Review Article

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To Study the Outcome of Bioimpedance Spectroscopy in Dialysis Patients

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Introduction

Accurate dry weight estimation is pivotal for optimal fluid management in hemodialysis patients to avoid both fluid overload and hypovolemia [1]. Traditional clinical assessment based on physical signs and symptoms is subjective and often imprecise, limiting reliable estimation of true fluid status [1]. Clinical consequences-fluid overload is associated with hypertension, left ventricular hypertrophy, arterial stiffness and increased cardiovascular risk [2]. Excessive fluid removal can lead to intradialytic hypotension, organ ischemia, early loss of residual kidney function and other adverse outcomes [1].

Bioimpedance Spectroscopy (BIS)- BIS is a non-invasive, objective technique that quantifies body fluid compartments (extracellular and intracellular water) to guide dry weight setting Emerging evidence supports BIS as a clinically useful adjunct to conventional methods for improving fluid management [1].

Aim and Objectives

Primary Objective: To determine whether BIS-guided fluid management improves cardiovascular and clinical outcomes compared to conventional fluid management in chronic hemodialysis patients.

Secondary Objectives:

- Compare antihypertensive medication burden between BIS and conventional care group at 2 years.
- Assess cardiac function including left ventricular ejection fraction (LVEF) and left ventricular mass index (LVMI).
- Evaluate fluid related adverse events.
- Analyze survival outcome, including overall survival (OS) and event free survival (EFS).

Hypothesis: BIS-guided management leads to improved cardiovascular outcomes and reduce complications by optimizing fluid status accurately.

Study Design

This is a prospective, randomized controlled trial conducted from May 2023 to May 2025. Total 126 eligible patients were randomly allocated (1:1) to either BIS-guided fluid management group or conventional clinical are group [3].

Inclusion criteria-patients older than 18 years of age, on maintenance hemodialysis for more than 3 months duration, undergoing 2-3 sessions of hemodialysis per week.

Exclusion criteria-patients not complaint with dialysis schedule or less than 5 times per two weeks, kt/v<1.2, metallic implants or serious life-threatening comorbid conditions like malignancy, uncontrolled infection, etc.

In BIS group dry weight estimation was done based on bioimpedance spectroscopy measurements of fluid compartments (extracellular and intracellular water), using a standardized protocol in terms of OH values along with conventional method and ultrafiltration was tailored accordingly at baseline and at every 15 days interval.

Measurements frequency and targets were based on validated protocols from prior BIS studies [4].

In conventional group dry weight and fluid removal were determined by established conventional clinical criteria which includes patient's history, vitals, physical examination to look for signs of hypo/hypervolemia and interdialytic weight gain.

Statistical analysis – continuous variables were summarized as mean ± SD and compared between groups using appropriate tests; categorical variables were compared using chi-square/fischer's exact tests. Survival outcomes (OS and EFS) were analyzed by generating Kaplan-Meier curves, which estimate time to event distributions accounting for censoring and group differences were tested using the log-rank test and a two-tailed $p < 0.05$ was considered statistically significant [5].

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Results and Observations

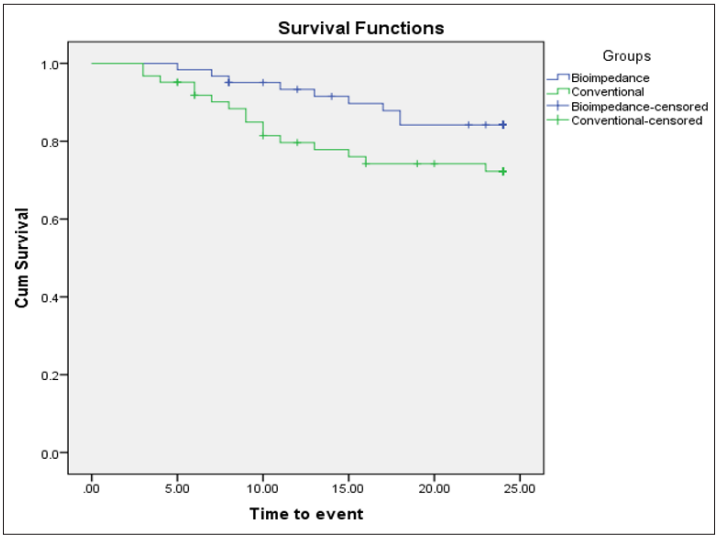
Table1: Distribution of Baseline Characteristics in Bioimpedance and Conventional Groups

