Original Research Article

Fluid Management Using Cardiometry in ARDS Patients

Abstract

Background: Fluid management is a complicated subject and one of the most difficult facets of medical care. Fluid balance has been shown to improve respiratory physiology for acute respiratory distress syndrome (ARDS) patients. The aim of this study was to assess the role of electrical cardiometry (EC) in fluid management in ARDS.

Methods: This pilot interventional study was carried on 15 patients who were 18 years or older and fulfill the Berlin definition of ARDS. Fluid management was guided by EC.

Results: ICU stay has a mean value of 13.67 ± 4.58 days and duration of MV has with a mean value of 10.27 ± 4.34 days. Lung injury score decreased significantly at 7, 14, 21, 28 days when compared to baseline. Intravenous fluid intake had significantly decreased in 4,5,6,7 days when compared to the 1st day. Urine output has significantly decreased in 5,6,7 days when compared to the 1st day. Hemodynamic instability was in 20% of patients, heart failure in 13.3% of patients, sepsis in 20.0% of patients and organ failure in 26.7% with no renal failure and no arrythmia.

Conclusions: EC was effective in the fluid management in ARDS as regards decreasing 28th day mortality, LIS, fluid intake, duration of MV and ICU stay.

Na conclusão do abstract citam a sigla “LIS”, mas antes não a descrevem, é preciso descrever antes de citarem a sigla.

Keywords: Electrical cardiometry, Fluid management, Acute respiratory distress syndrome.

1.Introduction:

Acute respiratory distress syndrome (ARDS) is a life-threatening condition characterized by poor oxygenation and non-compliant or "stiff" lungs. The disorder is associated with capillary endothelial injury and diffuse alveolar damage. Once ARDS develops, patients usually have varying degrees of pulmonary artery vasoconstriction and may subsequently develop pulmonary hypertension [1].

ARDS carries a high mortality, and few effective therapeutic modalities exist to ameliorate this deadly condition. This activity reviews the clinical presentation, evaluation, and management of acute respiratory distress syndrome and highlights the importance of coordinated interprofessional teamwork in caring for patients with this condition [2].

The diagnosis of ARDS depends upon the exclusion of cardiogenic pulmonary edema as well as several other competing etiologies (e.g., acute eosinophilic pneumonia). Similarly, ARDS may be complicated by conditions including pneumothorax, ventilator-associated pneumonia, or pulmonary embolism. Reasonably excluding such etiologies is appropriate before discontinuing LTVV and resorting to additional strategies [3].

Fluid management is a critical aspect of patient care, especially in the inpatient medical setting. What makes fluid management both challenging and interesting is that each patient demands careful consideration of their individual fluid needs. Unfortunately, it is impossible to apply a single, perfect formula universally to all patients. However, one general principle for all patient scenarios is to replace whatever fluid is being lost as accurately as possible. These fluid losses can differ depending on patients' medical conditions and differ by both volume and composition [4].

Fluid balance has been demonstrated to benefit ARDS patients' respiratory physiology [5]. However, numerous investigations have demonstrated that these indices are incapable of correctly predicting fluid responsiveness [6]. Instead, while time-varying indicators such as pulse pressure variation, systolic pressure fluctuation, stroke volume variation (SVV), and pleth variability index (PVI) have been acknowledged as efficient predictors of fluid responsiveness for ventilated patients, dynamic indicators like these have been previously overlooked. SVV has been demonstrated to be the most trustworthy of these indicators for determining volume status in chronic patients [7].

Bernstein and Osypka developed and described the technical background of electrical cardiometry (EC), a new model for interpreting thoracic bioimpedance [8]. EC is a technique used to determine the stroke volume (SV),CO, and other hemodynamic parameters in adults, children, and newborns [9].

The aim of this study was to assess the role of EC in fluid management in ARDS.

2. Material and methods:

This pilot interventional study was carried out on 15 patients with ARDS who underwent EC-guided fluid management in Tanta University Hospital - Egypt at surgical intensive care unit (SICU) from January 2020 to December 2020. The study was done after approval from institutional ethics committee. Written informed consent had been obtained from the patients' relatives.

