Fluid responsiveness assessment in Patients Managed with Extracorporeal Membrane Oxygenation using Electrical Cardiometry

Ahmed Yehia Mohamed, Yasser S Nassar, Akram M Abdelbary, Helmy H Elghawaby, Mahmoud S Nwar

Article History: Received:30.04.2023 **Revised:** 29.05.2023 **Accepted:** 06.06.2023

Abstract:
Background: An adequate correction of instability and tissue hypoperfusion during a proper time before the occurrence of irreversible shock is essential. ICON™ was utilized to detect increased thoracic fluid content (TFC) in ECMO patients.
Objective: This study was conducted to detect increased intrathoracic fluid content in ECMO patients and the accuracy of ICON™ to predict fluid responsiveness.
Patients and methods: This study is a prospective cross-sectional study on ten adult patients who were admitted to critical care department, Cairo University over a period of twenty months starting from June 2020 to February 2022and were eligible to ECMO (both VA and VV ECMO). Hemodynamic monitoring using Electrical cardiometry was done using ICON™. ICON™ was utilized to detect increased thoracic fluid content and predict fluid responsiveness. Assessment of fluid responsiveness was evaluated clinically and or by giving fluid challenge and recalculation of stroke volume using echocardiography if increased by 12 % or more considered fluid responder.
Results: ICON™ can used to detect increased intrathoracic fluid content and there was statistically significant positive correlation with ECMO flow and in VV ECMO group but statistically significant negative correlation in venoarterial ECMO group. ICON™ can predict fluid responsiveness in patients connected to venovenous ECMO and the cut of point was 12.5% increase in cardiac output in fluid responders.
Conclusion: ICON™ can predict fluid responsiveness in patients connected to VV ECMO.
Keywords: Extracorporeal Membrane Oxygenation, fluid response, Electrical Cardiometry

Critical Care Medicine Faculty of Medicine, Cairo University, Egypt.
[*]**Corresponding email:** ahmed-yehia@kasralainy.edu.eg

DOI: 10.48047/ecb/2023.12.8.50

Introduction:

An adequate correction of instability and tissue hypoperfusion during a proper time before the occurrence of irreversible shock is essential in critically ill patients [1].

Extracorporeal membrane oxygenation (ECMO) refers to a circuit that directly oxygenates and removes carbon dioxide from blood through an extracorporeal gas exchange device, commonly referred to as a membrane oxygenator [2].

Assessment of hemodynamics in extracorporeal membrane oxygenation patients is very important. ICON™ was utilized to detect increased thoracic fluid content (TFC) in ECMO patients (e.g., pulmonary edema, pleural effusion) [3].

TFC, correlates closely with the amount of fluid, both intravascular and extravascular, in the chest. In patients after pleurocentesis. a high degree of correlation is present between the amount of fluid obtained and the change in chest impedance [4]. a nearly ideal linear correlation is present between changes in central venous pressure and chest impedance [5]. This study was conducted to assess the utilization of ICON™ to detect increased intrathoracic fluid content in ECMO patients and the accuracy of ICON™ to predict fluid responsiveness.

Patients and methods:

This study is a prospective cross-sectional study on ten adult patients who were admitted to ***critical care department, Cairo university*** over a period of twenty months starting from June 2020 to February 2022and were eligible to ECMO (both VA and VV ECMO) after obtaining an informed written consent from the patients' next of kin or legal guardians before conducting the study regarding participation and publication of the study.

The study was approved by the Medical Ethics Committee of Cairo faculty of Medicine.

Patients

Inclusion criteria:

- Adults more than 18 years
- Genders eligible for study: both.

Exclusion criteria

Numerous factors may interfere with the accuracy of Electrical bioimpedance measurements as:

- Inability to attach neck or chest leads (e.g., Surgical dressing)
- Extensive chest wall edema
- Dilatation of the aorta; severe mitral regurgitation; severe aortic regurgitation.
- Electrical bioimpedance measurement may also be inaccurate if the patient is moving, agitated, restless, shivering, or hyperventilating

Methods

All patients were subjected to the following:

Detailed history taking, Full physical examination including assessment the vital signs [Heart rate (HR), respiratory rate (RR), oxygen saturation (So2) and temperature (Temp)].

