

Observational Study

Alternatives to Apical View in Predicting Fluid Responsiveness by Transthoracic Echocardiography: An Observational Study

Haimeur Yassine*, Aberouch Larbi, Tadili Jawad, Faroudy Mamoun and El Kettani Ali

Ibn Sina University Hospital, Rabat, Morocco

Abstract

Introduction: Flow analysis in the apical view of transthoracic echocardiography is validated to assess fluid responsiveness at the bedside. Still, it is not always reachable, especially in mechanically ventilated patients and during surgery. We compared it to supra-sternal and sub-xiphoid views to evaluate their validity in assessing fluid responsiveness in critically ill patients.

Method: A cross-sectional prospective monocentric pilot study of three months duration has been led in the critical care unit for surgical emergencies of Ibn Sina University Hospital of Rabat (Morocco). We used the time-velocity index (VTI) and peak velocity variation (ΔV_{peak}) values correlation between the three acoustic windows as the main judgment criteria. Measurement of data was made in the Left Ventricle Outflow Tract (LVOT) in the 5-chamber apical view, Descending Thoracic Aorta (DTA) in the supra-sternal view, and Right Ventricle Outflow Tract (RVOT) in the sub-xiphoid view.

Results: There were 14 adult patients involved in the study, and the data presented are preliminary results. There was no significant difference in VTI and ΔV_{peak} values between the three acoustic windows at each time of the study protocol, with a very high correlation for initial VTI value between 5-chamber apical view and supra-sternal view ($r = 0.96, p < 0.001$), and sub-xiphoid view ($r = 0.86, p < 0.001$). A very high correlation of initial ΔV_{peak} value was also observed between the 5-chamber apical view and supra-sternal view ($\rho = 0.89, p < 0.001$) and sub-xiphoid view ($\rho = 0.79, p < 0.001$).

Discussion: Supra-sternal and sub-xiphoid views showed high potential to predict fluid responsiveness, but further data are needed to validate their use for this purpose in ICU and in operating room.

Introduction

Fluid resuscitation aims to improve preload, Cardiac Output (CO), and Oxygen delivery (DO_2). In critically ill patients, it is crucial to predict fluid responsiveness, considering the risk of organ dysfunction induced by both hypovolemia and fluid overload, essentially in the perioperative period, sepsis, and heart failure context [1-3]. Dynamic assessment of CO is recommended to predict fluid responsiveness, except in cases of obvious hypovolemia [4]. CO and its surrogates compared measurements before and after preload changing allow to titrate intravascular volume expansion at the bedside. A significant Stroke Volume Variation (SVV) for a lower preload variation predicts favorable fluid responsiveness [5]. One

of the most used CO surrogates in critical care is the aortic Velocity-Time Integral (VTI), measured by Transthoracic Echocardiography (TTE) at the apical 5-chamber view, using Pulsed Wave Doppler (PWD) in the Left Ventricle Outflow Tract (LVOT) [6]. Although its use for volume expansion guidance is validated, its accuracy is highly operator-dependent, and its access may be difficult, with the limitation of artifacts during mechanical ventilation [7]. At the same time, other acoustic windows are available but are still not validated in predicting fluid responsiveness.

Our study compares flow analysis in LVOT by PWD at the apical 5-chamber view, to flow analysis in Descending Thoracic Aorta (DTA) at the supra-sternal window, and in

More Information

*Address for Correspondences:

Haimeur Yassine, Ibn Sina University Hospital, Rabat, Morocco,
Email: yassine.haimeur1@gmail.com

 <https://orcid.org/0000-0003-0329-1416>

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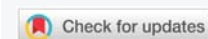
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Keywords: Fluid responsiveness; Supra-sternal view; Sub-xiphoid view; Velocity-time integral; Peak velocity variation





Right Ventricle Outflow Tract (RVOT) at the sub-xiphoid window in critically ill adult patients, in order to evaluate their validity and reliability to predict fluid responsiveness.

