Clinical evaluation of applying the results of bio-impedance analysis for fluid management during Continuous Renal Replacement Therapy (CRRT)

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Introduction

- Acute kidney injury (AKI) develops in 30 to 50% of critically ill patients and is associated with increased mortality.

- Recent studies have indicated that volume overload in patients with AKI admitted to the intensive care unit reduces the survival rate of patients.

- The estimation of volume status has always been a challenging issue in critically ill patients because the clinical and paraclinical findings have poor sensitivity in fluid assessment of these patients.

Prescribing ultrafiltration (UF) rate in patients receiving Continuous Renal Replacement therapy (CRRT)

- Currently, there is no guideline for detecting the optimal ultrafiltration (UF) rate in patients receiving CRRT.

- The traditional method is prescribing the UF rate based on the clinical estimation of fluid status and adjusting the rate by considering the changes in hemodynamic condition and urine output.

Applying BIA to estimate optimal UF during CRRT

- Bioelectric impedance analysis (BIA) can be an accurate, rapid, noninvasive, and inexpensive technique for the bedside evaluation of hydration status.

- The number of studies examining the diagnostic value BIA analysis in critically ill patients receiving CRRT is very low.

- Currently, there is no data regarding the clinical value of applying bio-impedance as a guide to prescribe UF rate.

- We designed a clinical trial in patients with AKI on CRRT to figure out the benefits of using the results of BIA in fluid management of these patients.

Materials and methods

- **Inclusion criteria**

  -Admission to the intensive care units of the Masih Daneshvari Hospital

  -Development of AKI

  -The requirement of CRRT prescription

- **Exclusion criteria**

  -Age less than 18 years

  -History of stage 4 or 5 of chronic kidney disease

  -History of cardiovascular resuscitations before the start of CRRT

  - History of limb amputation

CRRT performed by using the Baxter or B-Braun machine. The applied modes included continuous venovenous hemofiltration (CVVH) or continuous venovenous hemodiafiltration (CVVHDF).

The patient's weight was measured by a bed scale and the body composition by the BioScan 916, a single frequency electrical impedance analyzer at the baseline and every 8 hours during CRRT

Materials and methods

- The study was a randomized prospective trial. The patients and the data analyzer were blinded.

- After signing the consent forms by the patients or their guardians, all eligible patients during an 18-month-period were included. Participants were assigned into the case and control groups by using a software generated table of random numbers.

- In order to carry out allocation concealment, the patient code is sent to a third party who has the table of random numbers to decide whether this code directs the patient to the study or control group.

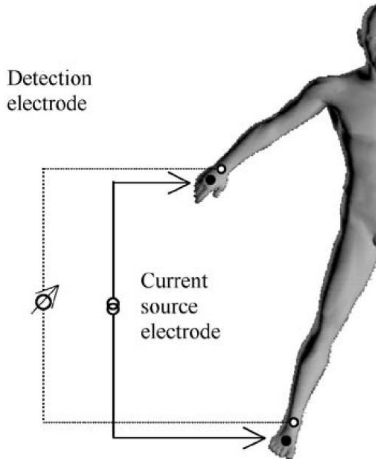
- Even though BIA analysis was performed for all patients, the results of bio-impedance analysis were used as a guide to treatment only in patients of study group.

Materials and methods

- The clinical and para-clinical information at the baseline and during CRRT were documented.
- Acute physiology and chronic health evaluation II (APACHE II) score for each patient was calculated during the first 24 hours after the ICU admission.
- The study was approved by the Ethics Committee of the Shahid Beheshti University of Medical Science.

