
Methods: This retrospective study was conducted on 500 consecutive echocardiograms and sought continuous flow from IVC into the RA in the subcostal view. RAP was then measured using IVC dynamics like size and respirophasic variation. Analysis was performed by comparison of the percentages.
Results: Out of the 500 echocardiograms, 60 (12%) had Doppler evidence of continuous IVC flow into the RA. Among these 60 echocardiograms, RAP was calculated in 57 patients. Accordingly, RAP was 3 mmHg in 54 (95%) and 8 mmHg in 3 (5%) patients. RAP could not be estimated in three patients due to lack of visualization of IVC. Furthermore, RA volume index was normal in 51 patients (85%), but increased in 9 ones (15%). Right Ventricular (RV) function was also normal in 48 (96%) and low in 2 (4%) patients.
Conclusion: The study findings supported the hypothesis that continuous flow from IVC into RA on CW Doppler is a surrogate for IVC dynamics in normal/low RAP and is particularly useful when subcostal views are suboptimal or inaccessible due to poor acoustic windows.

1. Background

Right Atrial Pressure (RAP) is the reflection of Central Venous Pressure (CVP) provided that caval flow is unobstructed (1). Estimation of CVP is important for determination of hemodynamic status (e.g. calculation of peak pulmonary artery pressure from Tricuspid Regurgitation (TR) jet velocity) and has prognostic importance in heart failure (2). Although several methods have been described in the literature to measure CVP, the gold standard is invasive monitoring using central venous catheters. However, due to its invasive nature and associated complications, it is not suited for routine clinical application (3-5). In clinical practice, CVP assessment is best performed by echocardiography. The American Society of Echocardiography (ASE) in conjunction with the European Association of Echocardiography (EAE) published a guideline for estimation of RAP on the basis of Inferior Vena Cava Diameter (IVCD) and its inspiratory collapse (6). Other parameters, such as hepatic vein Doppler interrogation, have been proposed and validated in clinical trials, but have not gained popularity in clinical practice.

In this article, we suggest an observation, which when present may aid in accurate estimation of RAP. During routine echocardiography, we have often observed an uninterrupted continuous flow signal from the IVC during Continuous Wave Doppler (CWD) sampling of the TR jet in the Parasternal Short Axis (PSAX) and Right Ventricular Inflow (RVI) views (Figures 1 and 2).

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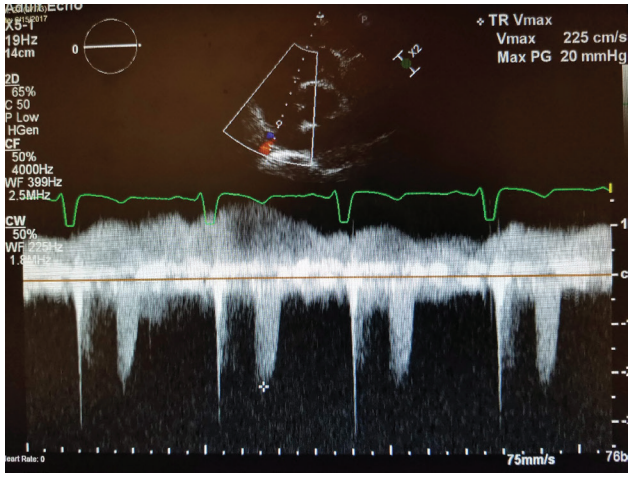

Figure 1. Continuous Flow from the Inferior Vena Cava into the Right Atrium Seen in the Right Ventricular Inflow View in the Parasternal Window

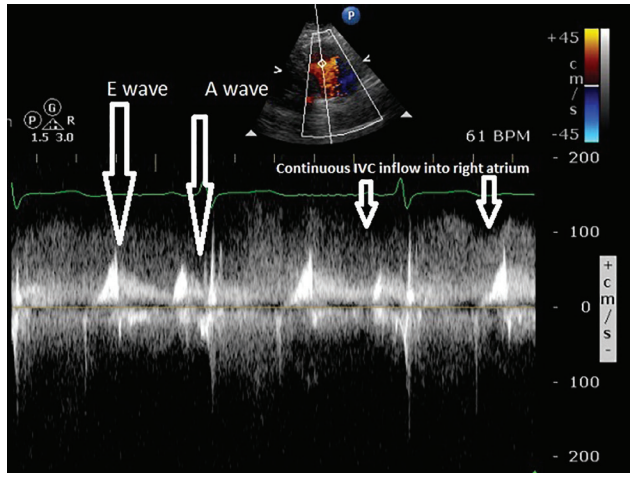

Figure 2. Continuous Flow from the Inferior Vena Cava into the Right Atrium Compared to E Wave and A Wave in the Parasternal View