Methods

Setting

We led a cross-sectional analytical and prospective single-center pilot study in the critical care unit for surgical emergencies in Ibn Sina University Hospital Center of Rabat (Morocco) from July to September 2022.

Participants

We included all patients admitted into the critical care unit for surgical emergencies aged up to 16 years with a reachable apical 5-chamber, sub-xiphoid, and suprasternal views. Exclusion criteria were arrhythmias, clinical evidence of fluid overload, heart failure with elevated Left Ventricle Filling Pressure (LVFP), right ventricle dysfunction, significant aortic valve disease, congenital heart disease, and low pulmonary compliance ($< 30 \text{ ml/cmH}_2\text{O}$) in mechanically ventilated patients.

Sample size

We calculated our sample size by estimation for cross-sectional studies using continuous outcome, and for a one-sided 5% significance test ($\alpha = 0.05$) when comparing VTI between acoustic windows. We also considered a type II error rate of 5% ($\beta = 0.05$) to optimize study power. The minimal sample size suggested was 26 patients, for a mean VTI value in LVOT of 14 cm and an estimated mean VTI value in DTA of 18 cm, according to data collected from healthy volunteers beforehand.

Data and measurements

For each included patient, we first collected demographic data, including age, sex, weight, ASA score, SOFA score, APACHE IV score, and the diagnostic of entry.

We recorded clinical data regarding ventilation mode (Assist-control ventilation, Pressure support ventilation, or spontaneous breathing) with setup parameters, including tidal volume (V_T) expressed in ml.kg^{-1} of Ideal Body Weight (IBW), positive end-expiratory pressure (PEEP) and pressure support level, both expressed in cmH_2O . We also recorded data regarding hemodynamic status, including systolic arterial pressure (SAP) and Mean Arterial Pressure (MAP), both expressed in mmHg, and the infusion rate of catecholamines (expressed in $\mu\text{g.kg}^{-1}.\text{min}^{-1}$) when used.

At each time point of the study protocol, we measured VTI and Peak Velocity variation (ΔV_{peak}) at the apical 5-chamber, suprasternal, and sub-xiphoid windows using PWD with a low-frequency phased-array ultrasound probe of a Sonosite M-Turbo Fujifilm® engine.

All data was recorded on an individual operating sheet with an assigned anonymous number and then reported on Jamovi software for analysis.

Study design

We used as main judgment criteria the correlation of VTI and ΔV_{peak} values between LVOT at the apical 5-chamber apical view—considered as a reference technique—RVOT at the sub-xiphoid view and DTA at the suprasternal view to evaluate the validity and reliability of those alternative acoustic windows to predict fluid responsiveness.

We evaluated fluid responsiveness using normal saline infusion related modifications of Venous Return (VR). The first step of the study protocol was the initial time of data collection when no intervention was performed. In the second step, we performed a mini fluid challenge by infusing 100 ml of normal saline 0.9% via central or peripheral venous access in 2 minutes, before collecting data of interest. In the third step, we performed a fluid challenge by infusing 200 ml of normal saline 0.9% via central or peripheral venous access in 10 minutes before collecting the same data. In patients with clinical evidence of hypovolemia, we skipped the second step and performed a fluid resuscitation by infusing 10 ml.kg^{-1} of normal saline 0.9% before collecting the data of interest.

We evaluated the facility of access for each acoustic window and defined difficult access as the need for 2 minutes or more for a nonexpert echocardiographer to obtain a target picture on the screen.

No adjustments in ventilation setup parameters or catecholamines infusion rate were made during the study protocol.

Statistical methods

Qualitative data were expressed in counts and percentages. Quantitative data were expressed as mean standard deviation when their distribution was normal and as median and interquartile range when it was asymmetric. The normal distribution of quantitative variables was verified by the Shapiro-Wilk test.