Patients included in this study were 18 years of age or older and met the Berlin criteria of mild to moderate ARDS. Hemodynamic instability, vasopressor usage, barotrauma, or organ/s malfunction at presentation or throughout pregnancy were excluded as exclusion criteria. Redundante

All patients were ventilated according to basal ventilator strategy of ARDS- network protocol **[10]** using volume assist-control mode, with tidal volume 4 to 8 mL/kg predicted body weight, an inspiratory plateau pressure < 30 cmH_2O. The ventilator rate was adjusted to achieve a pH >7.25 to 7.44, maximum respiratory rate 35 cycle/min. FiO_2 levels were manipulated to maintain peripheral oxygen saturation between 90 and 95 % or PaO_2 between 60 and 80 mmHg. Titration of PEEP according to FiO_2 as recommended by ARDS-network.

2.1. Electrical cardiometry:

EC monitor was attached to the sensor cable and patient data were sent into it (ICON Cardiotronics, Inc., La Jolla, CA 92307; Osyka Medical GmbH, Berlin, and Germany, model C3, serial number 1725303). The corrected flow time (FTC) and SV were continuously monitored. Fluids were allowed using the FTc algorithm, and the kind of bolus fluids was decided by the transthoracic fluid content (TFC). Vasopressors and inotropes were given in line with the EC, SVR, and ICON.

2.2. Measurements

Parameters of oxygenation by lung injury score (LIS), total intravenous fluid intake and urine output were recorded at the beginning of the study inclusion, 12 hours post-inclusion, and then on day 1, 2, 3, 4, 5, 6, 7, 14, 21, and 28.

Incidence of mortality at 28th day, duration of MV, duration of ICU stay, weaning categories and adverse effects (such as hemodynamic instability, or organ/s failure) were recorded.

2.3. Statistical analysis

Statistical analysis was done by SPSS v26 (IBM Inc., Chicago, IL, USA). Shapiro-Wilks test and histograms were used to evaluate the normality of the distribution of data. Quantitative parametric data were presented as mean and standard deviation (SD) and were compared by repeated measured ANOVA. Quantitative non-parametric data were presented as median and interquartile range (IQR). Qualitative variables were presented as frequency and percentage (%).

3. Results:

Consider use of a flow diagram - report numbers of individuals confirmed eligible and included in the study. If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period

Patients' characteristics of the studied patients. Table 1

Table 1 :Patients' characteristics

I suggest adjusting the configuration of the tables, in the format they are frames and not tables.

		EC group (n = 15)
Age (years)		48.6 ±11.96
BMI (kg/mm^2)		27.27 ± 3.59
Sex	**Male**	4 (26.67%)
	Female	11 (73.33%)
Cause of ARDS	**Pneumonia**	12 (80.00%)
	Aspiration	3 (20.00%)
Severity of ARDS	**Mild**	9 (60.00%)
	Moderate	6 (40.00%)

Data are presented as Mean ± SD or frequency (percent), BMI: body mass index, ARDS: acute respiratory distress syndrome

ICU stay has a mean value of 13.67 ± 4.58, duration of MV (days) was with a mean value of 10.27 ± 4.34, MV free days (days) with a median (IQR) 5 (0-6), Weaning categories were simple, difficult and prolonged. Table 2

Table 2: ICU stay, duration of MV, MV free days and weaning in the studied patients

		EC group (n = 15)
ICU stay (days)		13.67 ± 4.58
Duration of MV (days)		10.27 ± 4.34
MV free days (days)		5 (0-6)
Successful weaning		13 (87%)
Weaning categories	**Simple**	1 (7%)
	Difficult	9 (60%)
	Prolonged	2 (13%)

Data are presented as Mean ± SD or Median (IQR) or frequency (percent), ICU: intensive care unit, MV: mechanical ventilation.

