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Dynamic Carotid Doppler Indices Predict Fluid Responsiveness in Post-Operative Cardiac Patients

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ABSTRACT

Background: While it has been established that carotid blood flow (CBF) correlates significantly with stroke volume index (SVI), the accuracy of carotid flow Doppler indices in assessing fluid responsiveness in post-operative cardiac patients remains unknown.

Aim: to see if Fluid Responsiveness Can Be Predicted Using Dynamic Carotid Doppler Indices After Cardiac Surgery.

Patients and Methods: Research was done at Cairo University's critical care unit, which is part of the medical school. There were 70 patients admitted to the Surgical Intensive Care Unit in a row. Patients were divided into two groups: those who responded and those who did not.

Results: Δ total carotid flow, Δ systolic carotid flow, Δ corrected carotid flow time, and Δ HR % change were significantly higher among responder's group than non-responder (16.47±3.73, 13.18±4.19, and 14.00±5.22 vs 8.44±2.74, 5.68±3.33, and 10.16±5.12, p value: <0.001, 0.001, and 0.004 respectively). Significant Pearson link between Δ SV% and Δ TCF, Δ SCF, and Δ corrected CFT (p value: 0.024, 0.039, and 0.026 respectively). Δ TCF% was most reliable indicator of fluid responsiveness with sensitivity 93.1%, and area below the curve (AUROC) was 0.946 (p=0.031).

Conclusion: Fluid responsiveness after cardiac surgery may be predicted with high accuracy using dynamic Doppler indices.

Keywords: *Fluid reactivity, total carotid flow, and systolic carotid flow.*

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INTRODUCTION

Volume expansion (VE) is frequently the initial treatment for acute circulatory failure in an effort to boost cardiac output (CO), however improper or excessive VE can have a severe effect on the patient's prognosis(1)Therefore, accurate identification of patients in whom VE really raises CO is necessary for the appropriate delivery of fluids. (2) Before continuing with fluid challenge method VE, make sure CO has grown for real. But CO readings are rarely used as a VE reference. Because of the poor risk-benefit ratio associated with indwelling devices and catheters, the usage of CO monitoring devices is often constrained by their price. (3)Transthoracic echocardiography has been shown to correlate strongly with stroke volume index (SVI), and prior research has shown that cardiac blood flow (CBF) correlates with SVI. SVI is considered a gold standard in determining volume responsiveness. (4) Thus, Doppler measurement of common carotid artery flow following VE (ΔVE carotid Flow) could be appealing in determining fluid responsiveness; Since artery Doppler does not require a large transthoracic window and is less invasive than trans-esophageal echocardiography, it is becoming increasingly popular (TEE). Furthermore, it gauges flow rather than pressure (5). Using carotid flow Doppler indices to assess fluid responsiveness in post-operative cardiac patients was the goal of this investigation.

PATIENTS AND METHODS

This study examined seventy consecutive patients who had undergone cardiac surgery and were admitted to the surgical intensive care unit of Kobri Elkobba Military Hospital and El Maadi Military Hospital with evidence of any of the following signs or symptoms that suggest circulatory shock: hypotension, such as invasive systolic blood pressure (SBP) less than 90 mmHg or mean arterial pressure (MAP) less than 65 mmHg, oliguria (less than 0.5 ml/kg/hr) ,arterial lactate >2.5 mmol/ litre or drug infusion of a vasopressor, inotrope, or both.

Ethical consideration

The study was approved by critical care department, Cairo University review board. The participants' first degree relatives were informed of the study's objectives and procedures. It was gotten in writing and informed consent after explanation the nature and scope of the study.

Inclusion criteria

All post cardiac surgery patients with evidence of circulatory shock as previously mentioned were patients who (i)had an artery catheter in place, (ii) were getting closely monitored mechanical ventilation, and (iii) had VE ordered by their attending physician were included.

Exclusion criteria

(i) pregnant females,

(ii) patients` age < 18 yrs,

(iii) obvious contraindication for carotid Doppler examination,

(iv) requirement for immediate treatment,

(v) change in their minute ventilation that is statistically significant (arbitrary cut-off of 0.2 liters min1).

Measurements

ABP before and after VE, Heart rate, Cardiac output Measurements and Carotid Doppler Measurements.

Statistical Analysis

Information was recorded, tabulated, and analyzed statistically using an IBM-compatible personal computer running SPSS version 25 (SPSS Inc., 2015).