We compared quantitative variables between independent groups by Welch's test (when distribution was normal), Mann-Whitney test (when distribution was asymmetric) and the one-way analysis of variances (ANOVA). The comparison of proportions was made using Fisher's exact test. We accepted for all comparisons a risk of type I error α of 0.05 to express a statistically significant difference. The correlation of VTI and ΔV_{peak} values between acoustic windows was studied by Pearson's r and Spearman's ρ correlation coefficient, respectively.

We identified fluid responders using clinical evidence and/or a VTI variation threshold of 12% in LVOT after performing a fluid challenge. The fluid responders' group was compared

to non-responders using the Student's t-test for numeric variables. We calculated cut-offs for VTI and ΔV_{peak} variations in both DTA and RVOT using the ROC test and calculated for their respective acoustic windows sensibility, specificity, Positive Predictive Value (PPV), and negative predictive value (NPV), adding Area Under the Curve (AUC). We accepted for all comparisons a risk of type I error α of 0.05 to express a statistically significant difference.

Results

Sample description

During our study period, 73 patients have been screened and 44 patients met the inclusion criteria. Among them, 27 patients were excluded for not offering exploitable target pictures in at least one of the three acoustic windows. There were 3 patients with metabolic condition not allowing normal saline infusion. In sum, only 14 patients have been included in the study, which allowed us to provide preliminary results only.

The studied sample included 9 men (64.2%) and 5 women (35.8%), with a median age of 39.5[25 - 55] years. Half of the sample was admitted into critical care for severe traumatism, whereas 5(42.9%) patients were admitted for post-operative care of emergency laparotomy and only one patient for post-operative care of scheduled major surgery. There were 9 (64.2%) patients without any prior medical condition. Meanwhile, 5(35.8%) patients were classed ASA II for a prior history of diabetes mellitus, COPD, or smoking. The mean APACHE IV severity score was 27.1 ± 7.4 , whereas the median SOFA score was 6 [4-8]. There were 9 patients under norepinephrine with a median infusion rate of 0.35 [0.16 - 0.56] $\mu\text{g.kg}^{-1}.\text{min}^{-1}$, and 11 patients under mechanical ventilation with a mean V_T of $7.1 \pm 1.1 \text{ ml.kg}^{-1}$ of IBW and a mean PEEP of $7.8 \pm 1.1 \text{ cmH}_2\text{O}$. All demographic data are provided in Table 1 and Figure 1.

Flow analysis recordings

Target image acquisition was difficult in 5(35.8%) patients when performing a 5-chamber apical view, in 1(7.1%) patient

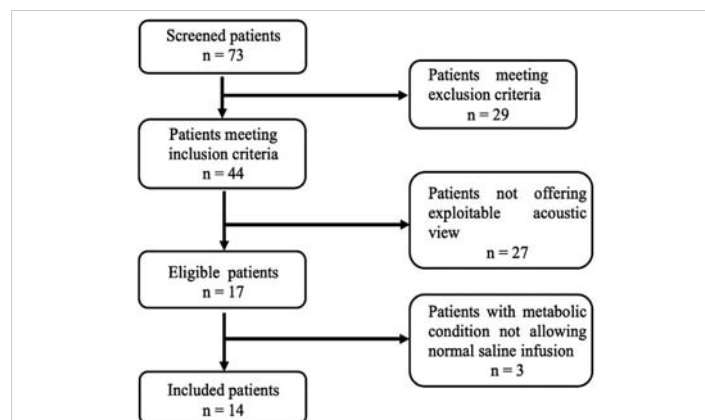


Figure 1: Flow Diagram of patient inclusion.

Table 1: Description of population.