Lung injury score decreased significantly at 7, 14, 21, 28 days when compared to baseline. Figure 1

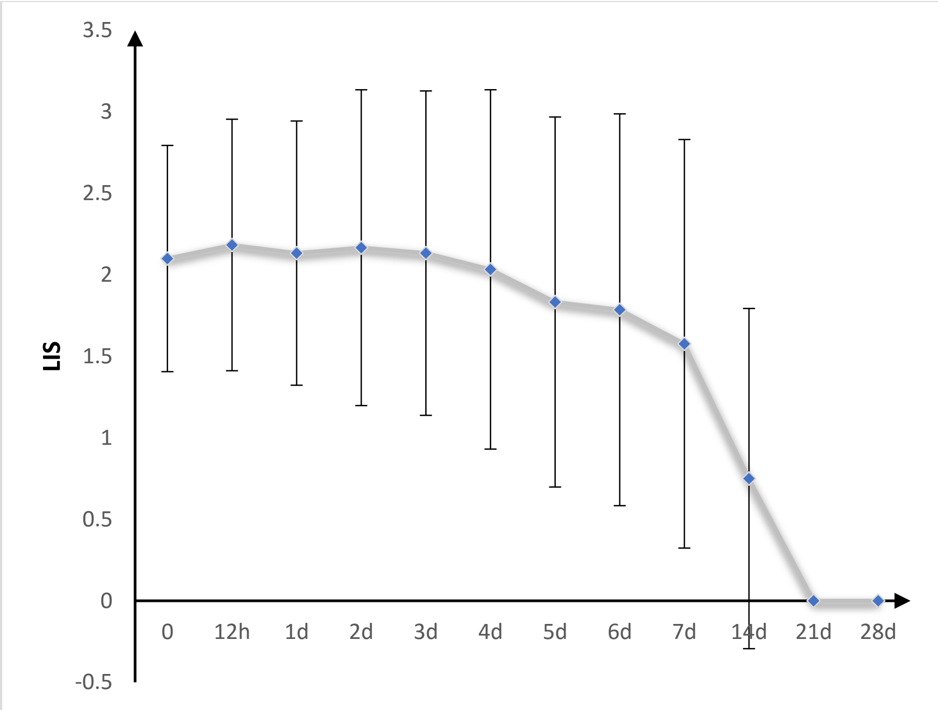

Figure1: Lung injury score (LIS) in the studied patients

Intravenous fluid intake had significantly decreased in 4,5,6,7 days when compared to the 1st day. Figure 2

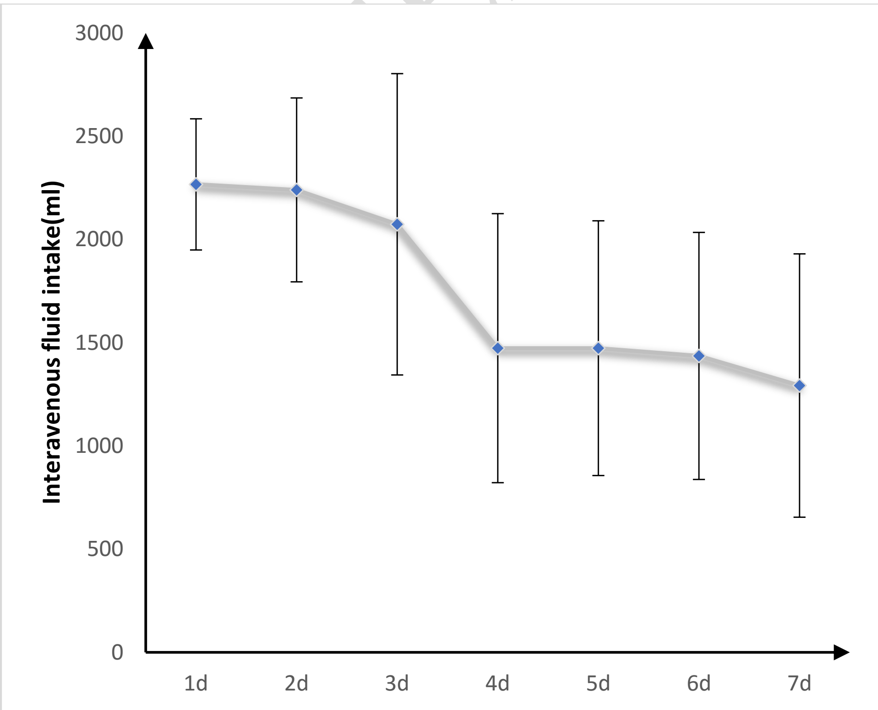

Figure 2: Intravenous fluid intake (ml) in the studied patients

Urine output has significantly decreased in 5,6,7 days when compared to the 1st day. Figure3