Demographic Parameters			Bioimpedance (N=63)	Conventional (N=63)	Total	P
Gender	Female	Number	23	17	40	0.251
		%	36.5%	27.0%	31.7%	
	Male	Number	40	46	86	
		%	63.5%	73.0%	68.3%	
Age distribution	Upto 30 Years	Number	7	1	8	0.019
		%	11.1%	1.6%	6.3%	
	31 to 40 Years	Number	11	3	14	
		%	17.5%	4.8%	11.1%	
	41 to 50 Years	Number	5	8	13	
		%	7.9%	12.7%	10.3%	
	51 to 60 Years	Number	20	21	41	
		%	31.7%	33.3%	32.5%	
	> 60 Years	Number	20	30	50	
		%	31.7%	47.6%	39.7%	
Age distribution	Mean		51.98	59.52	55.75	0.004
	SD		16.07	12.45	14.81	
SBP (Baseline)	Mean		151.95	152.24	152.10	0.93
	SD		17.24	19.20	18.17	
DBP (Baseline)	Mean		91.84	88.98	90.41	0.125
	SD		10.41	10.37	10.45	

The study included 126 total participants, equally divided into Bioimpedance and Conventional groups. There was no significant difference in gender distribution (p=0.251) or in baseline systolic (p=0.93) and diastolic (p=0.125) blood pressure between the groups.

However, the groups differed significantly in age: the age category distributions were different (p=0.019), with the Conventional group having a notably higher mean age (59.5 years) compared to the Bioimpedance group (52.0 years, p=0.004).

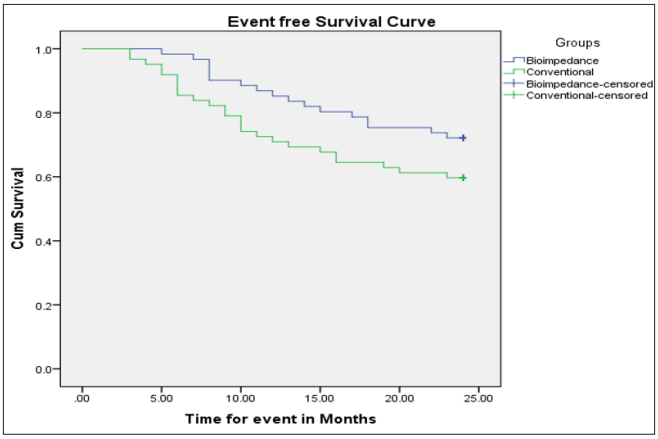
Table 2: Survival Outcomes and Event Distribution in Bioimpedance and Conventional Groups



Groups	Total N	N of Events	%	Mean survival (months)	P
Bioimpedance	63	9	14.2	22.2	0.1
Conventional	63	16	25.3	20.1	
Overall	126	25	0.19	21.1	

The Bioimpedance group had a lower event rate (9 events, 14.2%) and a higher mean survival time (22.2 months) and 85.2% OS compared to the Conventional group (16 events, 25.3%; 20.1 months; 74.2%). However, this difference did not reach statistical significance (p=0.1). BIS group experienced 44% fewer major events (9 vs 16).

Table 3: Survival Outcomes and Event Distribution in Bioimpedance and Conventional Groups



Groups	Total N	N of Events	%	Mean event free survival (months)	P
Bioimpedance	63	17	26.9	20.869	0.103
Conventional	63	25	39.6	18.387	
Overall	126	42	33.3	19.618	

Although the difference was not statistically significant (p=0.103), the Bioimpedance group demonstrated a lower event rate (26.9% vs. 39.6%) and a longer mean event-free survival time (20.9 vs. 18.4 months) and improved EFS (72.1% vs 59.7%) compared to the Conventional group. BIS group experienced 32% fewer events.

