Non-invasive testing to determine cardiac or non-cardiac etiology of dyspnea in the ED

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Objectives

This project was designed to determine the diagnostic threshold of hemodynamic values derived from impedance cardiography (ICG) and whether these thresholds are sex specific in determining the etiology of shortness of breath (dyspnea) in patients presenting to the emergency department (ED). These ICG hemodynamic values were also compared against results of point-of-care cardiothoracic ultrasonography and B-type natriuretic peptide (BNP) levels in patients presenting with dyspnea in the ED.

Introduction

Dyspnea, or shortness of breath, is a common presenting complaint among patients in the emergency department (ED). During ICG monitoring, four dual sensors are placed on the neck and thorax. A current is then passed between the electrodes to measure the impedance between the electrodes. Algorithms have been developed that utilize real time changes in the impedance through the thoracic cavity to measure changes in the blood flow through the aorta and inferior vena cava and thereby calculate hemodynamic parameters such as cardiac output (CO), stroke volume (SV), systemic vascular resistance (SVR), and contractility. ICG data can be collected in 3-5 minutes, making it a rapid, non-invasive method to calculate hemodynamic parameters. There are discrepancies between studies reporting the diagnostic threshold values that should be utilized in ICG derived hemodynamic values. It has been demonstrated that ICG is not affected by obesity, but it is uncertain at this time if ICG derived hemodynamic values vary by sex. This study attempted to examine these previously reported values as well as determine if the reported discrepancies can be attributed to differences by sex. ICG results were also compared to standard cardiothoracic ultrasound findings and BNP levels typically obtained in patients presenting with dyspnea.

Methods

A prospective cohort of 50 adult patients presenting to the Maricopa Medical Center ED with dyspnea were evaluated using ICG, bedside cardiothoracic ultrasound, and BNP to determine the etiology of their complaint.

The final etiology was determined through review of the patient's chart. Cardiac and non-cardiac groups were then compared to determine the accuracy, sensitivity, and specificity of ICG, bedside cardiothoracic ultrasound and BNP in identifying the etiology of their complaint. ICG data was further subgrouped by sex and each parameter was compared to identify differences between males and females in each group. The distribution of all measured parameters was charted for each group. The distributions were compared between the groups to identify parameters that best differentiated cardiac from non-cardiac etiology. The student's T-test was used to determine if significant differences existed between the groups. Receiver operating characteristic (ROC) curves were generated using STATA version 13 for the parameters that demonstrated significant differences. Using these ROC curves threshold values were established for distinguishing cardiac from non-cardiac etiology of dyspnea.

Results

Summary of significant ICG parameters by sex. Highlighted values indicate the most significant differences between cardiac and non-cardiac groups. *mean ± 1 standard deviation

Females

Parameter	Cardiac (n=8)	Non-cardiac (n=16)	P value
Stroke index* (mL/m^2)	30 ± 8 Median 30	39 ± 11 Median 39	0.021
Cardiac index* ($L/min/m^2$)	2.3 ± 0.7 Median 2.2	3.1 ± 0.7 Median 3.1	0.013
Velocity index* (1/1000/sec)	25 ± 10 Median 21	41 ± 11 Median 44	0.003
Acceleration index* ($1/100/sec^2$)	47 ± 14 Median 40	61 ± 17 Median 56	0.034
Left cardiac work* index ($kg \times m/m^2$)	2.6 ± 0.8 Median 2.6	3.6 ± 1.1 Median 3.4	0.017
Heather index* (Ohm/sec^2)	6.5 ± 3.5 Median 6.4	14.4 ± 5.1 Median 13.3	<0.001

Males

Parameter	Cardiac (n=12)	Non-cardiac (n=13)	P value
Heather index* (Ohm/sec^2)	5.6 ± 2.7 Median 5.2	8.9 ± 4.2 Median 7.9	0.026

Non-cardiac

Parameter	Female (n=16)	Male (n=13)	P value
Heather index* (Ohm/sec^2)	14.4 ± 5.1 Median 13.3	8.9 ± 4.2 Median 7.9	0.004

Summary of significant parameters of ICG, bedside ultrasound and BNP. Highlighted values indicate the most significant differences between cardiac and non-cardiac groups. *mean ± 1 standard deviation.

