ORIGINAL ARTICLE

Assessment of Nutritional Status Using Body Composition Analysis in Cardiac Surgery and Risk Association with Acute Kidney Injury

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Abstract

Poor nutritional status prior to surgery in cardiac patients is one of the risk factors for acute kidney injury (AKI), morbidity, and mortality. There is a lack of data in patients undergoing cardiac surgery with regard to nutritional status and risk of AKI.

This study was conducted with the objective of assessment of the nutritional status of cardiac surgery patients using body composition measures (BCM) and other biochemical parameters.

This study was conducted at Madras Medical Mission Hospital, Chennai. Before enrolling, informed consent from the patients and ethical authorization were obtained. All patients >18 years of age undergoing cardiac surgery had a BCM analysis done on the pre- and postoperative day 5. Paired *t*-test was used to compare the pre- and postoperative data.

Preoperative body mass index (BMI) of the patients showed that the majority of them were overweight, with a mean BMI of ±26.55 kg/m^2. There were no significant changes in the BCM results for protein weight in either study group (no AKI group—preop: mean ± SD, 9.0316 ± 2.39, $p = 0.67$; postop: mean ± SD, 9.1919 ± 2.57, $p = 0.77$; AKI group—preop: mean ± SD, 9.57 ± 8.00, $p = 0.67$; postop: mean ± SD, 9.56 ± 8.07, $p = 0.77$). There was a significant loss of body fat in all patients, but it was higher in patients who developed AKI (preop: mean ± SD, 33.28 ± 10.96, $p = 0.11$ vs postop: mean ± SD, 31.83 ± 10.94, $p = 0.53$). The skeletal muscle mass in both groups showed no significant changes. Those who developed AKI postoperatively had a higher preoperative visceral fat area (VFA) (mean ± SD, 116.87) and percentage body fat (PBF) (33%) compared to patients who did not develop AKI (VFA ±102.36 and PBF 30%).

We found that patients had lost body fat postsurgically. Those who were diagnosed with AKI had overhydration, high waist circumference, and VFA preoperatively.

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Introduction

Poor nutritional status prior to surgery in cardiac patients increases the risk of acute kidney injury (AKI), morbidity, and mortality. There is an excess paucity of data in cardiac surgery patients with regard to nutritional status and AKI outcomes. There is a lack of data in patients undergoing cardiac surgery regarding nutritional status and the risk of AKI. Older age-groups and patients requiring urgent surgical intervention may have protein-energy wasting (PEW), necessitating early assessment and intervention prior to adequate nutrition therapy. Therefore, assessment of nutritional status by body composition measures (BCM) and other biochemical parameters may provide adequate information to categorize patients as high, moderate, or low risk of malnutrition and AKI.[1] Cardiac surgery patients are often exposed to stressors and are at risk of inflammation, which may cause damage to the organ and can even lead to dysfunction. Cardiopulmonary bypass (CPB) may activate systemic inflammatory response syndrome (SIRS), which causes the release of reactive oxygen species (ROS), reactive nitrogen species (RNS), and pro-inflammatory cytokines.[2–4]

In the nutritional assessment of patients undergoing cardiothoracic surgeries, the percentage of overweight and obesity is high, which systematically increases the risk of complications, including AKI. Bioelectrical impedance analysis (BIA) is a noninvasive and easy technique for measuring body composition, including muscle, fat, and water content. The body composition equipment uses a three-compartment physiologic tissue model, which measures total body fluid water (TBW), extracellular water (ECW), intracellular volume (ICV), and helps in identifying fluid overload, euvolemia, or hypovolemia. AKI is a rare but significant complication of cardiac surgery. It occurs in up to 40% of all cases, with 1% of them requiring renal replacement therapy.[5,6] Even in individuals who have complete renal recovery, the risk of mortality related to AKI remains significant for 10 years following heart surgery, regardless of other risk factors. BCM can also be clinically used in the assessment and management of fluids in patients with end-stage kidney disease (ESKD) and heart disease.[6,7] Many times, a trained nutritionist is not available to assess preoperatively and postoperatively nutritional status and interact with the medical and surgical teams for a smooth postoperative course (R). In a critical care setting, cardiac surgery-related AKI is the second most common cause and is associated with increased mortality rates and increased length of hospital stay.[6] Several studies have found that preoperative, perioperative, and postoperative fluid assessment, blood pressure, and nutritional management have an impact on the postoperative course in preventing complications.[6,7] Therefore, preoperative technically assisted objective assessment of nutritional status and volume, electrolytes, acid-base balance, and albumin is useful to direct intra- and postoperative fluid and electrolyte administration. A previous observational study found that patients with a lower ECW had a greater risk of cardiac surgery-associated (CSA)-AKI compared to patients with stable coronary artery disease and lower ECW.[8,9] We, therefore, hypothesized that BIA-guided volume expansion could be inexpensive and effective in preventing CSA-AKI.