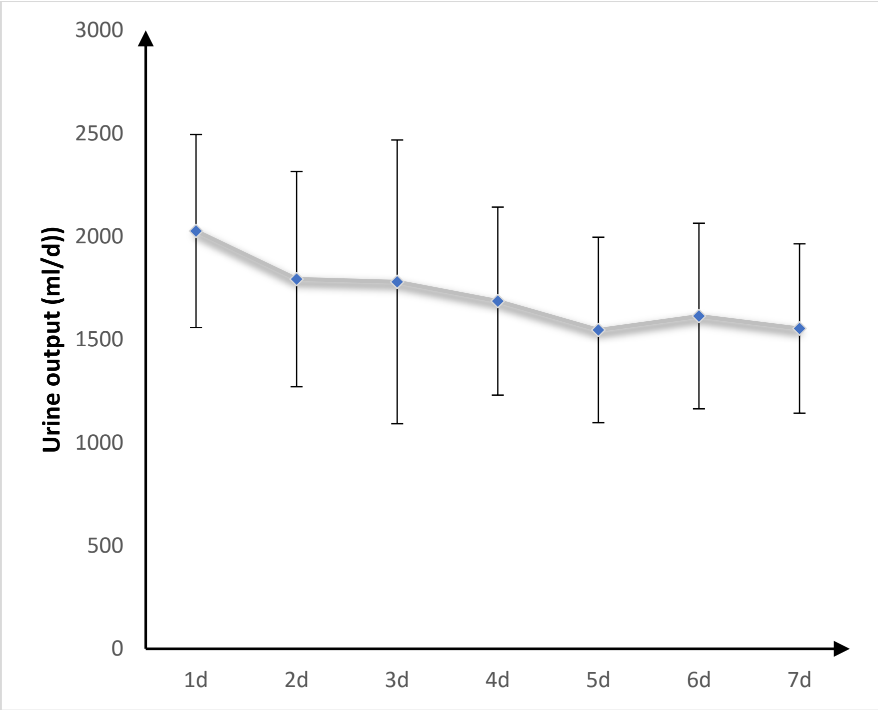

Figure3: Urine output (ml/d) of the studied patients

As regard complication, hemodynamic instability was in 20% of patients, heart failure in 13.3% of patients, sepsis in 20.0% of patients, organ failure in 26.7% with no renal failure and no arrythmia.

4. Discussion

Summarise key results with reference to study objectives in the first discussion paragraph

To our knowledge, this is the first study to examine the role of EC in ARDS patients. The development of a technology for continuous monitoring of SV and CO that is noninvasive, safe, reliable, and easy to use would be a monumental advancement for research and clinical use. The EC shows accuracy and precision in studies of healthy volunteers. However, the reliability of perioperative use is not proven especially with skin incision, which may be a source of error in bioimpedance measurements [12].

EC has been validated to monitor CO and other hemodynamic parameters non-invasively compared to different techniques such as thermodilution technique [15, 16], transesophageal Doppler echocardiography and cardiac catheterization including critically ill patients [16, 17], intra-operative settings, in pregnant women, in children with congenital heart diseases, even in obese children. **Elgebaly et al.** [18] For noninvasive continuous CO monitoring after lobectomy or pneumonectomy, EC was compared to transthoracic echocardiography (TTE). In contrast to the TTE, the EC provided accurate and reliable CO, SV, and HR measurements before to and after lung surgery.

However, in disagreement to the accuracy of EC, **Cox et al.** [12] demonstrated that cardiac index (CI) obtained by continuous pulmonary artery thermodilution catheter and CI obtained by EC are not interchangeable in cardiac surgical patients. This difference may be related to the skin incision done in cardiac surgeries.