Version 25.0 of the IBM SPSS Statistics for Windows program (Armonk, NY: IBM Corp.) Mean standard deviation (SD) was used to describe quantitative data, whereas frequency and percentage were used to describe qualitative data. Chi-square, Fisher's exact, Student t, Mann-Whitney, and analysis of variance (ANOVA) tests were among the analytical statistics used. If the probability level was less less than and equal 0.05, the results were regarded significant, and if it was less than and equal 0.01, it was considered highly significant.

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RESULTS

Median Age of the study patients was 56.78± 6.65 and 55.86± 11.27 years in responder and non-responder group respectively. As shown in tables 1, and 2, both groups were comparable regarding their Clinical and laboratory data

Despite significant Δ SV% and Δ CO% in fluid responder group compared to non-responders, Δ HR%, and Δ MAP% were not significantly different in both groups. Good to mention that, Δ TCF, Δ SCF, Δ corrected CFT, were significantly higher among responder's group than non-responder (16.47±3.73, 13.18±4.19, and 14.00±5.22 vs 8.44±2.74, 5.68±3.33, and 10.16±5.12, p value: lower than 0.001, 0.001, and 0.004 respectively. (Table 3)

In responders group, we found that values of TCF, SCF, and corrected CFT were significantly increased after PLR maneuver (525.45±85.38, 316.28±58.00, 0.28±0.05 vs 451.77± 75.24, 279.42± 49.55, and 0.25± 0.03 p < 0.001). (Table 4) Moreover, significant Pearson correlation between Δ SV% and dynamic carotid indices, namely Δ TCF, Δ SCF, and Δ corrected CFT (p value: 0.024, 0.039, and 0.026 respectively). (Tables 5), (Figures 1-3)

Concerning the diagnostic value of several Doppler carotid indices for determining fluid responsiveness, receiver operating characteristic (ROC) curve analysis showed that Fluid responsiveness in shocked individuals may be significantly predicted by any of the Doppler carotid indicators. Sensitivity was 93.1percentage points and AUROC was 0.946 (p=0.031) for Δ TCF% as a predictor of fluid responsiveness in our group. (Figure 4)

TABLE 1: General features of the studied patients. Results are presented as mean ± SD or number (percentage %). Abbreviations: HTN (hypertension), DM (diabetes mellitus), CKD (chronic kidney disease), BMI (body mass index).

		Group 1 Non responders	Group 2 Responders	P value
Age		56.78± 6.65	55.86± 11.27	0.670
Gender	Male	22(81.5)	31(72.1)	0.373
	Female	5(18.5)	12(27.9)	0.373
HTN		19(70.4)	35(81.4)	0.285
DM		15(55.6)	22(51.2)	0.720
CKD		5(18.5)	8(18.6)	0.993
BMI> 30		7 (10%)	9 (12, 8%)	,125
Off pump		7(25.9)	14(32.6)	0.556

TABLE 2: laboratory data of the studied patients. The data are shown as a mean ±SD or as a count (percentage). Hemoglobin (Hb), hemocrit (Hct), platelets (Plt), aspartate transaminase (Ast), alanine transaminase (Alt), albumin (Alb), creatinine (Creat), sodium (Na), potassium (K), glycated hemoglobin (Hba1c), C-reactive protein (Crp), and bicarbonate (HCO3) (Bicarbonate).

	Group 1 Non responders	Group 2 Responders	P value
Hb, gm/dl	10.01± 0.81	9.85±0.63	0.392
HCT,%	31.70±3.51	30.86±2.82	0.297
PLT, x10^3/cmm	205±38	206±51	0.955
AST, IU	28.89±7.03	28.91±7.65	0.992
ALT, IU	28.22±7.11	30.16± 6.86	0.265
Alb., gm	4.04±0.32	4.05±0.36	0.923
Creat., mg/dl	1.10±0.31	1.12±0.28	0.810
Urea, mmol/l	35.22± 9.05	31.95±11.59	0.192
Na, mmol/l	139.63±4.39	139.02±3.42	0.544
K, mmol/l	4.19±0.50	4.12±0.47	0.576
HBA1C, %	6.53±0.79	6.53±0.98	0.999
CRP– positive	8(29.6)	14(32.6)	0.797
Lactate, mmol/l	4.72±1.24	4.79±1.29	0.822
HCO3, mmol/l	19.04±2.19	18.74±1.68	0.556