Characteristics (n = 14)	
Age (years) ^a	39.525 - 55]
Gender	
Male ^c	9(64.2 %)
Female ^c	5(35.8 %)
Weight (kg) ^b	79.9 12.4
Diagnostic of entry	
Traumatism ^c	7(50%)
Emergency laparotomy ^c	6(42.9%)
Post-operative care ^c	1(7.1%)
ASA classification	
ASA I ^c	9(64.2%)
ASA II ^c	5(35.8%)
SOFA score ^b	6[4 - 8]
APACHE IV score ^a	27.1 7.4
Norepinephrine infusion ^c	9(64.2%)
Infusion rate ($\mu\text{g.kg}^{-1}.\text{min}^{-1}$) ^a	0.35[0.16 - 0.56]
Mechanical ventilation ^c	11(78.6%)
Tidal volume (ml.kg^{-1}) ^b	7.1 ± 1.1
PEEP (cmH_2O) ^b	7.8 ± 1.1

*Ideal body weight
a: Median [Q1 - Q3]
b: Mean $\pm$ SD
c: count (percentage)

when performing a supra-sternal view, and in 4(28.6%) patients when performing a sub-xiphoid view. No statistically significant difference in acquisition difficulty was observed between the three acoustic windows ($p = 0.273$).

There were also no statistically significant differences in both VTI and ΔV_{peak} values between the three acoustic windows at each time of the study protocol. Mean values of VTI and median values of ΔV_{peak} are presented in Table 2, with respective p -values when comparing 5-chamber apical view flow measurements to supra-sternal and sub-xiphoid views measurements.

We observed no statistically significant difference of VTI variation after a mini fluid challenge between 5-chamber apical, supra-sternal, and sub-xiphoid views, with respective median variations of 5[3 - 6.75]% vs. 5[2 - 7]% vs. 4[2.5 - 6.5]% ($p = 0.845$). In contrast, VTI variation after fluid challenge was significantly different between the three acoustic windows ($p = 0.016$). Post-hoc analysis showed a statistically significant difference between the 5-chamber apical view and supra-sternal view (respective median variations of 13.55 - 17.5% vs. 5 2 - 7.75%; $p = 0.027$) and sub-xiphoid view (median variation of 6[1 - 8]%; $p = 0.049$). No statistically significant difference in VTI variation after the fluid challenge was observed between the supra-sternal and sub-xiphoid view ($p = 0.986$).

Data analysis and comparisons

VTI variations under norepinephrine infusion were significantly higher than VTI variations when no norepinephrine was infused in all acoustic windows. Median VTI variation after mini fluid challenge under norepinephrine

Table 2: Flow measurements.

	5-chamber apical view	Supra-sternal view	Sub-xiphoid view	p - value
Initial recording				
VTI (cm) ^a	16.5 ± 3.05	18.1 ± 2.45	17.0 ± 2.26	0.297
ΔVpeak (%) ^b	9[6 - 13.3]	5[3.25 - 11.5]	6.5[5.25 - 11.7]	0.580
Mini fluid challenge				
VTI (cm) ^a	17.4 ± 2.76	18.9 ± 2.25	17.8 ± 1.98	0.264
ΔVpeak (%) ^b	5.5[4 - 12]	5.5[4 - 9.5]	6[3 - 8.5]	0.760
Fluid challenge				
VTI (cm) ^a	18.6 ± 2.67	19.8 ± 2.29	18.8 ± 1.86	0.351
ΔVpeak (%) ^b	5.5[3 - 7]	4[2.25 - 7.25]	4.5[3 - 6]	0.837

a: Mean ± SD
b: Median [Q1 - Q3]

was 6[5 - 7]% vs. 2[2 - 3]% when no vasopressor was administered ($p < 0.001$), while median VTI variation after fluid challenge was 8[7 - 13.5]% vs. 2[1 - 4]% respectively ($p < 0.001$). No statistically significant difference in VTI variations was seen when comparing according to ventilatory mode. Detailed comparison data are provided in Tables 3,4.

