Prediction of fluid status and survival by electrical cardiometry in septic patients with acute circulatory failure

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**Abstract**

Prediction of fluid status and survival by electrical cardiometry in septic patients with acute circulatory failure.

**Background:** Septic hemodynamic instability imposes challenges to critical care physician in deciding fluid management to optimize preload dependency state.

**Methods:** Thirty patients with severe sepsis and hypotension (Mean arterial pressure i.e. MAP < 65 mmHg) and evidence of tissue hypotension i.e. lactate level >4 mmol/L were enrolled in our study. Fluid resuscitation (30 ml/kg) was administered. Fluid response was defined as MAP > 65 mmHg with lactate level <4 mmol/L cardiac output (CO), measured by electrical cardiometry, in guiding fluid therapy.

**Results:** The study included 13 males (43.3%) with age 47.8 ± 19.7. Paired comparison showed significant change in MAP readings (P value < 0.001). ROC curve showed cutoff 12.5% for delta CO to predict fluid responsiveness with Area under Curve (AUC) 0.927, sensitivity 90.0%, and specificity 70.0%. ROC also showed delta CO cutoff 12.5% to predict survival with AUC 0.756, sensitivity 66.7% and specificity 66.7%.

**Conclusion:** Delta change in cardiac output, measured by electric cardiometry could be used to predict fluid response and survival in acute circulatory failure in septic critically ill patients.

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**1. Background**

Patients in severe sepsis are at risk of acute hemodynamic instability with resultant serious sequelae upon both morbidity and mortality measures. Sepsis results into an unopposed heterogenous vasodilatation associated with cardiac contractile impairment. Fluid therapy poses an important step in managing this acute circulatory failure and reversing morbidities.

However, this created the need to predict fluid responders to optimize fluid resuscitation and organ support therapies. Static measures were studied extensively, but the poor predictive value of static measures and clinical examination has led to investigation of the dynamic measures of fluid responsiveness. In contrast to static measures, dynamic indices rely on the changing physiology of heart lung interactions to determine whether a patient will benefit from increased preload. Increase in cardiac output emerged as an acceptable surrogate for positive fluid response [1].

This has led to investigating goal-directed fluid optimization which showed superiority over standard protocols in surgical settings. A recent meta-analysis of randomized controlled studies also showed superiority of early goal directed protocol over standard protocol in terms of survival benefits [2]. Currently, Surviving Sepsis Campaign (SSC) offers clarification on the implications of the new definition statements and guidance for hospitals [3].

Electrical velocimetry has been validated to monitor cardiac output non-invasively [4–7].

**2. Aim of study**

To examine an increase in cardiac output, measured by electrical cardiometry as a predictor of survival and fluid response in management of critically ill septic patients with hemodynamic instability.

**3. Methods**

This is a prospective observational study, which was conducted on thirty patients with the diagnosis of severe sepsis, admitted to the Critical Care department of Cairo University from June 2015 to April 2016. Sepsis was defined using the standard Surviving Sepsis Campaign criteria [2]. Our protocol was approved by the Ethical Committee Review Board of the Faculty of Medicine, Cairo University. All patients consented to participation.

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Patients who experienced hypotension (defined as MAP < 65 mmHg) or lactate >4 mmol/L were enrolled in our study. Exclusion criteria: Age < 18 years, history of heart disease (e.g. valvular, myopathy, ischemic), history of hepatic or renal diseases, evidence of pulmonary embolism or dysrhythmias. Acute Physiological And Chronic Health Evaluation (APACHE II) scoring system was calculated and lactate withdrawn on admission and 3 h later to assess tissue hypoperfusion, as recommended by current SSC guidelines [2].

Fluid resuscitation (30 ml/kg) was given, patients who exhibited persistent hypotension were maintained on vasopressors. Fluid response was defined as improvement in MAP after fluid resuscitation i.e. MAP > 65 mmHg and lactate < 4 mmol/L.

For volume expansion, 30 ml/kg Normal Saline 0.9% was infused over 2 h. Measurements were taken before and after fluid administration: cardiac output (CO) and pulse pressure by ICON CARDIOTRONIC, OSYPKA MEDICAL. Patients were studied in a supine position, measured before and after fluid administration. For this purpose, four sensors were applied- first: approximately 5 cm above left base of the neck, second on the left base of neck, third on the lower left thorax at level of xiphoid and the fourth one on the lower left thorax approximately 5 cm below the 3rd electrode at the level of anterior axillary line Fig. 1. The Electrical cardiometry monitor (Electrical Cardiometry monitor, ICON Cardiotronics, Inc., La Jolla, CA 92307; Osypka Medical GmbH, Berlin, and Germany) was connected to the sensor cable and the patient data were fed. The ICON monitor incorporates an algorithm which transforms the ohmic equivalent of mean aortic blood flow acceleration into an equivalent of mean aortic blood flow velocity [8–9].

4. Statistical methods

Numerical variables were described as Mean ± SD. Categorical variables were described as percentages. Comparisons were done using Student ‘t’ test for numerical variables, paired ‘t’ test for paired comparisons and Chi square test for categorical variables. ROC curves were plotted to predict survival and positive fluid response. P value was considered significant if < 0.05. Statistics were calculated using SPSS 21 package [10].

