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Original Research Article

The Impact of Bioimpedance Spectrometry-Guided Fluid Management on Hemodialysis Patients' Volume Status

Abhishek Raman[1], Naveen Kumar[2], Parvez Ahmad[3], Yogeshman Anand[4], Manish Malik[5], A. K. Bhalla[6]

[1]Consultant, Department of Nephrology, Jayprabha Medanta Superspeciality Hospital, Patna, Bihar, India

[2]Assistant Professor, Department of Urology, All India Institute of Medical Sciences, Patna, Bihar, India

[3]Senior Resident, Department of Urology, All India Institute of Medical Sciences, Patna, Bihar, India

[4]Consultant, Department of Nephrology, Fortis Memorial Research Institute, Gurgaon, India

[5]Senior Consultant, Department of Nephrology, Sir Ganga Ram Hospital, New Delhi, India

[6]Senior Consultant, Department of Nephrology, Sir Ganga Ram Hospital, New Delhi, India

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Corresponding Author: Dr. Abhishek Raman
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Abstract:

Objectives: The aim of the study was to contrast the efficacy of active fluid management using body composition monitor with conventional fluid management using clinical parameters.

Methods: The study conducted at the Nephrology department of Sir Ganga Ram Hospital, New Delhi, for over one year, focused on patients who were undergoing maintenance in center hemodialysis. It employed a comparative approach, randomly dividing 50 patients into two groups: Control group and Intervention group. The study compared parameters such as fluid overload (TAFO), pre-dialysis weight, laboratory values (serum creatinine, serum albumin, NT-proBNP), and changes in blood pressure (systolic and diastolic) between the control and intervention groups, along with assessing alterations in lean body mass (LBM) and adipose tissue mass (ATM).

Results: In this study, bioimpedance-guided fluid management demonstrated notable outcomes. The intervention group exhibited a reduction in hypotensive episodes (5.66 per week), a decrease in anti-hypertensive drug usage (from 18 to 9), and a more balanced distribution between overhydrated and normohydrated individuals (13 vs. 12). Stable hemoglobin levels were observed in both groups, while the intervention group displayed fluctuations in albumin (3.6±0.3 gm/dl to 3.5±0.3 gm/dl). Notably, NT Pro BNP levels and TAFO significantly decreased, emphasizing the positive impact of fluid management on clinical parameters.

Conclusion: This study reveals that bioimpedance-guided fluid management demonstrated improved hemodynamic stability, reduced hypotensive episodes, and optimized antihypertensive drug usage. These findings underscore the potential of active fluid management in enhancing clinical outcomes for hemodialysis patients.

Keywords: Bioimpedance, Hemodialysis, Fluid Management, Hypotension.

Introduction

Excessive fluid volume, which is linked to left ventricular hypertrophy, hypertension and other adverse cardiovascular outcomes, is more prevalent in individuals with end stage renal disease (ESRD) [1]. Besides this, fluid overload (FO) also serves as a major predictor of mortality rate in diabetic patients and patients undergoing hemodialysis [2]. Conventional indicators of volume status, like edema, body weight, and blood pressure, help to determine the appropriate amount of fluid to be removed during hemodialysis [3]. However, these rely on the assessment of the patient's dry weight, that is, the lowest weight attained without symptoms or hypotension [4, 5].

Clinically assessing the dry weight involves the evaluation of hypertension, respiratory distress, jugular venous pulsation, edema, and changes in body weight. The accurate assessment of these features is challenging, resulting in potential complications like intradialytic hypotension, arrhythmias, cramps, and compromised residual renal function in cases where the dry weight is overestimated [6-8]. Besides this, traditional methods, such as clinical observations and chest X-rays, also fail to serve as reliable indicators as they necessitate considerable physician time and expertise [9-11].

The objective methods for FO identification in hemodialysis patients comprise biochemical markers (BNP, ANP, cGMP) and ultrasound measurements of inferior vena cava diameter [12-14]. Other assessment methods like deuterium and sodium bromide measurements, commonly referred to as gold standard methods, are successful in providing accurate total body water assessment, but their arduous protocol makes them impractical for routine clinical use [15]. In contrast, the body composition monitor, which uses a bioimpedance spectroscopy, objectively determines extracellular and intracellular water compartments without much hassle [13]. This method possessing an established set of reference values for normal population FO has furthermore demonstrated comparable results to gold-standard techniques [16]. However, despite the improved accuracy in assessing factors like high blood pressure and arterial stiffness, studies, particularly in India, have yet to demonstrate a mortality difference between the classical methods and bioimpedance analysis [16-21].

