

Additive value of non-invasive haemodynamic and fluid profiling in emergency department congestive cardiac failure patients

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Dear Editor,

Patient symptoms and physical signs often lag behind haemodynamic changes in conditions, such as heart failure and cardiogenic shock.¹ Haemodynamic parameters, including cardiac index (CI) and stroke volume index (SVI), have shown prognostic value, with goal-directed therapies improving outcomes like hospital length of stay.² However, physicians' ability to accurately estimate these parameters remains limited. Non-invasive haemodynamic monitoring devices are increasingly available in the clinical settings, offering detailed evaluation of complex parameters and facilitating targeted therapy. For example, impedance cardiography can differentiate cardiac from non-cardiac dyspnoea and guide treatment in chronic heart failure.³ Its utility has yet to be established in the emergency department (ED).

The Non-Invasive Cardiac System (NICaS, NI Medical, Israel) uses whole-body impedance cardiography to calculate cardiac output and correlates well with thermodilution methods.⁴ The authors conducted a prospective observational study at the Singapore General Hospital ED from February 2019 to August 2022, evaluating NICaS-derived parameters in patients with congestive cardiac failure (CCF). Adults ≥ 21 years presenting with recurrent or worsening dyspnoea attributable to heart failure were included, while those unable to consent, cooperate or perform NICaS measurements were excluded.

Haemodynamic measurements (systolic blood pressure [SBP], diastolic blood pressure [DBP], mean arterial pressure, heart rate [HR], CI, SVI, total peripheral resistance index [TPRI] and total body water [TBW]) were recorded at baseline and every 10 minutes for 1 hour. NICaS monitoring was performed after participant enrolment in the ED and not extended as patients may transfer out of the ED. Demographics, medical history, chronic medications, laboratory values, interventions, disposition, length of stay, 30-day readmissions and mortality were also collected. Linear regression, Student's t-tests, Mann-Whitney U tests and analysis of variance

analyses were performed to evaluate associations between haemodynamic parameters, comorbidities, chronic medications and clinical outcomes.

A total of 148 patients were recruited (Supplementary Table S1). All except 1 were admitted; 131 were admitted to the general ward while 16 required high-dependency or intensive care. There were 8 occurrences of 30-day mortalities (5.4%). Compared with NICaS reference ranges for normal, patients with CCF showed elevated HR, TPRI and TBW, while CI and SVI were within NICaS reference ranges. TBW was significantly associated with 30-day mortality (odds ratio [OR] 1.375–36.642, $P=0.005$), with an optimal cut-off of 62.5% predicting mortality (sensitivity 85%, specificity 70%, area under receiver operating characteristic curve 0.828). Other non-invasive parameters (CI, SVI, TPRI) and traditional vital signs did not predict mortality (Supplementary Tables S2 and S3).

Non-invasive parameters did not differ significantly when comparing patients requiring intensive care with those who did not, while increased TBW was associated with 30-day mortality. Non-invasive parameters were not predictive of ED reattendance. Multivariable analysis indicated that comorbidities and chronic medications influenced haemodynamic readings: hypertension was linked to higher SBP and TPRI; ischaemic heart disease to lower HR and CI; chronic kidney disease to higher CI and SVI; angiotensin-converting-enzyme (ACE) inhibitors and angiotensin II receptor blockers (ARBs) to lower HR; and calcium channel blockers to lower HR but higher SVI. Other comorbidities and medications showed no significant effect (Supplementary Table S4).

The study demonstrates substantial heterogeneity in haemodynamic profiles generated by the NICaS among CCF patients, with coefficients of variation ranging from 18–43%, consistent with previous data.⁵ TBW was robustly associated with 30-day mortality, reflecting its potential as a prognostic marker. This aligns with prior studies indicating TBW's long-term prognostic relevance.⁶ TBW assessment may help

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quantify severity, guide patient counselling and suggest to the clinician difficulties in managing fluid overload due to pump failure or impaired renal clearance. Unlike traditional physical signs like lung crepitations or peripheral oedema which may be absent in half of patients with high jugular venous pressure,¹ TBW provides an objective measure of fluid status, reflecting the severity of decompensation. In the ED, non-invasive devices like NICaS can rapidly generate multiple haemodynamic parameters without the risks associated with invasive monitoring, offering a practical and safe approach to assessing acutely decompensated patients. This study underscores the potential for non-invasive haemodynamic monitoring to complement conventional ED triage and clinical scoring systems. Objective parameters like TBW and TPRI could be incorporated into future risk stratification models to identify patients at higher risk of adverse outcomes early. Integrating such technology into ED workflows may enhance clinical decision-making, optimise resource allocation and reduce delays in appropriate heart failure management.

Interventions such as diuretics may rapidly alter CI, SVI and TPRI, limiting their prognostic value in the ED,⁷ whereas TBW changes more slowly, retaining its relevance. Other studies have reported associations between SVI, CI and long-term outcomes, but differences in sample size, follow-up duration and patient selection likely explain the discrepancies with this study.⁸ ACE inhibitors or ARBs were associated with a significant reduction in HR, underscoring how chronic medications can directly influence non-invasive haemodynamic measurements and should be considered when interpreting these parameters in patients with CCF.⁹ Lower body weight was associated with higher mortality, suggesting a protective role of non-fluid body mass and highlighting the need to study sarcopenia and weight optimisation in CCF.¹⁰

Limitations of this study include convenience sampling, exclusion of critically ill or obtunded patients, a short monitoring duration, and lack of beat-to-beat analysis. Despite these constraints, the data provide baseline measurements, confirm the feasibility of non-invasive monitoring and suggest TBW as a potential prognostic marker. Several measures were taken to minimise bias: standardised data collection forms ensured consistent recording of variables while all haemodynamic readings were captured automatically by the device, eliminating observer variability. Although convenience sampling may limit external validity, the broad inclusion of patients across multiple years enhances representativeness of the Singapore CCF population. Further studies with larger cohorts, longer monitoring and subgroup analyses are planned to define the utility of non-invasive haemodynamic

parameters in diagnosis, therapy guidance and prognostication in CCF.

In conclusion, non-invasive haemodynamic monitoring using NICaS is feasible in the ED and may provide valuable information for patient-specific prognostication in CCF. TBW appears particularly promising as a prognostic indicator for short-term mortality. Integrating haemodynamic assessment with clinical history, comorbidities and chronic medications is essential, and future research should explore its role in targeted therapeutic strategies.

Ethics statement

Ethics approval was granted by SingHealth Centralised Institutional Review Board (2017-2866).

Declaration

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Supplementary materials

Table S1. Baseline demographics, medical history, chronic medications and outcome measures of patients enrolled.

Table S2. Initial haemodynamic parameters for patients in congestive cardiac failure.

Table S3. Comparison of parameters against outcomes.

Table S4. Linear regression of haemodynamic parameters against comorbidity or use of chronic medication.

Keywords: *emergency medicine, heart failure, mortality, non-invasive hemodynamic monitoring, total body fluid profile*

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