The improvement in outcome seen in our study with the EC-guided fluid management patients may be a result of the more restricted fluid intake. Fluid overload has been linked to organ failure and is well recognized as a major predictor of poor outcomes. Consistent evidence indicates that fluid restriction may be associated with better outcomes, especially in critical illness and ARDS. [20-22].

This was in accordance with, **Afandy et al.** [23] compared echocardiography (echo) derived indices to Indicators generated from EC in the therapy of septic patients. The EC-guided treatment group had a substantially lower mortality rate than the Early Goal Directed Therapy (EGDT) group. The EC group, on the other hand, required a longer period to wean off vasopressors and MV, as well as a lengthier stay in the ICU and hospital.

In disagreement to our results, **Gerent et al.** [27] assessed EC on patients receiving high-risk surgery for cancer treatment. Between the EC and standard care groups, there were no significant changes in mortality or any of the secondary outcomes (septic shock, ICU readmission, ICU stay). There was no significant difference in ICU or hospital stay, which may be explained by controlling preload through fluid loading until pressure pulse variation (PPV) was 10% in both groups.

The study's limitations include a limited sample size, a single-center design, and a follow-up period of just 28 days.

5. Conclusions:

EC was effective in the fluid management in ARDS as regards decreasing 28th day mortality, LIS, fluid intake, duration of MV and ICU stay.

COMPETING INTERESTS DISCLAIMER:

Authors have declared that no competing interests exist. The products used for this research are commonly and predominantly use products in our area of research and country. There is absolutely no conflict of interest between the authors and producers of the products because we do not intend to use these products as an avenue for any litigation but for the advancement of knowledge. Also, the research was not funded by the producing company rather it was funded by personal efforts of the authors.

References:

1. Feliciano H, Mahapatra S. Acute Respiratory Distress Syndrome (ARDS). 2017.

2. Shah F, Girard T, Yende S. Limiting sedation for patients with acute respiratory distress syndrome – time to wake up. Current Opinion in Critical Care. 2016;23:1.

3. Kotas ME, Thompson BT. Toward Optimal Acute Respiratory Distress Syndrome Outcomes: Recognizing the Syndrome and Identifying Its Causes. Crit Care Clin. 2021;37:733-48.

4. Martin C, Cortegiani A, Gregoretti C, Martin-Loeches I, Ichai C, Leone M, et al. Choice of fluids in critically ill patients. BMC anesthesiology. 2018;18:1-14.

5. Wiedemann HP, Wheeler AP, Bernard GR, Thompson BT, Hayden D, deBoisblanc B, et al. Comparison of two fluid-management strategies in acute lung injury. N Engl J Med. 2006;354:2564-75.

6. Kim KM, Gwak MS, Choi SJ, Kim MH, Park MH, Heo BY. Pulse pressure variation and stroke volume variation to predict fluid responsiveness in patients undergoing carotid endarterectomy. Korean J Anesthesiol. 2013;65:237-43.

7. Slagt C, Malagon I, Groeneveld AB. Systematic review of uncalibrated arterial pressure waveform analysis to determine cardiac output and stroke volume variation. Br J Anaesth. 2014;112:626-37.

8. Osypka MJ, Bernstein DP. Electrophysiologic principles and theory of stroke volume determination by thoracic electrical bioimpedance. AACN Clin Issues. 1999;10:385-99.

9. Suehiro K, Joosten A, Alexander B, Cannesson M. Guiding goal-directed therapy. Curr Anesthesiol Rep. 2014;4:360-75.

10. Rosenberg AL, Dechert RE, Park PK, Bartlett RH. Review of a large clinical series: association of cumulative fluid balance on outcome in acute lung injury: a retrospective review of the ARDSnet tidal volume study cohort. J Intensive Care Med. 2009;24:35-46.

11. Kangelaris KN, Calfee CS, May AK, Zhuo H, Matthay MA, Ware LB. Is there still a role for the lung injury score in the era of the Berlin definition ARDS? Annals of intensive care. 2014;4:4-.

12. Cox PBW, den Ouden AM, Theunissen M, Montenij LJ, Kessels AGH, Lancé MD, et al. Accuracy, Precision, and Trending Ability of Electrical Cardiometry Cardiac Index versus Continuous Pulmonary Artery Thermodilution Method: A Prospective, Observational Study. Biomed Res Int. 2017;2017:2635151.