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Methods and Materials

Objective

The objective of the study is to assess the nutritional status and investigate the association between body composition, fluid volume, and biochemical parameters in patients undergoing cardiac surgery and their correlation with the risk of AKI and prognosis.

Methods

This study was conducted at a tertiary cardiac care hospital in Chennai. Before enrolling, informed consent and approval from the Ethics Committee were obtained from all the patients and the institution. After informed consent, all adult patients underwent a BCM analysis performed by the trained nutritionist on the preoperative and postoperative day 5. The study period was 12 months.

Inclusion Criteria

Elective cardiac surgery patients above 18 years of age ($N = 325$ patients).

Exclusion Criteria

Those with no informed consent, those with metal implants, pacemakers, pregnant and lactating women, emergency surgery, and patients who underwent valvular cardiac surgery.

Statistical Analysis

The collected data were statistically analyzed using the *t*-test, percentage, median, interquartile range, or as frequency percentages. Pre- and postoperative comparisons among patients were made using the paired *t*-test. The relationship between variables was analyzed using the Pearson correlation coefficient. AKI was diagnosed using KDIGO guidelines—Kidney Disease Improving Global Outcomes.

Bioelectrical Impedance Analysis

Body composition monitor by Fresenius Medical Care, Germany, is a device based on multifrequency bioimpedance spectroscopy. The method of BIA consists of two components: (1) resistance and (2) reactance, and it is used to analyze body composition by sending a weak electric current through the five components of the body to calculate the impedance of the body fluid, fat, protein, and muscle mass. A low frequency (5 kHz) impedance reflects extracellular fluid because current does not flow through cell membranes. At frequencies above 100–200 kHz, the current will flow through the cell membrane, and the impedance will reflect both extracellular and intracellular fluids.[10] The edema index is defined as the ratio between intra- and ECW.

Results

About 325 patients (M = 265; F = 60), median age 57 years, IQR 49–62 years, who had undergone elective cardiac surgery, were admitted to this study. The results showed that 38 (11.69%) patients developed AKI. Baseline characteristics, such as gender and comorbidities, showed no statistical differences. Patients who developed AKI had a median age of 62.5 years (IQR 54–68 years) vs no AKI (IQR 49.5–64 years), $p = 0.004$. The incidence of AKI was higher in females (17.2%) compared to males (12.3%, $p = 0.2481$). Patients with comorbidities such as diabetes mellitus (71.05%, $p = 0.2964$), hypertension (52.63%, $p = 0.5431$), and cerebrovascular diseases (2.63%) had a higher risk of developing CSA-AKI (Table 1). The preoperative mean serum albumin level was 4.09 gm/dL for those without AKI, compared to 3.97 gm/dL for those who had AKI ($p = 0.1872$). Postoperatively, serum creatinine values increased in patients with AKI, and analysis of variance (ANOVA) confirmed this, with $p = 0.0000$ (Table 2).

Sepsis incidence and mortality rate were higher in those who developed AKI, with 23.33 and 4% death rates, respectively. In the non-AKI category, the incidence of sepsis was 5.51%, and there were no deaths. There was no noted difference in the length of intensive care unit (ICU) and hospital stays in both groups. The *p*-value was 0.001 (Table 3), showing a significant difference in the mechanical ventilation days. The duration of mechanical ventilation was longer in patients who developed postoperative AKI, with a mean of 2.34 days.

Overhydration was maximum with the ECW/TBW >0.38 in patients with AKI compared to non-AKI patients (mean ± SD 0.4006 ± 0.0409, $p = 0.05$) (Table 4); however, it was not significant. Parameters such as body fat, ECW, WHR, and visceral fat area (VFA) were higher in patients with AKI.

