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ORIGINAL ARTICLE

Non invasive adjustment of fluid status in critically ill patients on renal replacement therapy. Role of Electrical Cardiometry

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KEYWORDS

Electrical Cardiometry;
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Abstract *Background:* Electrical Cardiometry allows measurement of fluid status using thoracic fluid content (TFC), cardiac output, cardiac index, systemic vascular resistance index which could be ideal noninvasive hemodynamic monitoring for patients undergoing hemodialysis (HD). *Objectives:* Investigating the relation between changes in TFC and amount of fluid removal during HD session and to monitor hemodynamic parameters to avoid episodes of hemodynamic compromise during HD session. *Methods:* Thirty critically ill patients on HD were enrolled. Clinical assessment of volume overload and hemodynamics (BP, MAP, CVP), monitored by Electrical Cardiometry ICON® before HD and all through sessions. *Results:* Out of studied patients males represented 46.7% (n = 14) with mean age 48 ± 16 years. There was positive correlation between UF volume and TFC (r = 0.410, P = 0.025). Out of the 30 pts studied 18 pts (60%) were hemodynamically stable vs 12 pts (40%) that had hypotension represented by non responders group and had lower TFC compared to the hemodynamically stable group (26.45 kohm^{-1} vs 37.8 kohm^{-1}) with P value of 0.004 indicating that they were hypovolemic. Out of the 30 pts studied 18 pts (60%) weren't congested vs 12 pts (40%) remained persistently congested after accomplishing HD session with significantly higher TFC when compared to those who got rid of congestion (43.14 ± 9.9 kohm^{-1} vs 25.44 ± 5.5 kohm^{-1}) with P value of 0.0001 indicating that they were still hypervolemic. Using analysis of ROC curve TFC at 25.34 kohm^{-1} was a significant predictor of hypotension with P value of 0.002, AUC 83.4%, sensitivity 67% and specificity 100%. Also TFC cutoff value predicting persistent congestion was 37.02 kohm^{-1} with P value of 0.0001, AUC 95.8%, sensitivity 83% and

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specificity 100%. *Conclusion:* Electrical Cardiometry is an evolving noninvasive tool for adjusting fluid status of critically ill patient on RRT using thoracic fluid content as an indicator of fluid status that could be used to avoid hemodynamic instability and persistent volume overload and congestion during and after HD session.

1. Introduction

Intradialytic hypotension and orthostatic hypotension after the procedure are significant and independent risk factors affecting mortality in dialysis patients [1].

Several noninvasive methods for hemodynamic monitoring and determination of fluid status of critically ill patients have been developed. That can aid the intradialytic assessment of fluid removal objectively and avoid hemodynamic instability [2].

Impedance cardiography (ICG) and Electrical Cardiometry (EC) are recently developed technologies to measure thoracic fluid content (TFC), cardiac output (CO) and other hemodynamic parameters. Both ICG and EC derive CO from measurements of Thoracic Electrical Bioimpedance (TEB) [3].

TEB is the electrical resistance to high frequency low amplitude current that is transmitted from electrodes placed on the upper and lower thorax. The resultant value is indirectly proportional to the volume of thoracic fluids such that increasing fluid in the thorax results in less TEB. Therefore, the inverse of TEB, and thus changes in CO, are reflected as a change in total bioimpedance or fluid conductivity [3].

One of the parameters examined is thoracic fluid content (TFC), which is inversely associated with the patient's transthoracic electrical bioimpedance, and reflects the total (intravascular and extravascular) fluid volume contained in the chest cavity [4].

The fluid content is a pronouncedly variable parameter of a human's chest and this is why the dynamic measurements of chest impedance by means of ICG can reliably and accurately reflect its alterations. Potential changes in thoracic fluid content are directly proportional to total fluid changes; thus, ICG and EC parameters can prove to be extremely significant for the monitoring of thoracic blood volume changes during hemodialysis (HD) session [5].

The aim of our study was to investigate the relation between changes in the TFC and the amount of ultra filtration fluid volume and to provide a means of easily tracking fluid status during hemodialysis, to help in adjusting fluid removal (rate and amount). Secondly to continuously monitor hemodynamic parameters with the ultimate goal of understanding how monitoring patients with this system can help to avoid episodes of clinically significant hemodynamic compromise.

2. Patients and methods

Our study was designed as a cross-sectional study that was conducted between June 2014 and March 2015 in the critical care medicine department of Cairo university hospitals.

The study enrolled thirty critically ill patients on renal replacement therapy admitted because of renal failure (acute or chronic), AND/OR fluid overload due to cardiac or hepatic causes. Patients less than 18 years old, with implantable cardiac pace maker or defibrillator, significant valvular lesions and pleural effusion, pregnant females, end stage hepatic, cardiac or pulmonary diseases, terminal malignancy and patients refused to participate in the study were excluded.

The study was approved by our local scientific and ethics committee. All enrolled patients had signed an informed consent for participation in the study and subjected to detailed history taking and thorough clinical examination for clinical signs of volume overload including congested neck veins, orthopnea, rales on chest auscultation, and lower limb edema. Weighing the patient before and after HD session, CVP measurement before and after HD session and SBP, DBP and MAP measurement every 30 min, full laboratory investigations including blood gases, electrolytes and renal function, 12 lead ECG recordings and routine echocardiography examination including assessment of systolic function by 2D imaging, Doppler and M mode function, measurement using ATL machine 33 with 3.5 mHz probe.

Chest X-ray examination for detection of pulmonary congestion, abnormal chest X-ray was defined as having abnormal fluid (pulmonary congestion) if they were graded 1, 2 or 3 Table 1 [6,7].

All patients were monitored during HD session using new model "EC" based device (ICON®) starting 15–30 min prior to HD and every 30 min thereafter, with a 15 to 30 min stabilization period after the termination of HD session.

The Electrical Cardiometry monitor (Electrical Cardiometry monitor, ICON® Cardiotronics, Inc.) 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.

The ICON® device emits a high frequency (50 kHz) and low-amperage (2 mA) alternating electrical current of constant amplitude via a pair of surface electrodes across the left side of the thorax. The voltage drop due to the current application is

Table 1 Chest radiography grading definitions [7].

Garde	Chest X-ray grading
Grade 0	Normal pulmonary vascular distribution
Grade 1	Stage 1 pulmonary venous hypertension: vascular redistribution due to hypoxia induced basilar vasoconstriction from non visualized early edema
Grade 2	Stage 2 pulmonary venous hypertension: vascular redistribution due to early "peribronchial cuffing" or late "Kerly's B line" interstitial edema
Grade 3	Stage 3 pulmonary venous hypertension: vascular redistribution and perihilar pulmonary edema