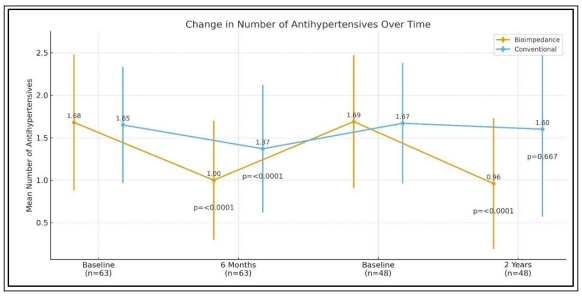


Figure 1: Change in Number of Antihypertensive Medications from Baseline to Follow-up in the Bioimpedance Group

The study demonstrates that guided therapy using bioimpedance led to a statistically significant and clinically meaningful reduction in the number of antihypertensive medications required. Patients showed a substantial decrease from a mean of approximately 1.68 medications at baseline to 1.00 after six months (mean diff 0.68, p<0.0001), an effect which was sustained and even enhanced after two years (mean diff 0.72 from 1.69 to 0.96, p<0.0001). In contrast, the control or comparison group showed only a modest, non-significant reduction after two years (mean diff 0.06, p=0.667). Systolic/diastolic BP reductions (133.90 vs 138.51mmhg, p=0.08; 60.03 vs 65.72mmhg, p=0.37 showed non-significant trend favoring BIS.

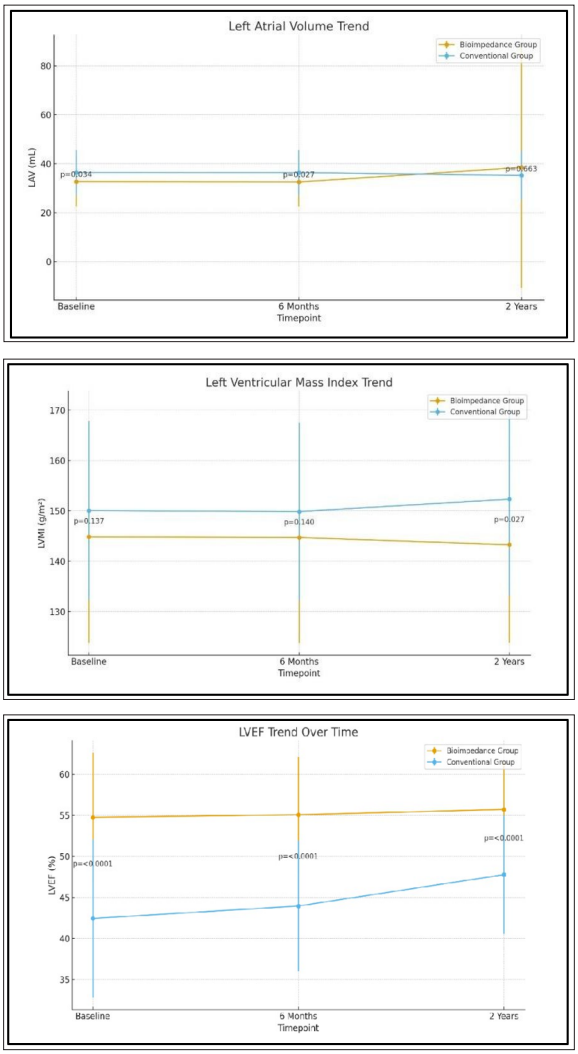


Figure 2: Comparison of Echocardiographic Parameters Between Bioimpedance and Conventional Groups at Baseline, 6 Months, and 2- Year Follow-up

Bioimpedance-guided therapy yielded superior cardiac outcomes, with a consistently higher LVEF (54.8% at baseline, 55.7% at 2 years) than conventional therapy (42.5% to 47.8%; all p<0.0001). By two years, it also showed better structural remodeling, with a lower Left Ventricular Mass Index (143.3 vs. 152.3, p=0.027). While conventional therapy initially resulted in larger Left Atrial Volumes (baseline: 36.4 vs. 32.7, p=0.034), this difference was not reliable at the two-year follow-up due to high data variability in the bioimpedance group.