As per the preoperative nutritional assessment, the majority of the patients were overweight, with a mean body mass index (BMI) of ±26.55 kg/m^2. The BCM results indicated no significant changes in the protein weight of both study groups (no AKI group—preop: mean ± SD, 9.0316 ± 2.39, $p = 0.67$; postop: mean ± SD, 9.1919 ± 2.57, $p = 0.77$; AKI—preop: mean ± SD, 9.57 ± 8.00, $p = 0.67$; postop: mean ± SD, 9.56 ± 8.07, $p = 0.77$). There was a significant loss of body fat in all the patients, but it was higher in patients who developed AKI (preop: mean ± SD, 33.28 ± 10.96, $p = 0.11$ vs postop: mean ± SD, 31.83 ± 10.94, $p = 0.53$). The skeletal muscle mass in both groups showed no significant changes. Those who developed AKI

Table 1: Demographic characteristics

	Patients without AKI				Patients with AKI				Difference = AKI – no AKI	
Patient characteristics	*N*	*Median*	*IQR*		*N*	*Median*	*IQR*		*Difference in means*	*ANOVA p-value*
Age in years	287	57	49	64	38	62.5	54	68	5.8555	0.0043
Gender	*N*	*%*			*N*	*%*			*Difference in %*	*Chi-square p-value*
Male	236	82.23			29	76.32			–5.91	0.2481
Female	51	17.77			9	23.68			5.91	0.2481
	N	*Mean*	*95% Confidence interval*		*N*	*Mean*	*95% Confidence interval*		*Difference in means*	*ANOVA p-value*
BMI kg/m^2 (day 0)	287	26.86	24.18	29.54	38	26.24	24.87	27.60	–0.6231	0.8681
Comorbidities	*N*	*%*			*N*	*%*			*Difference in %*	*Chi-square p-value*
Diabetes	179	62.37			27	71.05			8.68	0.2964
Hypertension	136	47.39			20	52.63			5.24	0.5431
CKD	6	2.09			6	15.79			13.70	0.0000
CVA	8	2.79			1	2.63			–0.16	0.4562

Table 2: Pre- and postoperative biochemical analysis

Parameters	*Patients without AKI*				*Patients with AKI*				*Difference = AKI – no AKI*	
	N	*Mean*	*95% Confidence interval*		*N*	*Mean*	*95% Confidence interval*		*Difference in means*	*ANOVA p-value*
Pre-operative parameters										
Serum albumin gm/dL	286	4.09	4.03	4.15	38	3.97	3.76	4.18	−0.1216	0.1872
Sodium mmol/L	286	137.99	137.03	138.94	38	138.47	137.61	139.33	0.4877	0.7156
Potassium mmol/L	286	6.27	2.84	9.69	38	4.60	4.46	4.75	−1.6655	0.7277
Bicarbonate mmol/L	283	27.43	26.97	27.89	38	26.24	24.44	28.04	−1.1907	0.0976
EGFR mL/minute	287	100.59	97.45	103.73	38	61.53	54.85	68.22	−39.0525	0.0000
	N	*Median*	*IQR*		*N*	*Median*	*IQR*		*Difference in means*	*ANOVA p-value*
Post-operative parameters										
Day 2 creatinine mg/dL	287	0.72	0.61	0.82	38	1.14	0.95	1.26	0.3949	0.0000
Day 3 creatinine mg/dL	287	0.76	0.65	0.89	38	1.20	1.03	1.48	0.5380	0.0000
Day 4 creatinine mg/dL	287	0.75	0.65	0.87	38	1.24	0.91	1.48	0.5420	0.0000
Day 5 creatinine mg/dL	287	0.74	0.61	0.88	38	1.14	0.90	1.43	0.5012	0.0000
Creatinine at discharge mg/dL	287	0.75	0.62	0.87	38	1.09	0.90	1.31	0.3323	0.0000

Table 3: Surgical outcome

Parameters	*Patients without AKI*				*Patients with AKI*				*Difference = AKI – no AKI*	
	N	*%*			*N*	*%*			*Difference in %*	*Chi-square p-value*
Sepsis	13	5.51			7	23.33			17.82	0.0005
Death	0	0.00			1	4.00			4.00	0.0046
	N	*Median*	*IQR*		*N*	*Median*	*IQR*		*Difference in means*	*ANOVA p-value*
ICU stay	287	3	2	3	38	3	2	3	0.6895	0.0442
Duration of hospital stay in days	287	10	9	11	38	10	8	10	0.0833	0.9045
Days on mechanical ventilation	287	1	1	2	38	1	1	1	1.0099	0.0013