TABLE 3: Hemodynamic and Doppler indices changes in the studied patients. Mean arterial pressure (MAP), central venous pressure (CVP), total carotid flow (TCF), systolic carotid flow (SCF), and carotid flow time (CFTc) are abbreviations used here (corrected carotid flow time)

	Group 1	Group 2	P value
Δ HR%	2.93±2.03	3.93±2.33	0.072
Δ MAP%	13.79±9.78	12.06±8.40	0.438
Δ CVP%	34.89±23.87	31.16±15.66	0.435
Δ SV%	10.18±2.93	18.39±2.43	<0.001*
Δ CO%	5.78±2.85	15.10±2.13	<0.001*
Δ TCF%	8.44±2.74	16.47±3.73	<0.001*
Δ SCF%	5.68±3.33	13.18±4.19	<0.001*
Δ CFTc%	10.16±5.12	14.00±5.22	0.004*

TABLE 4: Doppler carotid indices before and after PLR in VE responder patients. Abbreviations: PLR (passive leg raising), TCF (total carotid flow), SCF (systolic carotid flow), CFTc (corrected carotid flow time)

	Pre PLR	Post PLR	P value
TCF (ML/Min)	451.77± 75.24	525.45±85.38	<0.001*
SCF (ML/Min)	279.42± 49.55	316.28±58.00	<0.001*
CFTc (millisecond)	250± 30	280±5	<0.001*

TABLE 5: Correlation between Δ stroke volume %, and dynamic carotid Doppler indices in VE responder patients. Abbreviations: TCF (total carotid flow), SCF (systolic carotid flow), CFTc (actual carotid pulse rate).

Variable		**ΔSV %**
ΔTCF %	PearsonCorrelation	0.323
	Sig.(2-tailed)	0.024*
ΔSCF %	PearsonCorrelation	0.296
	Sig.(2-tailed)	0.039*
CFTc %	PearsonCorrelation	0.324
	Sig.(2-tailed)	0.026*

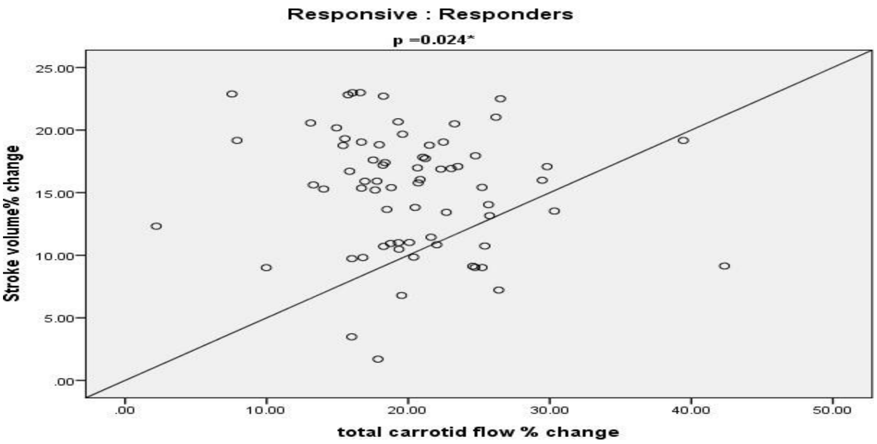

FIGURE 1: Correlation between Δ stroke volume % and Δ total carotid flow % in responder group.