Hemodynamic monitoring using Electrical cardiometry was done using ICON™ device from OSYPKA medical

- ICON™ is connected to the patients though four electrodes on the left side of the body

A: Over the forehead.
B: Root of the neck over the neck veins.
C: Opposite to the level of the Xiphoid process.
D: over the thigh.

- FTc which is the time of blood in the aorta (used for assessment of fluid status and patients preload)
- Stroke volume variation estimated by the electrical cardiometry
- Index of contractility (ICON parameter) which estimated by electrical cardiometry and reflects cardiac contractility

- Signal quality indicator (SQI): which determined the quality of the signal received by the device and SQI ranged from 60 to 100 to ensure the accuracy of ICON™ data
- Thoracic fluid content was used to detect increased intrathoracic fluid content.
- Assessment of fluid responsiveness was evaluated clinical ly and or by giving fluid challenge and recalculation of SV using echocardiography if increased by 12 % or more considered fluid responder.

1- <u>Measurements</u>

ICON™ values were taken: In VV ECMO patients 675 paired values were done, In VA ECMO patients 343 paired values were done

Also, Thoracic fluid content readings, stroke volume variations, corrected flow time and Index of contractility (ICON)

- Cardiac contractility was assessed by echocardiography (ejection fraction)

2- <u>Patients connected to ECMO</u>

- VV ECMO through femoral to jugular veins
- VA ECMO through femoral vein to femoral artery.

IN VA ECMO patients Total Cardiac output equals native Cardiac output and ECMO FLOW

Statistical methods:

Data were coded and entered using the statistical package for the Social Sciences (SPSS) version 28 (IBM Corp., Armonk, NY, USA). Data was summarized using mean and standard deviation for quantitative variables and frequencies (number of cases) and relative frequencies (percentages) for categorical variables. Comparisons between groups were done using unpaired t test. Comparison between paired values measured by the 2 methods was done using paired t test **.** Correlations between quantitative variables were done using Pearson correlation coefficient **.** ROC curve was constructed with area under curve analysis performed to detect best cutoff value of significant parameters for detection of response. Testing for inter-rater and intra-rater reliability was done using the Intra Class Coefficient (ICC) and Cronbach's alpha reliability coefficient with their 95% confidence interval (95%CI)**.** P-values less than 0.05 were considered as statistically significant**.**

Results:

Our study included 10 patients, supported by ECMO, six patients were connected to VV ECMO (675 paired values) and four patients were connected to VA ECMO (343 paired values)

Descriptive data

The age of the studied patients in VA ECMO group ranged from 40 to 65 years with a mean of 51 years, While in VV ECMO group, the age of the studied patients ranged from 30 to 55 years with a mean of 39 years. Seven (70%) of the studied patients were males and three (30%) were females, other descriptive data in table 1.

Table (1): Descriptive data

	Mean	SD	Minimum	Maximum
TFC in VV ECMO group	41.94	9.69	25.00	56.00
TFC in VA ECMO group	29.77	6.20	19.00	36.00

Utilization of ICON™ in detection of increased intrathoracic fluid content (TFC)

TFC estimated with ICON™ was correlated with clinically increased thoracic fluid content (e.g., pulmonary edema, pleural effusion)

Increased TFC values ranged from 34 to 96 kΩ−1 and mean was 52.2 kΩ−1 ±20.3 while normal TFC ranged from 36 to 65 kΩ−1 with mean 45.6 kΩ−1 ±8.1 as in table 2.

Table (1): Thoracic fluid content in studied group

Increased TFC				Normal TFC				P value
Mean	**SD**	**Minimum**	**Maximum**	**Mean**	**SD**	**Minimum**	**Maximum**	
52.26	20.31	34.00	96.00	45.60	8.12	36.00	65.00	< 0.001

Assess the accuracy of corrected Flow Time (FTc) to assess fluid responsiveness.