The present study conducted in India aims to address this gap by investigating the use of bioimpedance spectrometry in the management of fluid overload in hemodialysis patients. The study aims to compare the efficacy of active fluid management using a body composition monitor with conventional methods based on the clinical parameters. Importantly, the study draws a comparison in the changes seen in the cardiovascular and nutritional status of patients treated using the two management approaches.

Methods

A randomized control trial was carried out at the Nephrology Department of Sir Ganga Ram Hospital, New Delhi, for a period of 6 weeks. The study was specifically carried out on patients who were undergoing maintenance in the hospital’s hemodialytic center between January 2019 to January 2020. The study cohort consisted of patients aged 18 and above, diagnosed with CKD-5 and who were undergoing dialytic treatments for at least a month prior to the start of the study.

Patients with acute kidney injury, vascular access problems, benign or malignant tumors, acute or chronic infections, intra-dialytic BP instabilities (if BP is >180/120 or <90/60), or other chronic diseases were excluded from the study. In addition to this, patients with amputations or pacemakers were also disregarded from the study. A total of 50 patients meeting the inclusion criteria were enrolled for this study. These patients were equally divided into 2 groups of 25 patients, each making up the control and intervention group.

To confirm the difference in time-averaged fluid overload between the control and intervention groups, the sample size calculation was performed at 5 % significance level with 80 % power, using one-tailed test. As per this protocol, the minimum required sample size in each group was determined to be 84. However, due to time constraints regarding the study completion period, the current study was carried out as a pilot study with a smaller sample size of 25 individuals in both the control and intervention groups.

BCM Monitoring and TAFO Measurement: At the beginning of the study, biochemical parameters like serum creatinine, serum albumin, and NT-proBNP were evaluated for both the control and intervention groups. The dialysis session's pre- and post-weight, along with blood pressure readings before and after, were also recorded for both groups during each session. These served as the markers for nutritional and volume status.

Fluid overload assessments were conducted twice throughout the study using a Body Composition Monitor (BCM) device in the control group. The first assessment was done at the start of the study and the second one was carried out during the final week of initial hemodialysis session. Time-averaged fluid overload (TAFO) was also calculated specifically for the first and last weeks in the control group, keeping the clinician unaware of the results. The control group's fluid management adhered to conventional clinical parameters throughout the study, aligning with the standard of care in dialysis centers.

For the intervention group, FO measurements were taken just before the start of the first weekly dialysis session using a BCM device. TAFO calculations were made at the week's end, guiding the determination of the next week's post-dialysis weight target based on the preceding week's TAFO. The fluid status for the intervention group was maintained according to TAFO throughout the study, to direct the patients towards achieving a TAFO indicative of normovolemia (0.5L ± 0.75L). Besides this, any occurrences of intra-dialytic hypotension during each session were documented for both groups.

Statistical Methods: The data was analyzed using SPSS 23.0 software, employing unpaired student t test or Mann Whitney U test, with a significance level set at $p < 0.05$.

Results

Among the 50 patients enrolled for the study, the control group (n=25) exhibited a mean age of 58.92

± 10.7 years, comprising 17 males and 8 females. Hydration status in this group showed 16 overhydrated and 9 normohydrated individuals. They experienced 8.16 hypotensive episodes per week, with 20 initially using ≥2 anti-hypertensive drugs, reducing to 16 by the study's end. In the intervention group (n=25), with a mean age of 57.40 ± 11.3 years, there were 18 males and 7 females. Hydration status included 18 overhydrated and 7 normohydrated individuals. This group encountered 5.66 hypotensive episodes per week, and the number using ≥2 anti-hypertensive drugs decreased from 18 to 9 by the end of the study (Table 1).