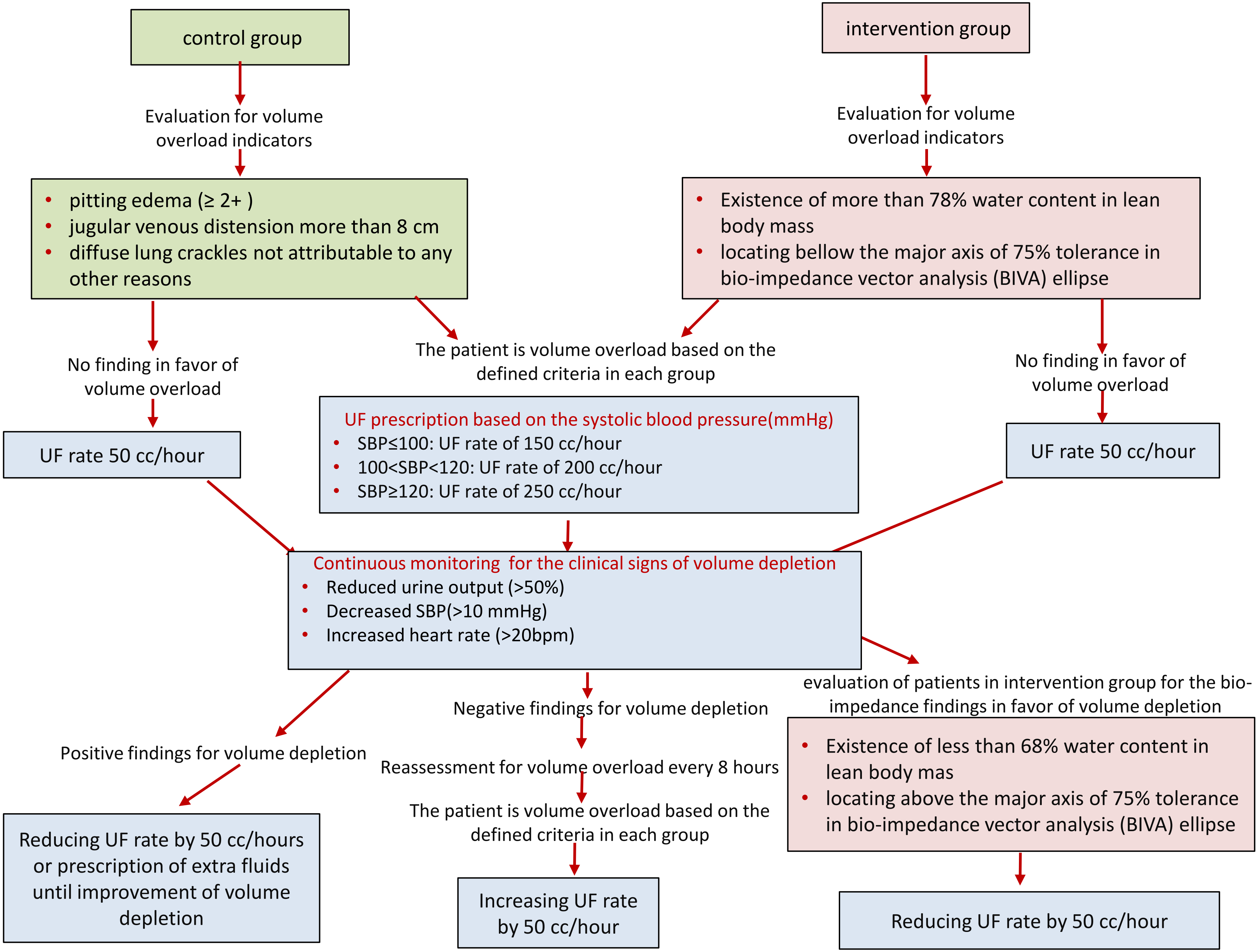
- To evaluate the body composition, the patients were lied flat on the back.

- Four electrode pads, two on the wrist and two on the ipsilateral ankle, were applied to transfer an external alternating current with a frequency of 50 kHz.



Principles of BIA

- Water and electrolytes are good conductors of electricity. Thus, Resistance (R) to an electrical flow is inversely related to the fluid content between two electrodes.
- As the cell membrane can act as a capacitor of electricity, the cell mass can be measured by another parameter during the bioelectrical analysis that is known as Reactance or Capacitance (Xc) .
- Impedance is the term used to describe the combination of resistance and capacitance.