A- <u>VV ECMO group:</u>

Corrected flow time (FTc) in fluid responder ranged from 247 to 410 ms and mean was 333.8 ms ± 31 and in non-responders, ranged from 247 to 530 ms and mean was 367.3ms ± 18.5. There was statistically significant correlation **(p value < 0.001)** as **in table (3) and figure (1)**

Table (2): Corrected Flow time in studied group

	Non Responder				Responder				P value
	Mean	**SD**	**Minimum**	**Maximum**	**Mean**	**SD**	**Minimum**	**Maximum**	
(FTc)	367.34	62.34	247.00	530.00	333.84	31.53	247.00	410.00	<0.001

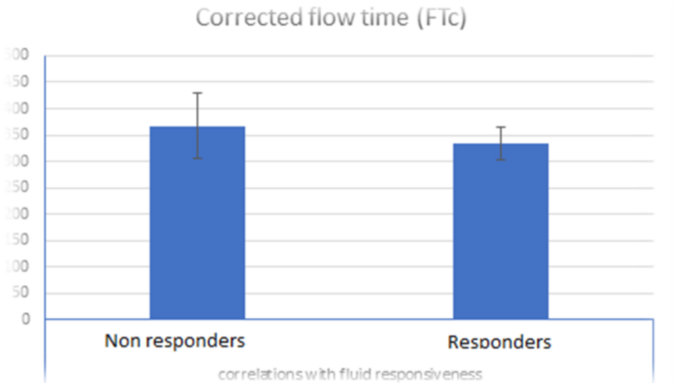

Figure (1): Corrected flow time in fluid responder and non-responders

ROC curve for detection of fluid responders using Corrected flow time (FTc)

AUC was 0.7 with sensitivity and specificity 81.9% and 64.7% respectively (**P value 0.002),** the cut off point for fluid responsiveness was 329.5 milliseconds as in table (4) and figure (2)

Table (4): fluid responders using Corrected flow time (FTc)

Area Under the Curve	P value	95% Confidence Interval		Cut off	Sensitivity %	Specificity %
		Lower Bound	**Upper Bound**			
0.705	< 0.001	0.663	0.747	329.5	81.9	64.7

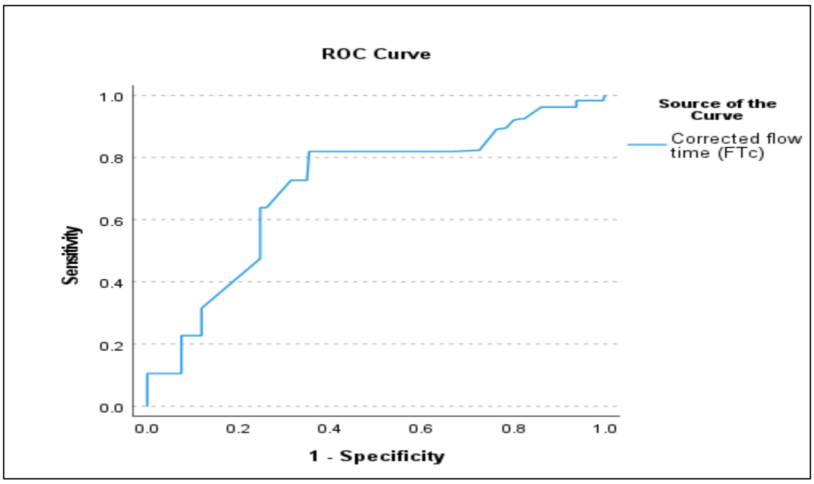

Figure (1): ROC curve for corrected Flow time

Assess the accuracy of Stroke Volume Variation to assess fluid responsiveness

VV ECMO group

SVV ranged in fluid responder from 7 to 34 and mean was 16.37±4.5 and in fluid non-responders SVV ranged from 6 to 34 and mean was 16.6±5.2. There was statistically significant correlation **(P value < 0.001)** as **in table (5) and figure (3)**

Table (3): Stroke volume variations in studied group

Correlations with fluid responsiveness								P value
Responder				Non responder				
Mean	SD	Minimum	Maximum	Mean	SD	Minimum	Maximum	
16.37	4.56	7.00	34.00	12.63	5.27	6.00	34.00	<0.001