13. Seitz KP, Caldwell ES, Hough CL. Fluid management in ARDS: an evaluation of current practice and the association between early diuretic use and hospital mortality. J Intensive Care. 2020;8:78.

14. Ho HS, Saunders CJ, Gunther RA, Wolfe BM. Effector of hemodynamics during laparoscopy: CO2 absorption or intra-abdominal pressure? J Surg Res. 1995;59:497-503.

15. Rajput RS, Das S, Chauhan S, Bisoi AK, Vasdev S. Comparison of Cardiac Output Measurement by Noninvasive Method with Electrical Cardiometry and Invasive Method with Thermodilution Technique in Patients Undergoing Coronary Artery Bypass Grafting. World J Cardiovasc Surg. 2014;4:123-30.

16. Zoremba N, Bickenbach J, Krauss B, Rossaint R, Kuhlen R, Schälte G. Comparison of electrical velocimetry and thermodilution techniques for the measurement of cardiac output. Acta Anaesthesiol Scand. 2007;51:1314-9.

17. Soliman R. Prediction of fluid status and survival by electrical cardiometry in septic patients with acute circulatory failure. Egypt J Crit Care Med. 2017;5:65-8.

18. Elgebaly AS, Anwar AG, Fathy SM, Sallam A, Elbarbary Y. The accuracy of electrical cardiometry for the noninvasive determination of cardiac output before and after lung surgeries compared to transthoracic echocardiography. Ann Card Anaesth. 2020;23:288-92.

19. Sanders M, Servaas S, Slagt C. Accuracy and precision of non-invasive cardiac output monitoring by electrical cardiometry: a systematic review and meta-analysis. J Clin Monit Comput. 2020;34:433-60.

20. Silversides JA, Major E, Ferguson AJ, Mann EE, McAuley DF, Marshall JC, et al. Conservative fluid management or deresuscitation for patients with sepsis or acute respiratory distress syndrome following the resuscitation phase of critical illness: a systematic review and meta-analysis. Intensive Care Med. 2017;43:155-70.

21. Silversides JA, Fitzgerald E, Manickavasagam US, Lapinsky SE, Nisenbaum R, Hemmings N, et al. Deresuscitation of Patients With Iatrogenic Fluid Overload Is Associated With Reduced Mortality in Critical Illness. Crit Care Med. 2018;46:1600-7.
22. Cordemans C, De Laet I, Van Regenmortel N, Schoonheydt K, Dits H, Martin G, et al. Aiming for a negative fluid balance in patients with acute lung injury and increased intra-abdominal pressure: a pilot study looking at the effects of PAL-treatment. Ann Intensive Care. 2012;2 Suppl 1:S15.
23. Afandy ME, El Sharkawy SI, Omara AF. Transthoracic echocardiographic versus cardiometry derived indices in management of septic patients. Egypt J Anaesth. 2020;36:312-8.
24. Zhao G, Peng P, Zhou Y, Li J, Jiang H, Shao J. The accuracy and effectiveness of goal directed fluid therapy in plateau-elderly gastrointestinal cancer patients: a prospective randomized controlled trial. Int J Clin Exp Med. 2018;11:8516-22.
25. Muñoz JL, Gabaldón T, Miranda E, Berrio DL, Ruiz-Tovar J, Ronda JM, et al. Goal-Directed Fluid Therapy on Laparoscopic Sleeve Gastrectomy in Morbidly Obese Patients. Obes Surg. 2016;26:2648-53.
26. Weinberg L, Mackley L, Ho A, McGuigan S, Ianno D, Yii M, et al. Impact of a goal directed fluid therapy algorithm on postoperative morbidity in patients undergoing open right hepatectomy: a single centre retrospective observational study. BMC Anesthesiol. 2019;19:135.
27. Gerent ARM, Almeida JP, Fominskiy E, Landoni G, de Oliveira GQ, Rizk SI, et al. Effect of postoperative goal-directed therapy in cancer patients undergoing high-risk surgery: a randomized clinical trial and meta-analysis. Critical Care. 2018;22:1-11.