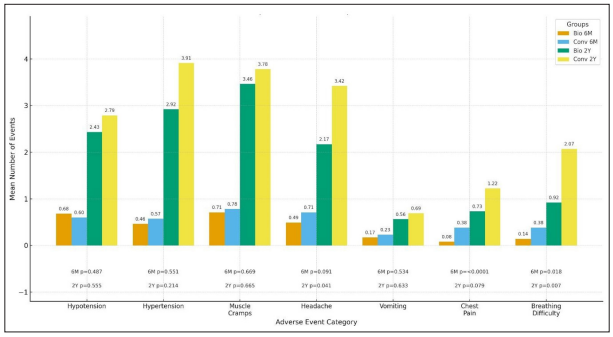


Figure 3: Comparison of Mean Adverse Event Frequency Between Bioimpedance and Conventional Groups at 6 Months and 2 Years

Significant adverse event reductions favored the bioimpedance group, with the conventional group experiencing more chest pain at 6 months (0.38 vs. 0.08 mean events, p<0.0001), more breathing difficulty at both 6 months (0.38 vs. 0.14, p=0.018) and 2 years (2.07 vs. 0.92, p=0.007), and more headaches at 2 years (3.42 vs. 2.17, p=0.041); in contrast, rates of hypotension (e.g., 2.79 vs. 2.43 at 2 years), hypertension (3.91 vs. 2.92), muscle cramps, and vomiting were statistically similar between groups.

Discussion

BIS-guided fluid management yielded superior cardiovascular remodeling: The BIS group showed significant improvements in LVEF and reduction in LV mass index, reflecting better structural cardiac adaptation compared to conventional care. This aligns with randomized evidence demonstrating regression of LV mass with bioimpedance-guided fluid adjustment [6]. Antihypertensive requirement decreased markedly with BIS: The significantly greater reduction in antihypertensive medication burden suggests improved fluid status and blood pressure control, consistent with prior intervention studies showing normalization of fluid status and BP with BIS use [7]. Reduction in fluid-related adverse events: Lower frequency of headaches and breathing difficulty in the BIS group supports improved intradialytic hemodynamic stability, a known benefit of objective fluid assessment over subjective clinical probing [1].

Survival Trends Favoring BIS: Though not statistically significant, the observed trend toward fewer mortality and composite events in the BIS group is directionally consistent with systematic evidence suggesting technology-guided fluid management may reduce cardiovascular risk and mortality in dialysis populations [2].

Limitations Affecting Interpretation: Baseline age differences and modest sample size may have limited power for some outcomes (e.g., mortality), and longer follow-up or larger trials are needed to confirm effects on hard endpoints [1].

Conclusion

Objective fluid assessment with BIS significantly enhances clinical management in chronic hemodialysis patients by improving cardiovascular surrogate outcomes and reducing fluid-related adverse events compared with conventional clinical evaluation.

BIS-guided strategies along with conventional method may contribute to better overall cardiovascular risk profiles, as supported by broader analyses showing technology-guided dry weight management is associated with reduced cardiovascular events and trends toward lower mortality in dialysis populations.

While statistical significance for survival endpoints was not achieved, the observed trends in OS and EFS suggest potential long-term benefit that warrants evaluation in larger, multicenter studies.

Clinical integration of BIS is justified for precise dry weight determination and volume optimization, but routine implementation should consider feasibility, device accessibility, and clinician training.

Future directions: Larger randomized trials with extended follow-up and incorporation of patient-centered outcomes (e.g., quality of life, hospitalization rates) are needed to further validate survival and hard clinical benefits of BIS-guided fluid management.

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