5. Results

Thirty patients were enrolled in the current study. The study included 13 males (43.3%) with age 47.8 ± 19.7. Average length of ICU stay (LOS) was 10.7 ± 6.2 days. Sepsis with an identified pathogen (proved by microbiological culture) was documented in twenty-five patients (83.3%). APACHE II was 16.7 ± 5.6. Lactate was 3.5 ± 1.9 mmol/L. Mortality was 50.0%

Paired comparisons between MAP and pulse pressure before and after fluid challenge showed significant differences in MAP readings after fluid challenge (P value < 0.001) while pulse pressure readings did not differ significantly, (P value 0.11) as shown in Table 1. Also paired comparisons for CO showed significant differences in both fluid responders and non-responders, (P < 0.001 for all).

In the current study, electrical impedance was applied to measure cardiac output. Fluid response was determined in 10 patients (33.3%). Fluid non-responders had higher length of ICU stay (12.9 ± 6.5 vs. 6.5 ± 2.3, P 0.001), worse APACHE II score (19.2 ± 4.1 vs. 11.7 ± 4.9, P < 0.001) and higher lactate levels on
6. Discussion

Surviving sepsis campaign guidelines have incorporated both 3-h and 6-h bundles to guide management of severe sepsis with evidence of tissue hypoperfusion. Surviving sepsis campaign recommended MAP < 65 mmHg and lactate ≥4 mmol/l as surrogates for tissue hypoperfusion and need for further fluid resuscitation.

In current study, fluid responders had shorter length of ICU stay, (6.5 ± 2.3 vs. 12.9 ± 6.5, P 0.001). This was in concordance with Lopes et al. who examined the relation between maximizing stroke volume (volume loading) during high-risk surgery and post-operative outcome. He concluded that maximizing stroke volume improved postoperative outcome and decreased the length of stay in hospital [11]. Our findings also showed that fluid responders had better survival rates and optimizing cardiac output could help in guiding fluid therapy to potential fluid responders with expected better morbidity and mortality outcomes.

Several static measures were examined as surrogates for fluid status. However, the poor predictive value of static measures and clinical examination has led to investigation of the dynamic measures of fluid responsiveness. Monnet et al. showed that Pulse pressure and systolic arterial pressure could be used for detecting the fluid-induced changes in cardiac output. However, changes in pulse pressure and systolic arterial pressure were unable to detect the changes in cardiac output induced by norepinephrine [12].

Pierrakos et al. also wrote that changes in MAP do not reliably track changes in CI after fluid challenge in patients with septic shock and, consequently, should be interpreted carefully when evaluating the response to fluid challenge in such patients [13].

Vincent concluded that the changes in MAP are dissociated from the changes in cardiac output because of the sympathetic modulation of the arterial tone, which tends to maintain MAP constant while cardiac output varies. These results suggested that precise assessment of the effects of volume expansion should not rely on simple blood pressure measurements but should rather be based on direct measurements of cardiac output [1].

Zhang et al. demonstrated that an optimization protocol, based on stroke volume variation and cardiac index, increased the PaO2/FiO2-ratio and reduced the overall fluid volume, intubation time and postoperative complications in thoracic surgery patients requiring one-lung ventilation [14].

A recent meta-analysis of randomized controlled studies also showed superiority of early goal directed protocol over standard protocol in terms of survival benefits [2]. Currently, Surviving Sepsis Campaign (SSC) offers clarification on the implications of the new definition statements and guidance for hospitals [3].

Electrical cardiometry has been validated to monitor non-invasively cardiac output in a variety of situations, including critically ill patients, intra-operative settings, and cardiac catheterization and in children with congenital heart diseases [4–7]. In our study, we utilized electrical velocimetry to predict positive fluid response and predict survival in acute circulatory failure, frequently met in sepsis patients. A cutoff 12.5% for delta CO to predict fluid responsiveness had sensitivity 90.0%, and specificity 70.0%. The same cutoff could predict survival with sensitivity 66.7% and specificity 66.7%. To our knowledge, this is the first study to document role of electrical velocimetry in predicting septic patients’ survival and positive fluid response with acute circulatory failure.

7. Limitations

Small sample size and need for larger samples to confirm our results. Also, readings of electrical velocimetry were not validated against thermodilution techniques to assess cardiac output in septic patients.

8. Conclusion

Monitoring cardiac output, using electrical velocimetry could be used to guide fluid therapy in critically ill patients, with beneficial impact on morbidity and mortality.

9. Consent

We have obtained consent from the participant (or legal parent or guardian) to report individual patient data.

Conflict of interest

The authors declare that there is no conflict of interest.

Protection of human and animal subjects. The authors declare that the procedures followed were in accordance with the regulations of the relevant clinical research ethics committee and with those of the Code of Ethics of the World Medical Association (Declaration of Helsinki).

Confidentiality of data. The authors declare that they have followed the protocols of their work center on the publication of patient data.

Right to privacy and informed consent. The authors have obtained the written informed consent of the patients or subjects mentioned.
in the article. The corresponding author is in possession of this document.

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References