There was no statistically significant difference in initial VTI value between ventilated and non-ventilated patients in 5-chamber apical view (16.4 ± 3.4 cm vs. 17 ± 1.5 cm respectively; $p = 0.628$), in supra-sternal view (18 ± 2.7 cm vs. 18.4 ± 1.5 cm respectively; $p = 0.709$) and in sub-xiphoid view (17 ± 2.5 cm vs. 16.9 ± 1.5 cm respectively; $p = 0.950$). No significant difference of VTI values was neither observed after mini fluid challenge between the two groups (17.4 ± 3.1 cm vs. 17.4 ± 1.3 cm respectively in LVOT, $p = 0.978$; 18.9 ± 2.5 cm vs. 18.8 ± 1.2 cm respectively in DTA, $p = 0.926$; 17.9 ± 2.2 cm vs. 17.5 ± 1.3 cm respectively in RVOT, $p = 0.689$), nor after fluid challenge (18.8 ± 2.9 cm vs. 17.4 ± 1.4 cm respectively in LVOT, $p = 0.505$; 20 ± 2.5 cm vs. 19 ± 1.1 cm respectively in DTA, $p = 0.331$; 19.1 ± 1.9 cm vs. 17.8 ± 1.8 cm respectively in RVOT, $p = 0.221$).

Recordings correlation between acoustic views

Initial VTI values in the 5-chamber apical view were strongly correlated with measurements recorded in the supra-sternal view ($r = 0.963$; $p < 0.001$) and in the sub-xiphoid view ($r = 0.864$; $p < 0.001$). Initial ΔVpeak values were also strongly correlated between 5-chamber apical view and supra-sternal view ($\rho = 0.893$; $p < 0.001$) and sub-xiphoid view ($\rho = 0.788$; $p < 0.001$). No significant correlation was observed between VTI and ΔVpeak values and arterial blood pressure values. After the mini fluid challenge, the correlation of VTI and ΔVpeak values was strong between the three acoustic windows. Same results were observed after a fluid challenge. Correlation data are presented in Table 5 and Figure 2.

Cut-offs for fluid responsiveness

VTI variation cut-off after a fluid challenge using flow analysis in DTA to determine fluid responders was 7%, with a sensitivity of 75% and a specificity of 83.3%, a PPV of 85.7%, and an NPV of 71.4%, for a Youden's index of 0.583 and an

Table 3: VTI variation compared according to norepinephrine infusion.

	VTI variations		
	Norepinephrine	No vasopressor	p - value
5-chamber apical view			
Mini fluid challenge ^a	6[6 - 9]	3[2 - 3]	0.009
Fluid challenge ^a	16[14 - 18]	5[4 - 5]	0.023
Supra-sternal view			
Mini fluid challenge ^a	7[5 - 7]	2[2 - 2]	0.008
Fluid challenge ^a	7[7 - 8]	1[0 - 2]	0.007
Sub-xiphoid view			
Mini fluid challenge ^a	5[4 - 7]	2[2 - 4]	0.024
Fluid challenge ^a	8[6 - 11]	1[1 - 1]	0.015

a: VTI variation in percentage of initial value (%).

Table 4: VTI variation compared according to ventilatory mode.

	VTI variations		
	Controlled ventilation	Spontaneous breathing	p - value
5-chamber apical view			
Mini fluid challenge ^a	6[4 - 8]	3[2.5 - 3]	0.059
Fluid challenge ^a	15[9 - 18]	5[4.5 - 6]	0.160
Supra-sternal view			
Mini fluid challenge ^a	6[3.5 - 7]	2[1 - 2.5]	0.068
Fluid challenge ^a	7[2.5 - 8]	1[0.5 - 2]	0.099
Sub-xiphoid view			
Mini fluid challenge ^a	5[3 - 7]	4[3 - 4]	0.298
Fluid challenge ^a	8[3.5 - 9.5]	1[1 - 2]	0.208

a: VTI variation in percentage of initial value (%).

Table 5: Correlation coefficients of flow measurements with 5-chamber apical view data.