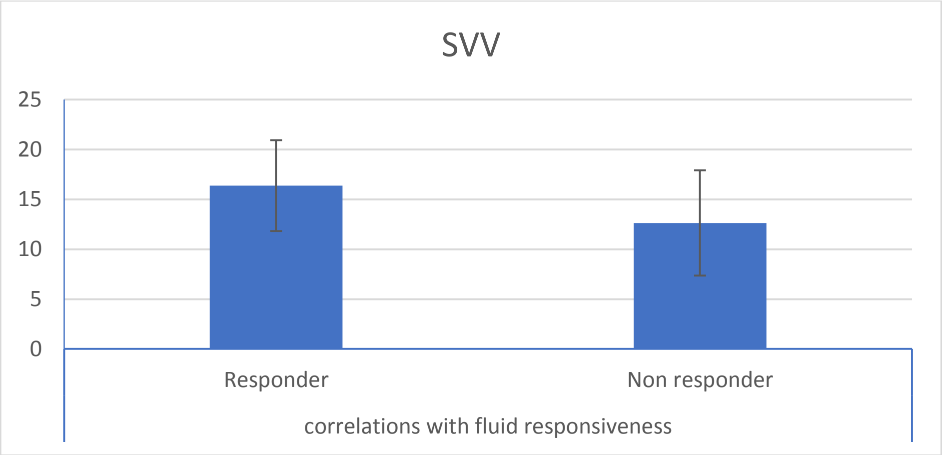

Figure (3): Stroke volume variations in fluid responder and non-responders

ROC curve for detection of fluid responsiveness using SVV

AUC was 0.755 (95% Confidence Interval ranged from 0.71 to 0.79) with sensitivity 68.1 % and specificity 63 %. Cut of value for fluid responsiveness was 12.5% as **in table (6) and figure (4)**

Table (6) : fluid responsiveness using SVV

Area Under the Curve	P value	95% Confidence Interval		Cut off	Sensitivity %	Specificity %
		Lower Bound	Upper Bound			
0.755	< 0.001	0.719	0.791	12.5	86.1	63

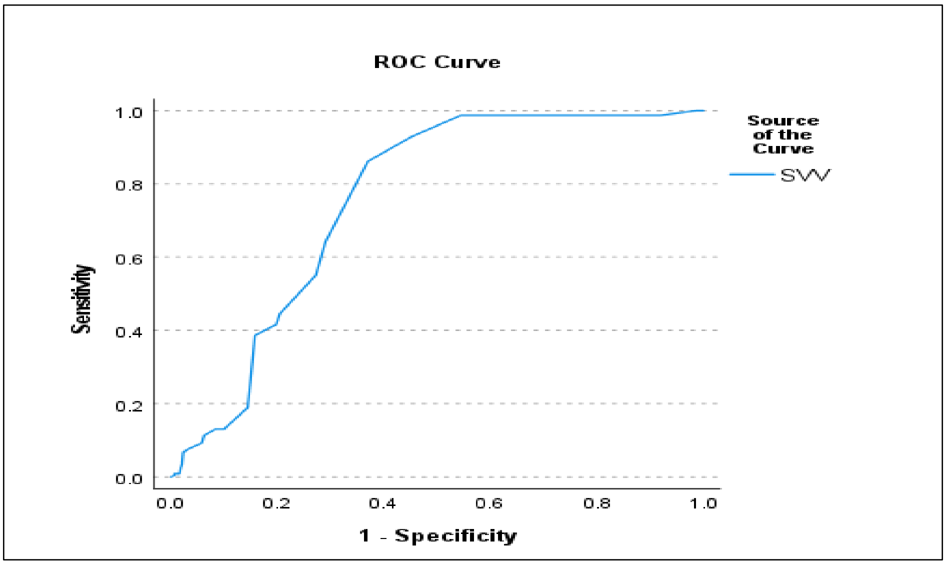

Figure (4): ROC curve Stroke volume variations

DISCUSSION:

The main problem in critical patients who need fluid resuscitation is the assessment of fluid adequacy (preload) and response to fluid administration (fluid responsiveness). The ICON™ monitor is a portable, cost-effective monitor for the measurement of hemodynamics in neonates, pediatrics, and adults. It works by the Electrical Cardiometry method which is a method for the non-invasive determination of stroke volume (SV), cardiac output (CO), and other hemodynamic parameters in adults, children, and neonates [6].

ICON™ was utilized to detect increased thoracic fluid content (TFC) in ECMO patients (e.g., pulmonary edema, pleural effusion) [3]

In our study, TFC estimated with ICON™ was correlated with clinically increased thoracic fluid content.

To our knowledge no previous studies using electrical cardiometry for estimation of TFC in ECMO patients however, lot of studies were done to validate ICON™ measurements for TFC e.g. K.H. Mahmoud et al. reported that Electrical Cardiometry (ICON™) is a 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 volume overload and congestion during and after hemodialysis sessions[7].