Table 4: Body composition analysis—hydration

Parameters	*Preoperative*				*Postoperative*			
	N	*Mean*	*Std. deviation*	*p-value*	*N*	*Mean*	*Std. deviation*	*p-value*
ICW—AKI (L)	38	20.8947	5.5312	0.6737	37	21.2757	5.9517	0.7854
ICW—no AKI (L)	287	22.1704	18.5273		278	22.1173	18.6376	
ECW—AKI (L)	38	13.0842	3.4418	0.6815	37	13.4865	3.2201	0.8648
ECW—no AKI (L)	287	14.0516	14.4456		278	13.8029	11.2150	
ECW/TBW total—AKI (L)	38	0.3858	0.0297	0.9958	37	0.3898	0.0152	0.7260
ECW/TBW total—no AKI (L)	287	0.3859	0.0138		278	0.5006	1.9202	
ECW/TBW (RA)—AKI (L)	38	0.3777	0.0196	0.9885	37	0.3780	0.0158	0.6422
ECW/TBW (RA)—no AKI	287	0.3778	0.0156		278	0.3766	0.0169	
ECW/TBW (LA)—AKI (L)	38	0.3807	0.0091	0.2591	37	0.3803	0.0098	0.5972
ECM/TBW (LA)—no AKI (L)	287	0.3778	0.0158		278	0.3790	0.0146	
ECW/TBW (TR)—AKI	38	0.3879	0.0296	0.6530	37	0.3906	0.0160	0.2579
ECW/TBW (TR)—no AKI (L)	287	0.3866	0.0146		278	0.3866	0.0202	
ECW/TBW (RL)—AKI (L)	38	0.3852	0.0432	0.8810	37	0.3891	0.0193	0.3115
ECW/TBW (RL)—no AKI (L)	287	0.3846	0.0208		278	0.3838	0.0307	
ECW/TBW (LL)—AKI	38	0.3869	0.0334	0.1866	37	0.3956	0.0158	0.2127
ECW/TBW (LL)—no AKI (L)	287	0.3917	0.0190		278	0.3905	0.0240	

postoperatively had higher VFA (mean ± 116.87) and percentage body fat (PBF) (33%) compared to patients who did not develop AKI (VFA ±102.36 and PBF 30%) (Table 5).

Those who developed AKI were overhydrated, as both intracellular water (ICW) (preop: mean ± SD, 20.89 ± 5.53, $p = 0.67$ vs postop: mean ± SD, 21.27 ± 5.95, $p = 0.78$) and ECW (preop: mean ± SD, 13.08 ± 3.44, $p= 0.68$ vs postop: mean ± SD, 13.48 ± 3.22, $p = 0.86$) increased during the postoperative state. They also had increased waist circumference

Table 5: Body composition analysis—fat and protein

Protein—AKI kgs	38	9.0316	2.3957	0.6760	37	9.1919	2.5750	0.7778
Protein—no AKI kgs	287	9.5787	8.0052		277	9.5697	8.0712	
FAT—AKI kgs	38	23.1474	8.9104	0.1414	37	22.3649	9.2578	0.3387
FAT—no AKI kgs	287	20.9780	8.4742		278	20.9421	8.3800	
Skeletal muscle mass—AKI kgs	38	25.2553	7.2265	0.6748	37	25.7405	7.7644	0.7692
skeletal muscle mass—no AKI kgs	287	26.9129	24.1575		278	26.9241	24.3236	
Percent body fat—AKI	38	33.2895	10.9633	0.1138	37	31.8324	10.9414	0.5315
Percent body fat—no AKI (%)	287	30.5449	9.8993		278	30.7183	10.0589	
BMI—AKI kg/m^2	38	26.2368	4.1444	0.8681	37	26.2243	4.2194	0.8624
BMI—no AKI kg/m^2	287	26.8599	23.0280		278	26.8950	23.4314	
Body cell mass—AKI kgs	38	29.9289	7.9353	0.6740	37	30.4784	8.5231	0.8027
Body cell mass—no AKI kgs	287	31.7544	26.5372		278	31.5870	26.7591	
Waist cir—AKI	38	89.3605	13.7119	0.2825	37	90.2270	13.4341	0.5678
Waist cir—no AKI cms	287	87.2031	11.3077		278	88.9558	12.6030	
VFA—AKI cms	38	116.8737	63.2090	0.0972	37	115.0595	56.6129	0.3242
VFA—no AKI cms	287	102.3672	48.6376		278	105.7712	53.3678	

(preop: mean ± SD, 89.36 ± 13.71, $p = 0.28$ vs postop: mean ± SD, 90.22 ± 13.43, $p = 0.56$), which may be due to overhydration.