	Supra-sternal view		Sub-xiphoid view	
	Correlation coefficient	p - value	Correlation coefficient	p - value
Initial recording				
VTI ^a	0.963	< 0.001	0.864	< 0.001
ΔVpeak ^b	0.893	< 0.001	0.788	< 0.001
Mini Fluid Challenge				
VTI ^a	0.946	< 0.001	0.847	< 0.001
ΔVpeak ^b	0.801	< 0.001	0.878	< 0.001
Fluid Challenge				
VTI ^a	0.925	< 0.001	0.778	< 0.001
ΔVpeak ^b	0.805	< 0.001	0.835	< 0.001

a: Pearson's r
b: Spearman's rho

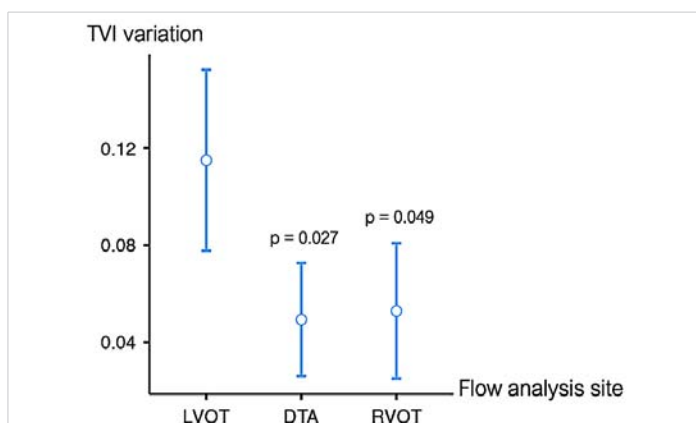


Figure 2: VTI variation after fluid challenge.

AUC of 0.792. The post-test probability of fluid responsiveness was 85.7% for a Positive Likelihood Ratio (PLR) of 4.5, and the post-test probability of non-responsiveness was 71% for a Negative Likelihood Ratio (NLR) of 0.3. Flow analysis in RVOT showed a VTI variation cut-off of 6%, with a sensitivity of 87.5% and a specificity of 83.3%, a PPV of 87.5% and a NPV of 83.3%, for a Youden's index of 0.708 and an AUC of 0.781. The post-test probability of fluid responsiveness was 87.5% for a PLR of 5.25, and the post-test probability of non-responsiveness was 83.3% for an NLR of 0.15 (Figure 3).

Regarding initial ΔV_{peak} , the cut-off to discriminate fluid-responsive patients from non-responsive patients in DTA was 5%, with a sensitivity of 100%, a specificity of 83.3%, a PPV of 88.9%, and an NPV of 100%, for a Youden's index of 0.833 and an AUC of 0.938. The post-test probability of fluid responsiveness was 88.9% for a PLR of 6, and the post-test probability of non-responsiveness was 100% for an NLR of 0.002. Cut-off in RVOT was 8% with a sensitivity of 75%, a specificity of 100%, a PPV of 100%, and an NPV of 75% for a Youden's index of 0.750 and an AUC of 0.885. The post-test probability of fluid responsiveness was 100% as PLR was up to 15, and the post-test probability of non-responsiveness was 75% as NLR was 0.25 (Figure 4).