However, there is a correlation of intrathoracic blood volume (VITBV) with the pregnant patient's body weight[8], the presence of a fetus may lead to overestimation of the patient's body weight that leads to CO overestimation by ICON™. Second, the significant increase in fat and fluid levels in the body during pregnancy might affect transthoracic electrical conduction and the measurement of SV and CO as reported by ***Teefy et al***. [9], overweightness and obesity have a significant effect accuracy of measurements compared with thermodilution. Third, the cesarean operations may affect with the ICON™ measurement; specifically as abdominal surgeries have been reported to cause a shift of $>1 Lmin^{-1}m^{-2}$ in the bioimpedance readings of the CO index with the shift direction being unpredictable.[10]

Also, TFC can moderately predict weaning outcome in surgical critically ill patients with cardiac function while in patients with reduced ejection fraction (less than 40%), TFC above 50 $k\Omega^{-1}$ has an excellent ability to predict failure of weaning trails as reported by Fathy et al. [11].

Our study showed statistically significant positive correlation with ECMO flow and TFC in VV ECMO group but statistically significant negative correlation with VA ECMO group .

Our explanation was, in VV ECMO patients increased intrathoracic fluid content may be due to ECMO flow (our patients were connected through femoro-jagular approach so blood was drained from IVC to SVC and right atrium), also this increase in TFC may be part of the ARDS pathology, so we recommend further animal studies to abolish the other variables by comparing TFC in ARDS, after ECMO initiation in normal animals.

While in VA ECMO group, drainage of blood from right atrium to internal iliac artery and descending aorta causes decrease in TFC. However, VA ECMO increases afterload that may produce pulmonary edema and increases TFC, LV unloading maneuvers and cardiac resting achieved by VA ECMO can prevent pulmonary edema occurrence.

In contrast to our study Lydia Sumbel et al in their cohort study conducted on critically ill children, admitted to Pediatric Intensive Care Unit (PICU) with acute respiratory failure and/or shock and who were monitored for fluid status using ICON™, TFC did not correlate with conventional measures of fluid balance FIMO (Fluid Intake Minus Output) and AFIMO (Adjusted Fluid Intake Minus Output), but can predicted outcomes in critically ill children[12].

SVV ranged in fluid responder from 7 to 34 and mean was 16.37 and in fluid non-responders SVV ranged from 6 to 34 and mean was 16.6.

There was statistically significant correlation **(P value < 0.001)**, ROC curve for detection of fluid responsiveness AUC was 0.755 (95% Confidence Interval ranged from 0.71 to 0.79) with sensitivity 68.1 % and specificity 63 % Cut of value for fluid responsiveness was 12.5%

A lot of studies go with our results in the effectiveness of electrical cardiometry (ICON™) in assessment in SVV and fluid responsiveness' e.g ***I.H. OMAR et al*** as they performed a goal-directed fluid therapy (GDFT) protocol established on stroke volume variation (SVV) using Electrical cardiometry (EC) monitor and they reported effectiveness in reducing perioperative packed red blood cells (RBCs) transfusion[13] ROC curve was drawn to measure the cut off point for fluid responsiveness for each case in GDFT group. Increase in CI ≥ 15%, after administration of the first fluid bolus, is considered positive response to fluid bolus. AUC was statistically significant = 0.947, P = 0.003)

Also ***Hassan Effat et al*** found in fifty critically ill septic patients that an overall good agreement between EC measurement of percentage of change in CO and percentage of change in CO by echocardiography (P value <.001) so EC can be used to predict fluid responsiveness post PLR and fluid challenge [14]

In contrast to our study ***Kurniawan Taufiq Kadafi*** reported that ICON™ is unable to assess preload and the response of fluid resuscitation in children as they performed a study on in 45 patients with median age of 14 months and showed that the sensitivity and specificity of ICON™ were 58%

and 74%, respectively. The optimal cut off point of SVV using ICON™ was 16.5% and (AUC value was 53% and P > 0.05) and cut off point of SVV using ultrasonic cardiac output monitor (USCOM) was 33.5% with the (AUC value was 70% and P < 0.05) [6] and our explanation to this is the different group of patients.