control group
Evaluation for volume overload indicators
pitting edema (≥ 2+)
jugular venous distension more than 8 cm
diffuse lung crackles not attributable to any other reasons
No finding in favor of volume overload
UF rate 50 cc/hour
intervention group
Evaluation for volume overload indicators
Existence of more than 78% water content in lean body mass
locating bellow the major axis of 75% tolerance in bio-impedance vector analysis (BIVA) ellipse
No finding in favor of volume overload
UF rate 50 cc/hour
The patient is volume overload based on the defined criteria in each group
UF prescription based on the systolic blood pressure(mmHg)
SBP≤100: UF rate of 150 cc/hour
100<SBP<120: UF rate of 200 cc/hour
SBP≥120: UF rate of 250 cc/hour
Continuous monitoring for the clinical signs of volume depletion
Reduced urine output (>50%)
Decreased SBP(>10 mmHg)
Increased heart rate (>20bpm)
Positive findings for volume depletion
Reducing UF rate by 50 cc/hours or prescription of extra fluids until improvement of volume depletion
Negative findings for volume depletion
Reassessment for volume overload every 8 hours
The patient is volume overload based on the defined criteria in each group
Increasing UF rate by 50 cc/hour
evaluation of patients in intervention group for the bio-impedance findings in favor of volume depletion
Existence of less than 68% water content in lean body mas
locating above the major axis of 75% tolerance in bio-impedance vector analysis (BIVA) ellipse
Reducing UF rate by 50 cc/hour

results

Maltron Test test 93 (Metric)

Results | Fat & FFM | BMI & Weight | Metabolic | Density | Body Water | Hydration | ECW & ICW | ECW Target | BCM | Muscle | Minerals Protein | BIA Chart | Electrical

Back | Print | Save Comments

Results — Maltron

Body Compision

	Selected 09, Jun 18 Right Body	Previous not found Right Body	
Fat Free Mass :	74.96		kg
Fat Free Mass %	83.29		%
Fat Mass :	15.04		kg
Fat Mass %	16.71		%
Body Volume :	84.90		lt
Body Density	1.0606		Kg/lt
Resting Metabolic Rate :	1731.00		kcal
Body Mass Index :	29.30		kg/sq
Target Fat Min/Max % :	22.00 to 27.00		%
Target Weight Min/Max :	62.00 to 74.00		kg

Fluid Status

Total Body Water	61.92	lt
Total Body Water %	68.80	%
Extracellular Water	41.25	lt
Extracellular Water %	66.61	%
Intracellular Water	20.67	lt
Intracellular Water %	33.38	%
Extra/Intracellular Water	1.995	
Extracellular Fluids	43.72	lt
Interstitial-Fluid (Extra.)	30.59	lt
Plasma -Fluid (Intra.)	8.74	lt
Extracellular Solids :	6.77	kg
Target Water Min/Max %:	51.00 to 58.00	%

Cell Mass

	Selected 09, Jun 18 Right Body	Previous not found Right Body	
Body Cell Mass :	34.28		kg
Extracellular Mass :	40.68		kg
Muscle Mass :	30.02		kg

Minerals Protein and Glycogen

Protein Mass :	9.64	kg
Mineral Mass :	3.39	kg
Total Body Calcium Mass :	1333.00	g
Total Body Potassium :	167.30	g
Glycogen Mass :	681.00	g

GFR and Dry Weight

Glomerular Filtration Rate	22.52	mL/min
Creatinine Clearance	34.00	mL/min
Dry Weight	76.55	kg

Electrical Model

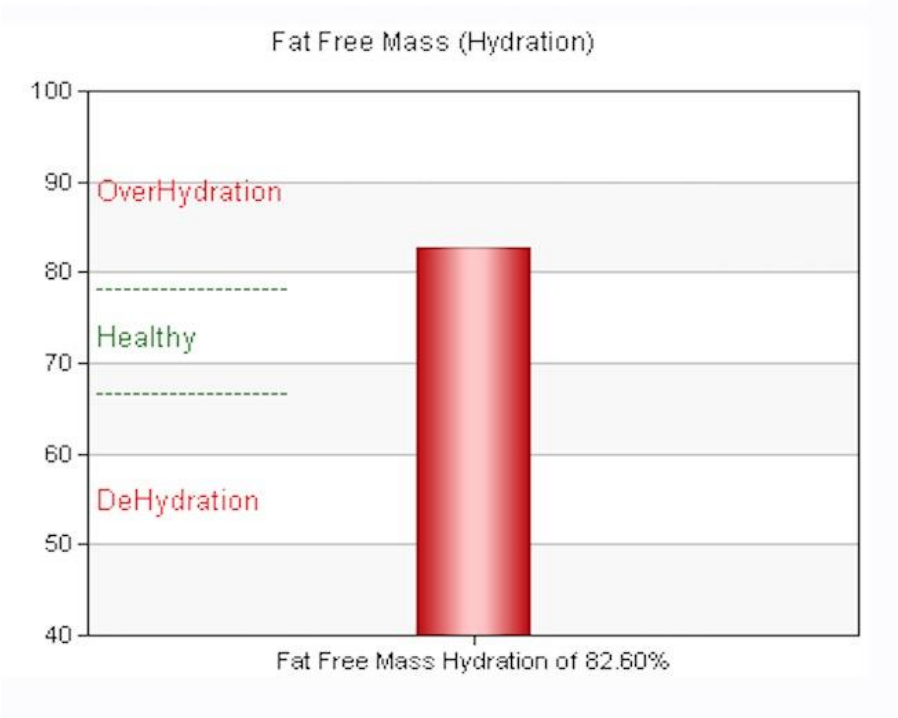
Capacitance Series :	196.40	nF
Resistance Parallel :	259.00	ohms
Reactance Parallel :	4125.00	ohms
Capacitance Parallel :	771.60	pF