Discussion

Main results

The main goal of our study was to demonstrate the

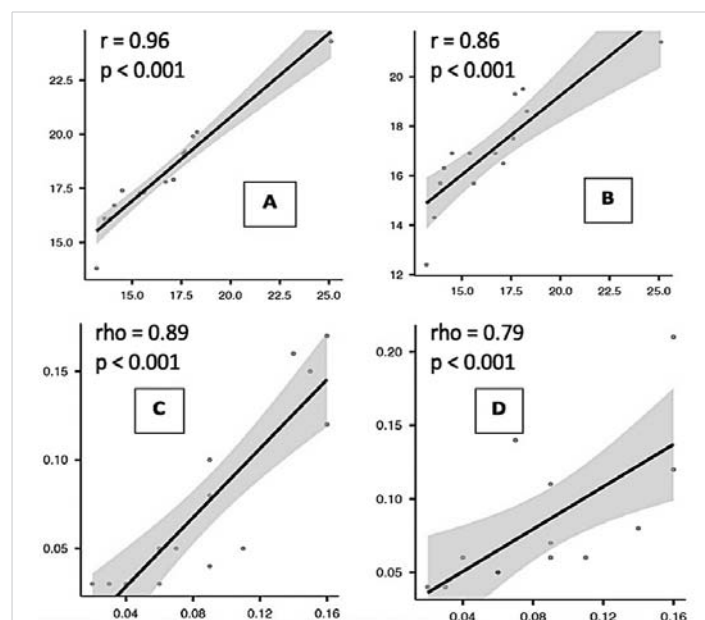


Figure 3: Correlation matrix of initial flow measurements in supra-sternal and sub-xiphoid views with the 5-chamber apical view. A: Correlation matrix of initial VTI values between 5-chamber apical view and supra-sternal view. B: Correlation matrix of initial VTI values between 5-chamber apical view and sub-xiphoid view. C: Correlation matrix of initial ΔV_{peak} values between 5-chamber apical view and supra-sternal view. D: Correlation matrix of initial ΔV_{peak} values between 5-chamber apical view and Sub-xiphoid view.

usefulness of flow analysis in DTA from the supra-sternal view and in RVOT from the sub-xiphoid view to guide fluid expansion non-invasively. Patients under mechanical ventilation may present difficulties regarding access to the 5-chamber apical view, which is also the case in the operating room when patients are covered by sterile fields. The two acoustic windows show promise for non-invasive fluid responsiveness assessment in the lack of Transesophageal Echocardiography (TEE) or a reliable CO monitoring tool, which is often the case in low-income settings (Figure 5).

The high correlation of VTI and ΔV_{peak} values observed between acoustic windows in different VR statuses suggest that supra-sternal and sub-xiphoid views are good alternative acoustic windows in CO evaluation. However, absolute values of VTI in DTA were higher than expected, considering that a substantial fraction of CO is supposed to rejoin coronary and supra-aortic vessels [8]. Initial ΔV_{peak} and VTI variations after fluid challenge, which most importance was given – as dynamic assessment of CO is more likely to predict fluid responsiveness – were reliable parameters to discriminate fluid responders from non-responders, allowing us to determine a cut-off value using flow analysis in both DTA and RVOT. Differences in VTI variation observed between the norepinephrine group and the no-vasopressor group may be due to the importance of hypovolemia-related hypotension at the acute phase of illness,

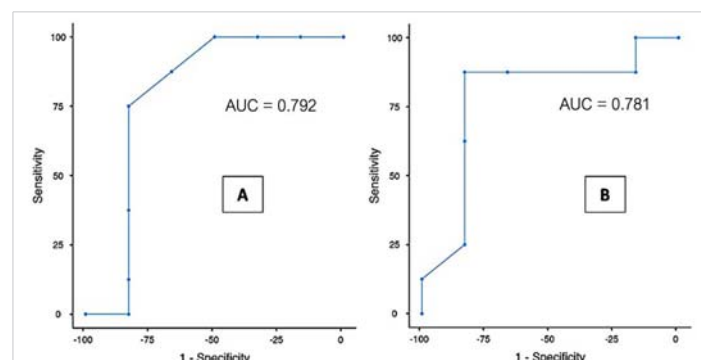


Figure 4: ROC curve of VTI variation after fluid challenge. A: ROC curve of VTI variations using supra-sternal view. B: ROC curve of VTI variations using sub-xiphoid view.

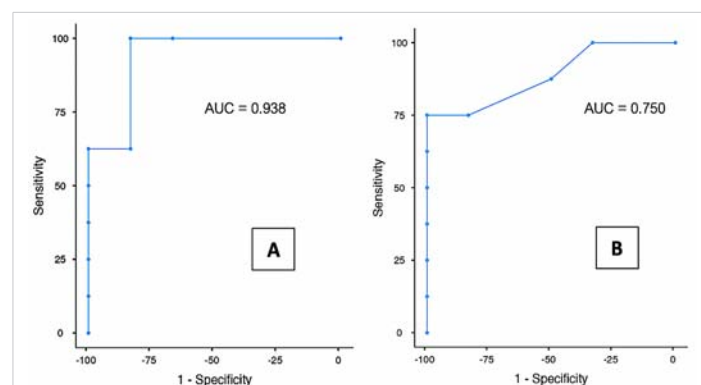


Figure 5: ROC curve of initial ΔV_{peak} value. A: ROC curve of initial ΔV_{peak} value using supra-sternal view. B: ROC curve of initial ΔV_{peak} value using sub-xiphoid view.