Table 1: General characteristics of the patients

	Control group (n = 25)	Intervention group (n = 25)
Mean age (years)	58.92 ± 10.7	57.40 ± 11.3
Male	17	18
Female	8	7
Hydration status		
Overhydrated	16	18
Normohydrated	9	7
Underhydrated	0	0
Mean number of Hypotensive episodes during the therapy/week	8.16	5.66
Use of ≥2 anti- Hypertensive drugs		
Before start of study	20	18
End of study	16	9

The hydration status distribution revealed that in the control cohort, 14 individuals were overhydrated, 11 were normohydrated, while in the intervention group, 13 were overhydrated and 12 were normohydrated. Furthermore, it was observed that the anti-hypertensive drug usage was higher in overhydrated patients in both groups. The pre-dialysis weight, lean tissue mass, and adipose tissue mass were also consistently higher in overhydrated individuals as compared to the normohydrated counterparts. A similar observation was also noted with the case of systolic blood pressure (SBP) pre- and post-dialysis, and diastolic blood pressure (DBP) readings both pre- and post-dialysis (Table 2).

Table 2: Hemodialysis Patient Characteristics and Measurements

	Control group (n = 25)	Intervention group (n = 25)
Hydration status		
Overhydrated	14	13
Normohydrated	11	12
Underhydrated	0	0
Use of anti-hypertensive drugs as per hydration status		
Normohydrated	7	9
Overhydrated	18	16
Predialysis weight (in kg)		
Normohydrated	73.02±6.92	69.67±5.33
Overhydrated	74.24±6.92	75.32±5.73
Lean tissue mass (in kg)		
Normohydrated	45.36±3.74	44.61±4.1
Overhydrated	44.95±4.00	46.50±3.26
Adipose tissue mass (in kg)		
Normohydrated	26.77±4.32	24.47±3.78
Overhydrated	26.29±4.95	26.66±4.07
Systolic blood pressure (SBP)		
Pre dialysis	145.6±7.11	143.12±7.4
Post dialysis	142.64±6.4	140.4 ± 6.58
Pre-dialytic SBP		
Normohydrated	139.33±6.24	135.43±4.86
Overhydrated	149.13±4.84	146.11±5.91
Post-dialytic SBP		
Normohydrated	136.89±5.49	134.00±4.62
Overhydrated	145.88±4.29	142.89±5.0

Diastolic blood pressure (DBP)		
Pre dialysis	81.28 ± 6.92	77.84 ± 8.10
Post dialysis	79.36 ± 6.95	75.28 ± 7.6
Pre-dialytic DBP		
Normohydrated	75.56±5.27	72.86±5.01
Overhydrated	84.50±5.59	79.78±8.34
Post-dialytic DBP		
Normohydrated	74.00±6.0	71.14±4.45
Overhydrated	82.38±5.57	76.89±8.12

Comparative analysis of the biochemical parameters revealed that both in the control group and intervention group, hemoglobin (Hb) levels remained relatively stable from the start to the end of the study. The normohydrated subgroups showed comparable Hb levels over time, with overhydrated subgroups exhibiting similar trends. The levels of albumin in the control group remained consistent (3.5±0.3 gm/dl), while that in the intervention group displayed slight fluctuations (3.6±0.3 gm/dl to 3.5±0.3 gm/dl). Residual renal function, in contrast, showed a decrease in both groups, with notable differences in the overhydrated subgroups. NT Pro BNP levels and Time-averaged fluid overload (TAFO) also decreased in both groups, with the latter being more prominently visible in the overhydrated subgroup of the intervention group, emphasizing the impact of fluid management on clinical parameters (Table 3).

Table 3: Clinical parameters of the patient cohort at the start and end of the study

	Control group		**Intervention group (n = 25)**	
	Start of study	**End of study**	**Start of study**	**End of study**
Hb (g/dl)	9.6± 0.3	9.6± 0.3	9.5± 0.4	9.5± 0.4
Hb (g/dl) normohydrated group	9.8±0.4	9.7±0.4	9.6±0.3	9.6±0.5
Hb (g/dl) overhydrated group	9.6±0.2	9.5±0.3	9.5±0.4	9.5±0.4
Albumin (gm/dl)	3.5± 0.3	3.5 ± 0.3	3.6±0.3	3.5 ± 0.3
Albumin (gm/dl) Normohydrated group	3.7±0.3	3.6±0.3	3.6±0.3	3.6±0.5
Albumin (gm/dl) overhydrated group	3.4±0.3	3.4±0.2	3.6±0.4	3.5±0.3
Residual renal function (ml/day)	395±216.5 ml/d	344.0 ± 170.97 ml/d	366.0 ±244.4ml/d	250.0 ± 261.3 ml/d
Residual renal function Normohydrated group	566.6±187.08ml/d	494.4±133.33 ml/d	585.71±271.9ml/d	571.42 ± 289.9 ml/d
Residual renal function Overhydrated group	298.4±169.42ml/d	259.37±126.78ml/d	280.56±175.01 ml/d	125.0 ± 87.86 ml/d
NT Pro BNP (pg/ml)	4054±2704	3339±2001	4024±2890	2784±1972
NT Pro BNP (pg/ml) normohydrated group	1338±124	1316±147	1155±135	668±146
NT Pro BNP (pg/ml) over-hydrated group	5583±2184	4477±1598	5140±2660	3607±1709
TAFO	1.6±0.81	1.48± 0.69	1.65±0.75	1.04±0.58
TAFO (normohydrated group)	0.67±0.08	0.68±0.06	0.67±.05	0.34±0.05
TAFO (Overhydratedgroup)	2.16±0.47	1.93±0.40	2.03±0.51	1.31±0.40