50 kHz Raw Data

	Selected 09, Jun 18 Right	Previous not found Right	
Impedance :	258.00		ohms
Phase Angle :	3.58		degrees
Resistance :	258.00		ohms
Reactance :	16.20		ohms

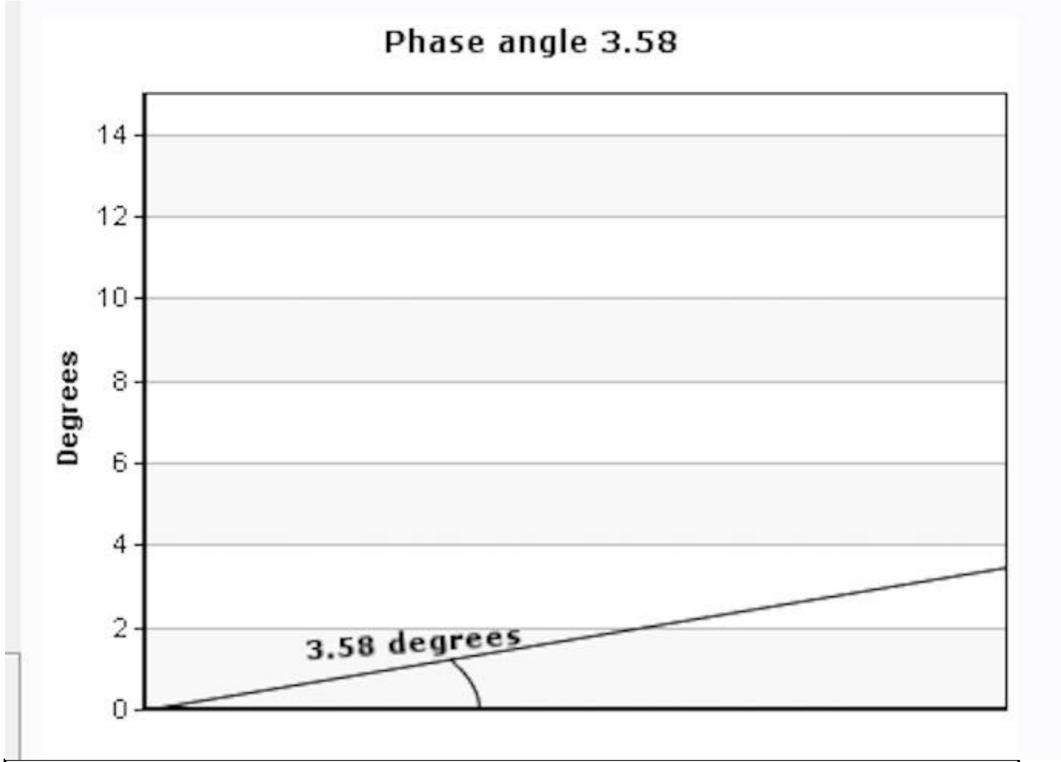
An example of the body composition and fluid status in one of our patients

Test number: 93



For a healthy individual water content should be about 73% of fat free mass (FFM)
Overhydration: water content of FFM> 78%
Underhydration: water content of FFM <68%
The patient was overhydrated.
Test number 93