CONCLUSION: ICON™ can used to detect increased intrathoracic fluid content with a statistically significant positive correlation with ECMO flow and in VV ECMO group but statistically significant negative correlation in VA ECMO group. ICON™ can predict fluid responsiveness in patients connected to VV ECMO and the cut of point was 12.5% increase in CO in fluid responders.

abbreviations: thoracic fluid content ; TFC, Extracorporeal Membrane Oxygenation; ECMO, venoarterial ;V, venovenous ;VV, Stroke Volume Variation; SVV

REFERENCES

[1]A. Messina, J. Bakker, M. Chew, D. De Backer, O. Hamzaoui, G. Hernandez, S.N. Myatra, X. Monnet, M. Ostermann, and M. Pinsky, Pathophysiology of fluid administration in critically ill patients. Intensive Care Medicine Experimental 10 (2022) 1-15**.**

[2]P. Rao, Z. Khalpey, R. Smith, D. Burkhoff, and R.D. Kociol, Venoarterial extracorporeal membrane oxygenation for cardiogenic shock and cardiac arrest: cardinal considerations for initiation and management. Circulation: Heart Failure 11 (2018) e004905**.**

[3]L. Sumbel, A. Wats, M. Salameh, E. Appachi, and U. Bhalala, Thoracic Fluid Content (TFC) Measurement Using Impedance Cardiography Predicts Outcomes in Critically Ill Children. Frontiers in pediatrics 8 (2020) 564902**.**

[4]J.R. Petersen, B.V. Jensen, H. Drabaek, K. Viskum, and J. Mehlsen, Electrical impedance measured changes in thoracic fluid content during thoracentesis. Clin Physiol 14 (1994) 459-66**.**

[5]T.J. Ebert, J.J. Smith, J.A. Barney, D.C. Merrill, and G.K. Smith, The use of thoracic impedance for determining thoracic blood volume changes in man. Aviat Space Environ Med 57 (1986) 49-53**.**

[6]K.T. Kadafi, A. Latief, and A.H. Pudjiadi, Determining pediatric fluid responsiveness by stroke volume variation analysis using ICON® electrical cardiometry and ultrasonic cardiac output monitor: A cross-sectional study. International journal of critical illness and injury science 10 (2020) 123-128**.**

[7]K.H. Mahmoud, M.S. Mokhtar, R.A. Soliman, and M.M. Khaled, Non invasive adjustment of fluid status in critically ill patients on renal replacement therapy. Role of Electrical Cardiometry. The Egyptian Journal of Critical Care Medicine 4 (2016) 57-65**.**

[8]D.P. Bernstein, and H. Lemmens, Stroke volume equation for impedance cardiography. Medical and Biological Engineering and Computing 43 (2005) 443-450**.**

[9]P. Teefy, R. Bagur, C. Phillips, K. Karimi-Shahri, J. Teefy, R. Sule, A.A. Dempsey, and K. Norozi, Impact of obesity on noninvasive cardiac hemodynamic measurement by electrical cardiometry in adults with aortic stenosis. Journal of cardiothoracic and vascular anesthesia 32 (2018) 2505-2511**.**

[10]L. Huang, L.A. Critchley, and J. Zhang, Major upper abdominal surgery alters the calibration of bioreactance cardiac output readings, the NICOM, when comparisons are made against suprasternal and esophageal Doppler intraoperatively. Anesthesia & Analgesia 121 (2015) 936-945**.**

[11]S. Fathy, A.M. Hasanin, M. Raafat, M. Mostafa, A.M. Fetouh, M. Elsayed, E.M. Badr, H.M. Kamal, and A.Z. Fouad, Thoracic fluid content: a novel parameter for predicting failed weaning from mechanical ventilation. Journal of Intensive Care 8 (2020) 1-7**.**

[12]L. Sumbel, A. Wats, M. Salameh, E. Appachi, and U. Bhalala, Thoracic Fluid Content (TFC) Measurement Using Impedance Cardiography Predicts Outcomes in Critically Ill Children. Frontiers in Pediatrics (2021) 668**.**

[13]I.H. Omar, A.S. Okasha, A.M. Ahmed, and R.S. Saleh, Goal Directed Fluid Therapy based on Stroke Volume Variation and Oxygen Delivery Index using Electrical Cardiometry in patients undergoing Scoliosis Surgery. Egyptian Journal of Anaesthesia 37 (2021) 241-247**.**

[14]H. Effat, K. Hamed, G. Hamed, R. Mostafa, and S. El Hadidy, Electrical Cardiometry Versus Carotid Doppler in Assessment of Fluid Responsiveness in Critically Ill Septic Patients. Egyptian Journal of Critical Care Medicine 8 (2021) 96-113**.**