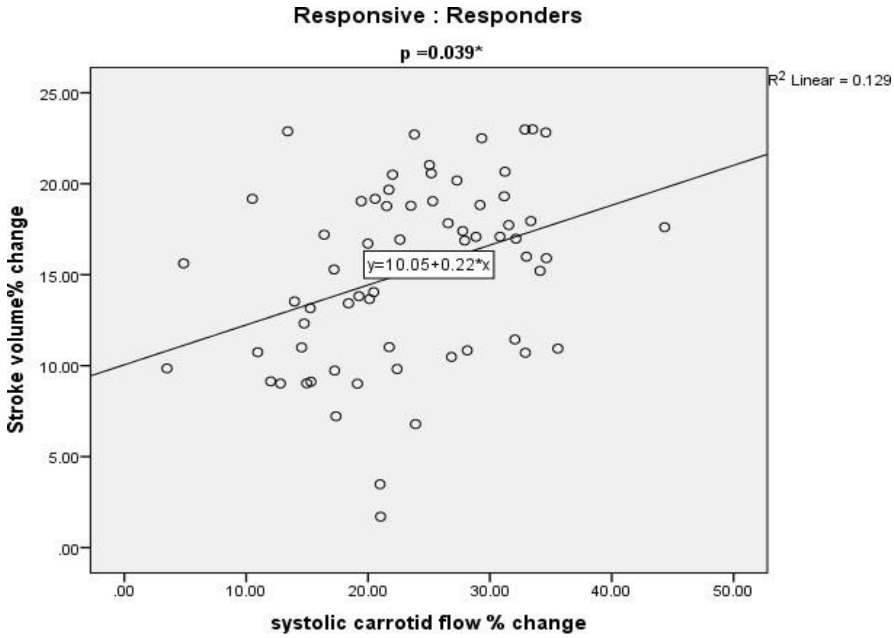

FIGURE 2: Correlation between Δ stroke volume % and Δ systolic carotid flow % in VE responder patients.

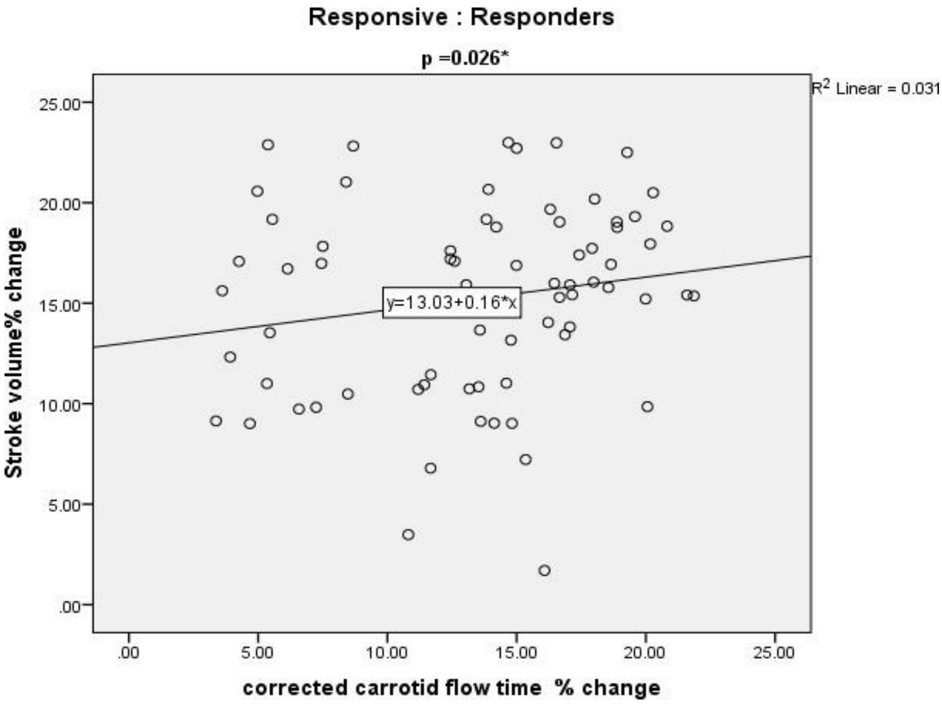

FIGURE 3: Correlation between Δ stroke volume % and Δ corrected carotid flow time % in VE responder patient.

TABLE 6: Diagnostic ability of different dynamic carotid flow indices fluid-response forecasting. Abbreviations: CI: confidence interval for odds ratio, TCF (total carotid flow), SCF (systolic carotid flow), CFTc (corrected carotid flow time)

Variable	AUROC(95%CI)	Pvalue	Sensitivity %	Specificity %	Accuracy %
Δ TCF %	0.946(0.886-1.00)	**0.031***	93.1	96.2	95%
Δ SCF %	0.911(0.838-.0983)	**0.037***	92.3	97.5	93.8%
Δ CFTc %	0.678(0.540-0.815)	**0.014***	90.7	88.5	87%