Discussion

In the current investigation the effectiveness of Bioimpedance Spectrometry guided fluid management in hemodialysis patients analyzed by grouping the patients into 2 cohorts- the control group and the intervention group. The age distribution of patients and the male predominance observed in both the groups of this study was consistent with the findings of previous studies [19-21]. Moreover, in accordance with the initial time averaged fluid overload, the patient cohorts were further subdivided into 3 groups. In this juncture, it was noted that the intervention group, particularly the overhydrated subgroup, showed an improved hydration status concomitant with a reduction in pre-hemodialysis FO by the end of the study. This finding was in line with earlier studies that have demonstrated the potential of this method in achieving normovolemia and reducing fluid overload in hemodialysis patients [21-24].

In the present investigation, the average time-averaged fluid overload (TAFO) at baseline was 1.65L for the intervention group and 1.6L for the control group. This attribute, however, significantly decreased to 1.04L in the intervention group and to 1.48L in the control group by the end of the study. Notably, in the case of overhydrated patients of the intervention group, a substantial reduction in TAFO from 2.03L to 1.31L was observed, aligning with the findings from the study carried out by Moissl U et al. [19]. The study also observed a significant decline in systolic pre-dialysis blood pressure, especially among the overhydrated subgroup in the intervention arm.

Another crucial aspect assessed was the impact on anti-hypertensive medication usage, revealing a significant reduction in the intervention group. Initially, 18 patients in the intervention cohort took ≥2 anti-hypertensive drugs, but this decreased to 9 by the end of the study. A similar trend was reflected in the control group, although this was seen in a lesser proportion. These findings resonate with the studies by Machek P et al and Passauer J et al, emphasizing the correlation between FO and anti-hypertensive drug consumption [21, 26].

Various clinical parameters, such as episodes of hypotension, changes in body composition, and biochemical parameters like NT-Pro BNP, hemoglobin, and serum albumin were also investigated in this study. Interestingly, increased incidence rates of hypotensive episodes in the intervention group, particularly among overhydrated individuals was observed aligning with the findings of previous studies [27-29]. Surprisingly, the present study did not report any major cardiovascular events that could possibly result from these hypotensive episodes. Additionally, no significant changes in lean and adipose tissue mass, hemoglobin levels, or serum albumin values were noticed during the duration of the study. Despite this, the trial demonstrated a significant decline in the residual renal function in overhydrated patients belonging to the intervention cohort, which is in accordance with the previous findings [21, 22]. This observation may be attributed to the lowering of FO in these patients.

Conclusion

The present study reveals the superiority of the effectiveness of Bioimpedance Spectrometry-derived Fluid Overload (TAFO) when compared to that of traditional markers. This approach offers an independent assessment that remains unaffected by changes in body composition. Moreover, the study emphasizes the link between increasing life expectancy and hemodialytic maintenance. This was demonstrated by achieving the TAFO target in the investigation which correlates with maintaining a pre-dialysis fluid overload below 2.5 L, a factor frequently associated with proven survival benefits. Further research should focus on the adoption of TAFO towards improved survival rates, reduced hospitalizations, and for the identification of characteristics that hinder some patients from reaching normovolemic values. The implementation of active fluid management guided by bioimpedance spectroscopy into routine practices is beneficial in shaping the overall clinical outcome for hemodialysis patients.

Limitations

The study is limited by its short duration, small sample size, and the absence of dehydrated subjects in both intervention and control arms. Additionally, being a single-center study restricts the diversity of the study population, and the lack of hard endpoints such as mortality or hospital admission evaluation further limits comprehensive outcome assessment.

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