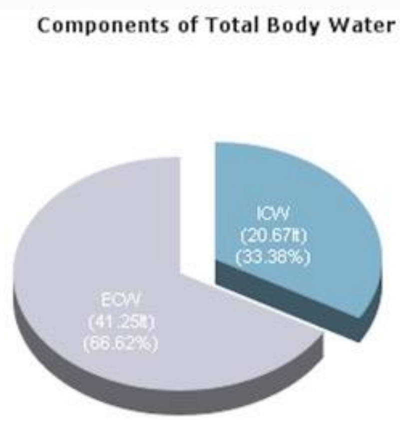
The phase angle: the arctangent of Xc/R

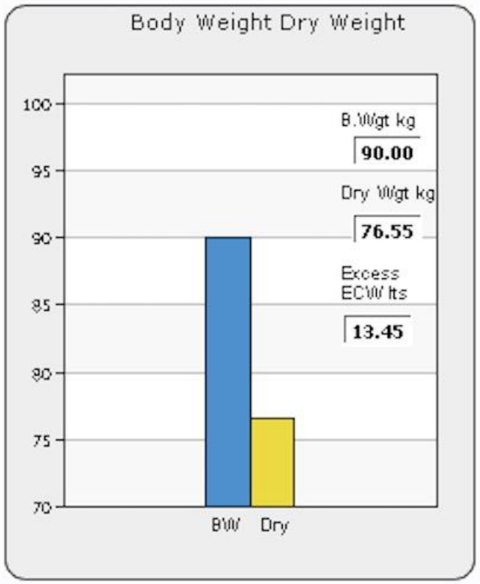


The reasons for low phase angle:

1. Low cell mass
2. Fluid overload

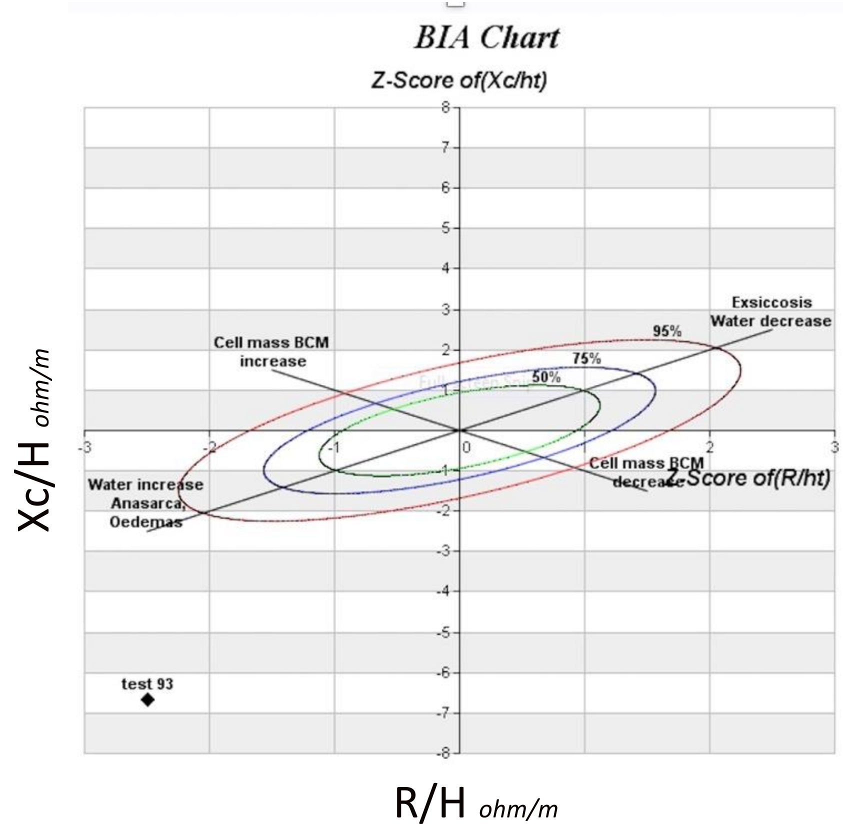
Test number:93





The proportional of intracellular and extracellular fluids and the suggested dry weight and excess water by BioScan analyzer

Test number:93



Bioimpedance Vector Analysis Tolerance Ellipse (BIVA)
with data expected to fall within 75% tolerance ellipse.
The patient is overhydrated because his location is below the major axis of 75% tolerance ellipse.