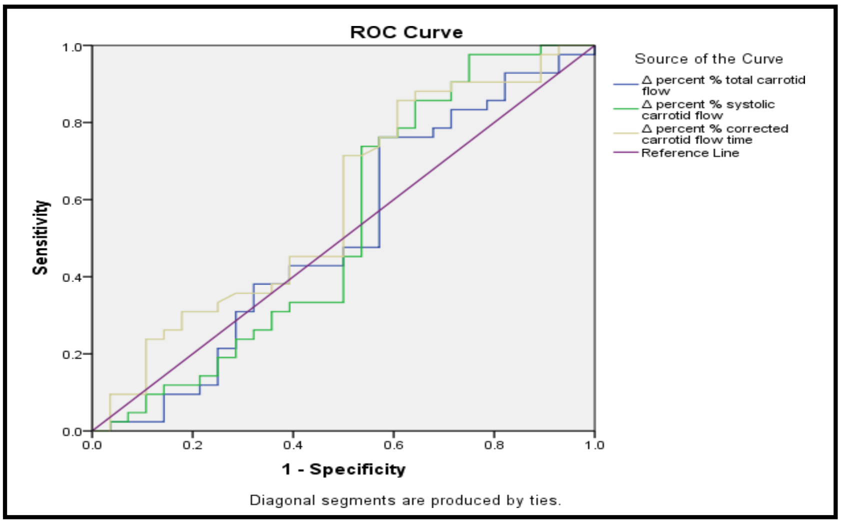

FIGURE 4: Receiver operating characteristic curve for diagnostic ability of different Doppler carotid indices in forecasting fluid reactivity.

DISCUSSION

The study proved that carotid Doppler dynamic indices could be used as predictors of fluid responsiveness in post-operative patients with heart problems. We also proved significant correlation between Δ SV% change and dynamic Doppler carotid indices in VE responder patients. In our cohort, Δ TCF% was the most factor predicting fluid reactivity.

Method of differentiation between VE responder and non-responder patients should be quick, noninvasive, accurate, and better if it requires minimal experience/trainingInferior vena cava (IVC) ultrasound evaluation was proposed to fulfill these requirements; however, its accuracy in some circumstances has been called into question. (6) So, carotid artery ultrasound is appealing to address all of these features.

In agreement with our study, Marik et al. (7) conveyed significant rise in CBF in Patients with acute sepsis and septic shock who are fluid sensitive per the PLR test. They added that 20% upturn in carotid Doppler flow was predictor for fluid responsiveness in their cohort. A similar high degree of connection was found between the percentage change in SVI and CBF after PLR.In contrast, Girotto et al. (8) failed to prove association between fluid responsiveness and dynamic Doppler indices in both carotid and femoral flow and their systolic velocities, AUROCs were 0.58±0.10, 0.57±0.16, 0.56±0.09, and 0.64±10, respectively. They used a cutoff of 10% change in cardiac index (CI) using PICCO2. In the present study, we used 15% or more increase in SV using TEE as a gold standard. This difference in differentiation between fluid responder and non-responder patients may explain the contradictory results.

According to Ma et al. (9), CO measured using invasive right heart catheterization was correlated significantly with CBF, CFT measured simultaneously using carotid ultrasound. Many studies mentioned that corrected flow time could be appropriate surrogate for the patients`volume position.

(10-12) An increase in systolic time or corrected flow time would make sense as a reflection of the rise in CO following a fluid challenge in a volume responder heart (FTc). Because it can be challenging to get the views necessary to make this measurement, several surrogate sites have been investigated, such as the brachial artery, with varying degrees of success in terms of diagnostic accuracy. (13, 14)

Blehar et al. (15), Jung S etal (16) Similarly, Jung S, et al. (16) Reported value of CFTc in predicting fluid response in mechanically ventilated patients who are dehydrated or otherwise hypohydrated. The Doppler waveform in the descending thoracic aorta has been shown to be helpful in directing fluid management, and this fact forms the basis for FTc. (17).

To the contrary of our finding, Judson PI, et al, (18) establish that there was no alteration in CFT among the fluid responder and non-responder patients. In addition, they mentioned that Neither cerebral blood flow nor cerebral vascular resistance changed in tandem with cerebral vascular resistance.This study was conducted in the ED, among patients with varied diagnosis and volume status, in contrast to our post-operative cardiac cohort. Also, in this study, they used variation in CBF to categorize people into those who responded and those who didn't which is not a gold standard.

In summary, we discovered that TCF% was the best predictive of fluid responsiveness in our patients, but other dynamic Doppler indices such as SCF and CFTc were also useful. However, this study may have been hindered by a lack of patients.

Also, our patient represent only a small category in the surgical ICU. It would be helpful to replicate our results in a bigger research of surgical ICU patients with a wider range of illnesses.

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