as all data were collected at the admission of patients into critical care. Regarding initial ΔV_{peak} accuracy, it is markedly high in DTA, where measurements are more likely to correlate with pulse pressure variation; the cut-off value to predict fluid responsiveness is established at 12% [9]. That leaves place for further research in order to use it as a dynamic, non-invasive, punctual, and repeatable tool to predict fluid responsiveness using heart-lung interactions.

Limits of the study

The main limitations of our study are the small sample size, which is lower than the initial calculated size, and the selection of patients for VTI and ΔV_{peak} interpretation. We intend to lead separate and large studies to focus on each aspect of hemodynamic status, starting with healthy patients in order to establish a normal values range before investigating shock state and other conditions that may modify VR. We also consider that the validation of supra-sternal and subxiphoid views should involve a CO monitoring tool, which is lacking in our study as a gold standard tool to predict fluid responsiveness. Moreover, the assessment of validity for a sonographic tool is limited by its repeatability, which demands more than a single operator with a comparison protocol according to expertise [10].

Review of the literature

While numerous studies investigated the usefulness of flow analysis in Ascending Aorta (AA) by supra-sternal view, none have been done in DTA, and the reasons are that VTI is considered as a surrogate of stroke volume considering the formula: $CO = VTI \times LVOT \text{ surface} \times \text{heart rate}$ [11]. Souto and Coll. found a moderate correlation of VTI values between LVOT and AA from the suprasternal view ($r = 0.52$) in healthy volunteers, with an error percentage of 52.6% using Bland-Altman analysis [12]. Although expert echocardiographers were involved in evaluating the accuracy of measurements obtained by non-expert sonography users, the limitations of this study were the small sample size with a sampling bias and the lack of data regarding SVV in response to preload modification. A pilot study led in the operating room showed a suitable sensitivity and specificity of flow analysis in AA from a supra-sternal view, with an AUC of 0.7 in fluid-responsive patients and 0.57 in non-responsive patients [13].

Few studies investigated about reliability of flow analysis in RVOT to guide intravascular fluid expansion. A recent study led in ICU compared LVOT data to RVOT measurements before and after fluid bolus, finding a high sensitivity and specificity for VTI variation of 15.4%, for an AUC of 0.879 (CI95% [0.744 - 0.989]), a PLR of 12.4 and a NLR of 0.15 [14].

Perspectives

All data considered, flow analysis in DTA and in RVOT have giant potential to substitute commonly used monitoring tools in the ICU and in the operating room. However, some

reservations should be taken as a gap exists between our results and literature data, most likely due to the small sample size, which prevents us from generalizing on a large population and incites further research in this area.

Conclusion

Fluid responsiveness is a common issue at the bedside that needs quick assessment. Depending on illness severity, invasive or noninvasive tools are available for this purpose. TTE is a noninvasive, validated, and reliable tool that is widely used in critical care fields and operating theaters. While the classic acoustic apical view is sometimes unreachable, some alternative views could be helpful in such circumstances, as patients under mechanical ventilation and during surgery.

Our study enhances the interest of those alternative views—suprasternal and subxiphoid views—with relevant preliminary results that support the utility, reliability, and the need for more investigations in different critical conditions and areas, in order to confirm our observations and to allow their use in routine point-of-care assessments by ultrasonography.

We intend to extend our study protocol in the intensive care unit for critically ill patients in a separate way, exploring shock states and controlled ventilation separately, and in the operating rooms in nonthoracic surgery.

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