Parameter	Cardiac (n=20)	Non-cardiac (n=29)	P value
Cardiac Index* ($L/min/m^2$)	2.4 ± 0.6 Median 2.4	2.9 ± 0.8 Median 2.9	0.005
Velocity Index* (1/1000/sec)	26 ± 11 Median 25	40 ± 16 Median 40	0.001
Acceleration Index* ($1/100/sec^2$)	48 ± 19 Median 41	62 ± 27 Median 54	0.042
Heather Index* (Ohm/sec^2)	6.0 ± 3.0 Median 5.6	11.9 ± 5.4 Median 11	<0.001
Left cardiac work* index ($kg \times m/m^2$)	2.9 ± 0.8 Median 2.8	3.5 ± 1.2 Median 3.3	0.031
Systemic vascular resistance index* ($dyne \times sec \times cm^{-5}/m^2$)	3080 ± 770 Median 2970	2531 ± 767 Median 2182	0.018
Systemic vascular resistance* ($dyne \times sec \times cm^5$)	1644 ± 531 Median 1607	1328 ± 450 Median 1310	0.036
Parameter	**Cardiac (n=18)**	**Non-cardiac (n=25)**	**P value**
Maximal Inferior Vena Cava diameter* (cm)	1.76 ± 0.57 Median 1.70	1.41 ± 0.42 Median 1.26	0.037
Right Ventricle diameter during systole* (cm)	2.30 ± 1.07 Median 2.03	1.46 ± 0.65 Median 1.52	0.007
Right Ventricle diameter during diastole* (cm)	3.43 ± 1.07 Median 3.16	2.66 ± 0.88 Median 2.57	0.018
Left Ventricle diameter during systole* (cm)	2.95 ± 2.19 Median 2.58	1.42 ± 0.98 Median 1.27	0.011
Left Ventricle diameter during diastole* (cm)	4.30 ± 1.84 Median 4.10	3.00 ± 0.92 Median 2.89	0.011
Parameter	**Cardiac (n=19)**	**Non-cardiac (n=24)**	**P value**
B-type natriuretic peptide* (pg/mL)	3129 ± 4447 Median 1150	128 ± 135 Median 79	0.008

Discussion and Conclusions

In comparing the modalities utilized, it was noted that BNP levels were the most accurate for predicting cardiac vs. non-cardiac etiologies for dyspnea. In this study, bedside cardiothoracic ultrasound was less accurate than BNP levels and ICG analysis. The ICG results did demonstrate some sex-specific thresholds, however, the 95% confidence intervals were wide secondary to our small sample size. Future multicenter, randomized controlled studies will be required to delineate these thresholds more clearly.

Summary of ROC curves. Highlighted values show most predictive parameter for each modality. Comparing AUC's (area under the curve) we see that BNP had the largest AUC and was therefore the most predictive.

Parameter	Threshold	Sensitivity	Specificity	AUC	95% CI
Cardiac index	2.7 $L/min/m^2$	72.41	65.00	0.7172	0.56737 - 0.83416
Velocity index	29 $1/1000/sec^2$	79.31	55.00	0.7534	0.61130 – 0.86657
acceleration index	45 $1/100/sec^2$	68.97	60.00	0.6733	0.52460 - 0.80051
Heather index	9.2 Ohm/sec^2	72.41	85.00	0.8405	0.70343 – 0.92678
left cardiac work index	3.1 $kg \times m/m^2$	65.52	60.00	0.6569	0.50361 – 0.78328
Systemic vascular resistance index	2760 $dyne \times sec \times cm^{-5}/m^2$	70.00	72.41	0.7224	0.56737 - 0.83416
Systemic vascular resistance	1577 $dyne \times sec \times cm^{-5}$	60.00	82.76	0.6810	0.52460 - 0.80051
Maximal inferior vena cava diameter	1.68 cm	61.11	68.00	0.6933	0.53875 - 0.82818
Right ventricle systolic diameter	1.71 cm	77.78	60.00	0.7489	0.58828 - 0.86481
Right ventricle diastolic diameter	3.07 cm	66.67	68.00	0.7122	0.56331 - 0.84671
Left ventricle systolic diameter	1.64 cm	66.67	64.00	0.7111	0.56331 - 0.84671
Left ventricle diastolic diameter	3.34 cm	66.67	72.00	0.7100	0.56331 - 0.84671
BNP	164 pg/mL	84.21	79.17	0.8684	0.72068 - 0.94702

Acknowledgements

Thank you Jena for tolerating an absentee husband and father at times.