2. Objectives

The present study aims to show that the CWD signal from the IVC into the Right Atrium (RA) is a surrogate for normal/low RAP.

3. Methods

Study population and design: This retrospective study was conducted on 500 consecutive Trans-Thoracic Echocardiograms (TTE) performed in our echocardiography laboratory at Einstein Medical Center in Philadelphia, USA in September 2013. The study sought continuous flow from IVC into the RA at the IVC-RA junction on the subcostal view. The echocardiograms performed on patients with complex congenital heart disease who had undergone surgical redirection of caval blood flow were excluded from the study. The echocardiograms with evidence of mechanical obstruction of caval blood flow, such as IVC filters, massive ascites, mediastinal mass, and pregnancy, were excluded, as well. The remaining TTEs were reviewed regardless of the medical history and patients with continuous flow from the IVC into the RA were selected. The following parameters were then studied in this subgroup of patients: RA pressure derived based on the current ASE guidelines (7) using IVCD and dynamics, RA volume using single plane area length at end-systole in the apical four-chamber view, Right Ventricular (RV) systolic function using Tricuspid Annular Plane Systolic Excursion (TAPSE), Doppler dynamics of the hepatic vein, pulmonary artery pressure by TR jet peak velocity + RA pressure, and presence and severity of TR based on ASE guidelines (8). Tricuspid inflow by Pulse Wave Doppler (PWD) was analyzed for peak E and peak A velocities and E/A ratio. The PWD measurements were performed during breath hold at end-expiration and an average of three beats was used. Volumes were indexed for body surface area.

Data and statistical analysis: An offline computer-assisted analysis system (Syngo Dynamics, Siemens Healthcare Inc., USA) was used to review the images. All analyses were conducted using SPSS® 15 for Windows® (SPSS Corp, Chicago, IL, USA) and Microsoft excel 2010 (Microsoft®Corp). Analyses were mainly done by comparison of the percentages.

4. Results

Of the 500 TTEs reviewed, CWD signal indicating continuous flow from the IVC into the RA was noted in 60 patients (12%). Demographic characteristics of the patients can be found in Table 1. In the remaining 440 patients, the sampling of TR jet did not reveal continuous flow from IVC. Out of the 60 patients with this signal, RA pressure was calculated in 57 patients based on the current ASE guidelines, which was ≤ 3 mmHg in 54 (94%) and 8 mmHg in 3 (6%) patients. In 3 patients, the RA pressure could not be estimated due to inability to visualize IVC. Average IVCD was 1.4 cm (range: 0.6-2.3 cm). Three out of four patients with reported RA pressure of 6-10 mmHg had IVCD > 2.1 cm. Furthermore, RA volume index was normal (22 ± 7 mL/m2 in males and 21 ± 6 mL/m2 in females) in 51 (85%) and increased in 9 (15%) patients. Average RA volume index was 19 ± 7 mL/m2. In the 3 patients in whom the IVC could not be visualized, the RA volume index and RV systolic function were normal.

RV systolic function was calculated in 50 patients, 48 ones of whom (96%) had normal RV function (TAPSE > 1.8). Indeed, average values for tricuspid E wave, A wave, and E/A ratio were 0.7, 0.6, and 1.1, respectively. Pulmonary Arterial Pressure (PAP) was also calculated in 40 patients (66%) either due to absence of TR jet or inability to measure it amongst the rest. Average PAP was 28 ± 7 mmHg. Moreover, TR was either absent or trace in 55 patients (96%) and mild in the remaining.

