



Incremental Doppler stress echocardiographic evaluation of cardiovascular reserve in heart failure: A case comparison of 2D independent CW Doppler and thermodilution.



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BACKGROUND

Heart failure (HF) is a common and serious condition characterised by impaired cardiac output (CO), and increased morbidity and mortality.^(1,2,3) Doppler ultrasound is a reliable and reproducible method of measuring CO, and is routinely used to diagnose and monitor patients with HF.⁽⁴⁾ While pharmacotherapy may be used to maintain reasonable health in HF patients, intractable cardiac failure, in which cardiovascular reserve is diminished, may require cardiac transplantation for the prolongation of life. Assessment of cardiovascular reserve, the ability to up-regulate CO on demand, may be influential in determining appropriate short and long term management. One method currently used to evaluate cardiovascular reserve is pulmonary artery catheter thermodilution (TD) CO measurements during incremental exercise testing. However TD is recognised to be of variable reliability, reproducibility and safety,^(5,6) while CW Doppler ultrasound may provide such measurements more accurately and non-invasively.^(7,8)

METHOD

Serial CO measurements were made in a subject in HF at rest and during exercise, using invasive TD and a dedicated 2D independent CW Doppler ultrasound device (USCOM Ltd, Australia). This device uses a novel height referenced algorithm to calculate pulmonary annular diameter and determine flow volumes from Doppler transpulmonary stroke distance. Contemporaneous TD and USCOM measurements were made with the subject supine at rest, erect at rest, and during incremental bicycle exercise testing. Five consecutive CW Doppler outputs were measured using ASE guidelines,⁽⁹⁾ and averaged for comparison with each invasive measure to minimise the effects of beat to beat physiologic variability. Continuous and cold injectate TD outputs were compared to the USCOM results using mean values and Bland-Altman bias analysis.⁽¹⁰⁾



RESULTS

The mean cardiac output at rest and during exercise by TD was 3.51±0.66l/min, and 3.42±0.51l/min for USCOM (n=16), with COV's of 19% and 15% respectively. There was a mean difference between methods of 0.09±0.58l/m. Critchley in a meta-analysis of CO measurement method comparisons proposed that the %LOA (95%CI/mean x 100) for adoption of a new CO measurement method be < 30%.⁽¹¹⁾ Despite the small sample numbers in this study, the USCOM method compared favourably with TD using the Critchley criteria.

Results are demonstrated in Figures 1-5

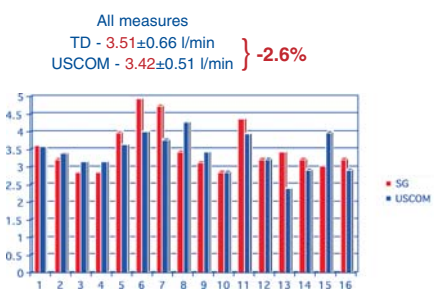


Figure 1. Thermodilution CO measures compared with 5 consecutive average USCOM measures at rest (1 to 11) and during incremental stress (12 to 16).

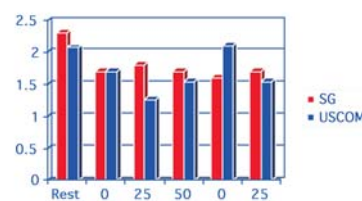


Figure 2. Thermodilution measures compared with 5 consecutive averaged USCOM measures during incremental stress demonstrating CI (L/min/m²) at rest sitting erect, and during incremental stress (Watts).

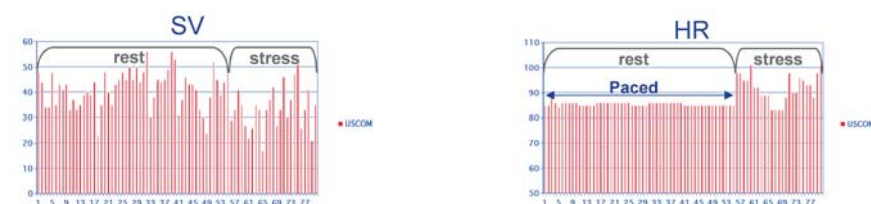


Figure 3. USCOM CO measures of SV and HR demonstrating fixed paced HR at rest (1 to 54) with stroke volume modulation, while during stress (55 to 82) CO is both rate and volume modulated.

Thermodilution vs USCOM (n=16)
Comparison of mean values TD with USCOM
CI l/min/m², (BSA = 1.9m²)

	Rest (hot+cold)	Stress	%Δ
TD	2.06±0.46	1.80±0.25	-13
USCOM	1.95±0.27	1.70±0.33	-13
% Diff	-5.3	-5.5	

Figure 4. CI at rest and during stress measured by TD and USCOM demonstrating a post stress decrease in CI of 13% by each method.

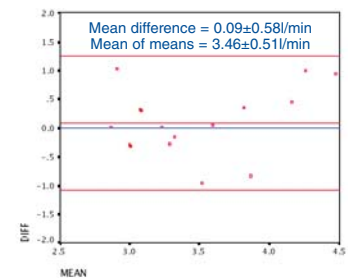


Figure 5. Bland-Altman plot of differences between paired thermodilution and USCOM CO measures (n=16).

DISCUSSION

- Doppler in HF is well established with AHA and ACC evidence based recommendations that 2D echocardiography and Doppler flow studies are the most useful diagnostic test in the evaluation of HF with a class I recommendation and level-C evidence for diagnosis and class IIa recommendation and level-C evidence for serial evaluation to detect change in clinical status or evaluate therapy.⁽¹²⁾
- 2D stress echocardiography is well established for detection of ischaemia despite the method being highly user dependent.⁽¹³⁾ However Doppler echocardiography is an accurate, reliable and reproducible method for assessment of resting haemodynamics with reported inter and intra observer variability of 3.2% and 5.4% respectively for measurement of stroke distance, and 6-8% and 5-9% for measurement of CO.⁽¹⁴⁾
- CW is preferred to PW because of superior reproducibility.⁽⁹⁾
- USCOM measures of CO at rest and during exercise using a proprietary algorithm for cross sectional area calculation agree well with TD measures.
- USCOM Doppler stress is feasible and may be a cost-effective approach for evaluation of HF.

LIMITATIONS

- This study compared USCOM with TD as "gold standard", however TD is recognised to be of variable reliability, reproducibility and safety. TD reliability could possibly be decreased in the challenging setting associated with stress testing where the patient sits erect and is mobile and heart rate and respiration are increased, and thermister location may vary.
- This study compared 5 consecutive USCOM cycles while thermodilution averages approximately 20s of output, and it is possible that the USCOM measures will show more intra subject variability (greater SDs) and may more accurately represent beat to beat physiology.
- This study compared mean CO values while the complexity of cardiac performance may be better understood with less averaged data and using new stress Doppler parameters of rate or volume variability.
- Optimal stress testing for detection of ischaemia depends on achieving in excess of 85% of age predicted heart rate maximum (220-age), which represents 127bpm for a 70 year old. The lower peak heart rates achievable by HF patients during stress, usually less than 120bpm, are more suited for CW Doppler analysis and suggests that this method may be feasible in most HF patients.
- This study was of a single subject and more observations are required to prove the clinical utility of this method.

CONCLUSION

This case demonstrates favourable comparison of CO measurements at rest and during exercise, using USCOM and thermodilution. Doppler stress echo using a 2D independent CW Doppler device may be a cost effective, non-invasive alternative for evaluation of subjects with cardiac failure and warrants further investigation.

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