Discussion

This investigation examines the role of BCM with biochemical parameters in the assessment of nutritional status and its associated risk for AKI in pre- and postoperative cardiac surgery patients. The assessment consisted of patients in the older age-group with type 2 diabetes mellitus (T2DM), hypertension, and other comorbidities. Those patients with a mean eGFR of ≤61.8 mL/minute developed more AKI, which is not surprising, as their residual kidney reserve was low. Preoperative fluid status, body composition, and edema index were helpful markers in supporting patient management intraoperatively, perioperatively, and postoperatively, as it was not possible to measure the weight of the individuals. This assessment provided value-added information for better management of AKI and recovery. This information helped us reduce the dialysis requirement to a minimum of two patients. We suggest that the tools we used and the information we gathered can be used as a model for improving outcomes following cardiac surgery.

The biochemical parameters such as serum iron, sodium, bicarbonate, and albumin showed no significant changes among patients who developed AKI and those who did not. It is possible that patients who were on ACE inhibitors or ARBs had higher potassium, which was not statistically significant between the two groups. Hyperkalemia ≥5.5 mmol/L was carefully monitored and treated with insulin-glucose infusion or potassium-binding resins. There was an increase in the ECW, ICW, and edema index (EI) in the immediate postoperative period, which declined on postoperative day 5. This increase in ECW was greater than the ICW, and the decline in ECW was faster than in ICW. Cardiac surgery with CPB leads to a rise in the total body fluid due to the infusion of fluids such as intravenous fluids and priming solution. In addition, systemic inflammation was also caused by the interaction of extracorporeal circulation and priming volume with the endogenous body fluids.[11] The EI, defined as the ratio of ECW to TBW, is recognized as a surrogate marker for extracellular volume status. Studies showed that the EI was a useful marker for heart failure (HF), with an EI value of ≥0.390 being a predictor of HF readmissions and all-cause mortality in patients with acute decompensated HF.[12,13]

The preoperative BMI was ± 26.55 kg/m^2 for patients in both groups, indicating overweight. The cutoff BMI of World Health Organization (WHO) for Asian populations was used, which classified BMI into four groups: normal weight (18.5–22.9 kg/m^2), underweight (<18.5 kg/m^2), overweight (23.0–27.4 kg/m^2), or obese (≥27.5 kg/m^2). We observed increased loss of fat in the patients who developed AKI, suggesting augmented lipolysis. Lipolysis begins to dominate in patients who have undergone surgery, and fatty acids become the main source of energy. This can lead to insulin resistance and reduce the anabolic effect of insulin.[14] It was also found that the preoperative PBF, VFA, and waist circumference were higher in patients who developed AKI. Overweight and obese cardiac patients are at an increased risk of developing AKI postoperatively, due to a greater number of comorbidities and underlying structural changes that occur in the kidneys, such as oxidative stress, inflammation, and endothelial dysfunction.[14] There was no significant loss of muscle mass seen in both groups, as the study was limited to 5 days. Preoperative nutritional status and avoidance of increased hospitalization due to complications and comorbidities determine postoperative muscle proteolysis with skeletal muscle loss, which can be managed by appropriate counseling by a trained nutritionist providing protein, calories, and micronutrients.[15] Although a prospective study, the limitations are that it was time-limited to 5 days, accurate information on urine output and thoracic drain tube volumes were not considered, and valvular surgery and very sick patients with hypotension were excluded from our analysis.

Conclusion

This study concludes that higher body fat, visceral fat, and body fat percentage are risk factors for developing AKI postcardiac surgery. The development of AKI after cardiac surgeries can have a significant effect on a patient's body composition. We assessed nutritional status and body fluid status using BCM and biochemical parameters pre- and postcardiac surgery, which helped us tailor nutrition therapy, fluid management, and prevention and management of AKI. The use of the BCM device is a simple and acceptable method to assess nutritional status.

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