Test number:93

results

105 patients underwent CRRT during the study period in intensive care units of the Masih Daneshvari Hospital

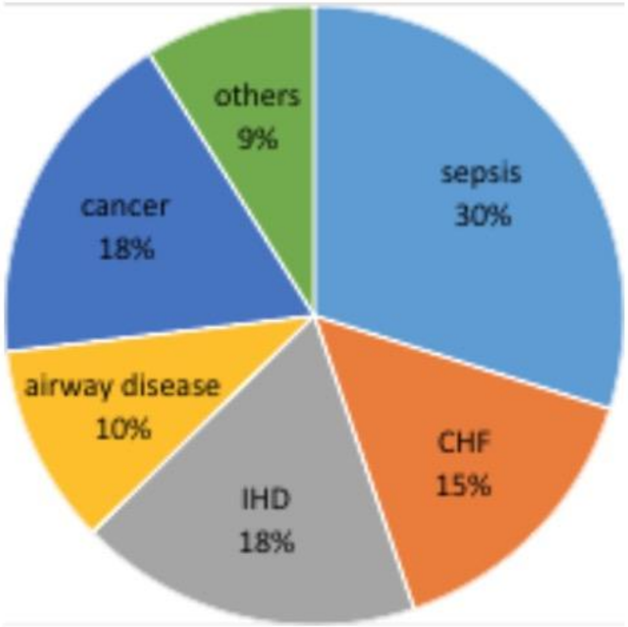
21 patients were excluded for being in stage 4 and 5 of CKD and12 others for having the history of cardiovascular resuscitation before the start of CRRT

72 patients were included

7 patients were excluded because of technical problems in the measurements and recording of the data

Final analysis was performed for 65 patients
(32 cases and 33 controls)
Total hours of CRRT: 4320 hours

results



Pie diagram shows the ratio of the main reasons leading to admission to the intensive care unit in the patient

Table 1: demographic and clinical characteristic of the patients

characteristic	Patients of intervention group (applying the results of BIA in UF prescription) N=32	Controls (using clinical criteria for UF prescription) N=33	P Value
Age-yrs.	58.88±16.61	62.94±11.73	NS
Male sex-n.%	19 (54.3)	16(45.7%)	NS
Smoker-n.%	9(45%)	11(55%)	NS
Comorbidities-n			
-CKD	2	0	
-IHD	26	22	
-sepsis	20	20	NS
-CHF	22	28	
-Airway disease	24	29	
-Cancer	24	24	
APACHE2	24.17±6.46	25.03±5.59	NS
History of conventional hemodialysis during current admission	6/32 18.7%	8/33 24.2%	NS
Being under mechanical ventilation	27/33 84.3%	31/33 93.9%	NS

Table 2: The comparison of bio-impedance parameters at the baseline and after the intervention in two groups

Parameter of bio-impedance analysis	Patients of intervention group (applying the results of BIA in UF prescription) N=32	Controls (using clinical criteria for UF prescription) N=33	P Value
ECW-lit			
- baseline *	61.98±12.41	60.98±14.24	NS
- average †	62.37±13.68	63.90±14.48	NS
- endpoint ‡	62.17±16.13	66.23±14.58	NS
FFM water %			
- baseline *	81.74±9.28	83.56±9.37	NS
• average †	82.50±11.38	87.68±8.61	**P=0.007**
• endpoint ‡	82.32±10.37	86.74±9.28	**P=0.005**
PA-degree			
- baseline*	4.14±2.67	5.82±6.84	NS
• endpoint †	2.77±0.95	4.28±3.22	NS
• the first PA minus the last PA ∫	0.35 ± 2.94	2.08 ±6.38	NS
ECW/ICW			
- baseline *	1.94±1.10	1.95±1.11	NS
- endpoint ‡	2.15±1.32	2.54±1.30	NS
FFM			
- baseline	76.76±10.40	72.47±12.70	NS
- endpoint ‡	73.98±11.88	72.65±11.41	NS