Left Ventricular (LV) diastolic function was normal for age in 53 patients and showed pseudo normalization of LV filling pattern in four ones. Diastolic function could not be assessed in three patients. Furthermore, the hepatic vein flow was systolic dominant in 42, diastolic dominant in two, and co-dominant in two patients. In the remaining 14 patients, the hepatic vein flow could not be assessed (Table 2).

Table 1. Demographic Characteristics of the Subjects

Parameter	Values
Age (years)	55 ± 16.5
Gender	
Male	30 (50)
Female	30 (50)
BMI (kg/m2)	29.5 ± 9.6
BSA (m2)	1.91 ± 0.31
Blood pressure (mmHg)	
Systolic	128 ± 19
Diastolic	70 ± 11
Heart rate	80 ± 16

Abbreviations: BMI, body mass index; BSA, body surface area.
Values are expressed as N (%) or mean ± SD.

Table 2. Echocardiographic Variables

Parameters	Values
RA volume index (cm^3/m)	19 ± 8
Peak Tricuspid E wave (cm)	0.7 ± 0.2
Peak Tricuspid A wave (cm)	0.6 ± 0.2
TAPSE (cm)	2.4 ± 0.4
PAP (mmHg)	26 ± 7
IVCD (cm)	1.4 ± 0.4
LV diastolic function (n = 52)	
Normal	23 (44)
Impaired relaxation	28 (53)
Moderately decreased	1 (2)
Tricuspid regurgitation	
None or Trace	55 (92)
Mild	5 (8)
Right atrial pressure (mmHg) (n = 57)	
3	54 (95)
8	3 (5)
15	0

Abbreviations: RA, right atrium; TAPSE, tricuspid annular plane systolic excursion; PAP, pulmonary arterial pressure; IVCD, inferior vena cava diameter; LV, left ventricle.
Values are expressed as N(%) or Mean ± SD

5. Discussion

The most important finding of the present study was that continuous and uninterrupted flow from IVC into the RA was a surrogate for low/normal RAP and identified patients with low/RAP with a high degree of confidence. This observation could be used in conjunction with other established methods of CVP assessment. This is important as RAP assessment by echocardiography is an indirect measurement and multiple factors must be taken into account to provide its most accurate estimation. Other parameters, such as acceleration rate of RV early fillings (9), RA volume index (10), and RV regional isovolumic relaxation time (11), have been proposed as alternatives for measuring RAP. However, they have seldom been reported in clinical practice due to a degree of complexity in their assessment. The current observation, on the other hand, was practical, simple, and present in 60 (12%) out of the 500 reviewed TTEs. While interrogating the tricuspid valve with the CWD in these 60 patients, a continuous signal was noted above the baseline and reflected the inflow from the IVC into the RA. Based on the predetermined selection criteria, only patients with continuous CWD signal were included, while those in whom the inflow from the IVC was visually interpreted to be continuous but who lacked the continuous CWD signal were excluded. We believe that RAP must also be low or normal in this subset of patients, and absence of continuous CWD signal could be a result of non-alignment of the CWD with the IVC inflow. Further prospective studies are needed to prove this theory.

The current study findings were relevant to the clinical practice and reporting of TTE results as this observation was noted in the images acquired as per the current image acquisition protocol (PSAX and RVI views) and did not require additional ultrasound views, most importantly subcostal views. Subcostal imaging can be occasionally suboptimal and limiting due to obesity, ascites, hepatic tumors, other abdominal malignancies either with or without hepatic involvement, advanced pregnancy, or simply due to patient's non-compliance.

Overall, the study findings supported our hypothesis that continuous flow from IVC into RA encountered during precordial examination of TR signal on CWD is a surrogate for IVC dynamics in normal/low RAP and is particularly useful when subcostal views are suboptimal or inaccessible.

5.1. Limitations

One of the limitations of the present study was its retrospective design. Thus, further prospective studies are needed to validate the findings. Another study limitation was not investigating the patients who had normal RA pressure based on the current guidelines but did not have continuous CWD signal in the precordial views.

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Authors' Contribution

Rupesh Ranjan and Nelson B. Schiller developed the original idea and the protocol and abstracted and analyzed the data. Esra Gucuk Ipek and Hesam Mostafavi Toroghi contributed to the development of the protocol, abstracted and analyzed the data, and prepared the manuscript.

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