• Parameters of bio-impedance at the start of CRRT, before intervention

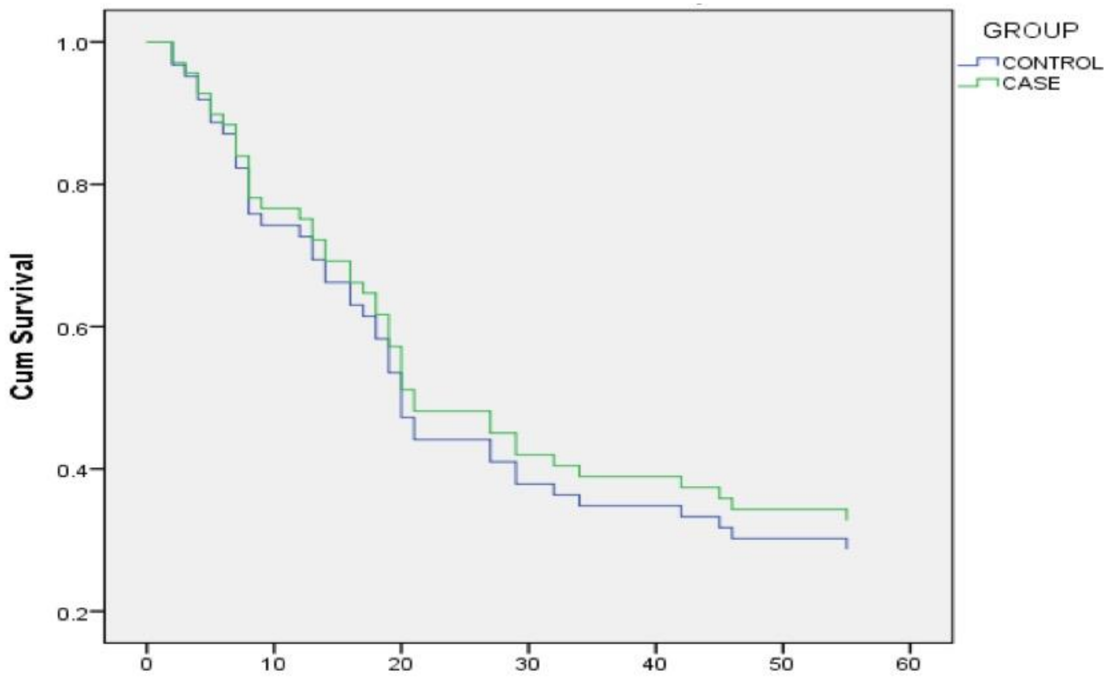
†parameters of bio-impedance at the end of last session of CRRT

‡ The average the bio-impedance parameters which were measured every 8 hours during the sessions of CRRT

∫ The difference between phase angle measured at the start of the first CRRT session and at the end of the last CRRT session

Table 3: The comparison of final outcomes between two groups

Outcomes	Patients of intervention group (applying the results of BIA in UF prescription) N=32	Controls (using clinical criteria for UF prescription) N=33	P Value
Mortality rate			
• 10 days	7/32(22%)	9/33(27%)	NS
• 30 days	18/32(56%)	21/33(63%)	NS
• 60 days	22/32(68%	23/33(69%)	NS
Duration of hospital admission-days	22.69±27.69	26.56±28.35	NS
Duration of ICU admission-days	16.73±25.63	16.41±25.35	NS
Improvement of urine output after the start of CRRT	20/32 62.5%	18/33 54.5%	NS
Improvement of AKI during hospital admission	10/32 31.25%	8/33 24.24%	NS
Ability to stop inotropes after the start of CRRT	8/12	5/20	NS
inotrope medication requirement	20/32 62.5%	25/33 75%	NS
Ability to stop mechanical ventilation after the start of CRRT	3/24	4/27	NS



The cumulative incidence of death from initiation of CRRT assessed by Kaplan-Meier method and compared in the two groups by Cox regression analysis with no significant difference

results

- In patients of both group the duration of admission in intensive care unit was significantly higher in patients with higher fat free mass water content. (P=0.004)

- The frequency of AKI improvement was significantly higher in patients with the APACHI II score less than 25, 42% vs. 18% in patient with score less than and more than 25 respectively(P=0.03).

Conclusion

- Volume overload is a frequent finding in critically ill patients and may be associated with increased ICU admission period.
- Applying Bioimpedance analysis may be an effective method for assessment of volume status and prescription of appropriate ultrafiltration volume during CRRT.
- In our study the more efficient fluid removal by BIA guide on patients in intervention group did not lead to increased survival.
- This finding may be explained by the fact that because of the huge cost difference between CRRT and the conventional hemodialysis, we chose CRRT only for patients with hemodynamic instability with very poor prognosis.