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Nutritional Prehabilitation Program and Cardiac Surgery Outcome in Pediatrics

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Abstract:*Congenital heart diseases (CHDs) are the most common birth defects with an incidence of approximately 6-8 in 1,000 live births accounting for 6-10% of all infant deaths and 20-40% of all infant deaths from malformations. Thesedefectsdisruptnormalhemodynamics,causing pathophysiologyresponsibleforinadequatenutrientintake,insufficientnutrientabsorption,andincreasedmetabolic demands .The concept of "prehabilitation," essentially preparing the patient for the upcoming insult and major metabolic stress, has gained momentum and is of keen interest in many surgical circles.Prehabilitation program was applied on 40 patients (group A who received nutrition 2 weeks before surgery and group B who received nutrition 1 week before surgery) inside the postoperative pediatric ICU. Postoperative complications and mortality were statistically lower in-group A, furthermore, postoperative weight gain, duration of mechanical ventilation, length of hospital stay showed significant difference between both groups.We concluded that the nutritional and other clinical outcomes as well as fate of the patients were markedly improved after application of the prehabilitation nutritional program. So we recommend that nutrition delivered to the patients pre and post operative should be guided by prehabilitation program and with regular assessment of the nutritional status of the patients clinically and laboratory.*

Keywords:*Congenital heart diseases,Nutritional status,Prehabilitation nutritional program, Postoperative complications.*

I. Introduction

Congenital heart diseases (CHDs) are the most common birth defects with an incidence of approximately 6-8 in 1,000 live births, accounting for 6-10% of all infant deaths and 20-40% of all infant deaths from malformations [1]. Thesedefectsdisruptnormalhemodynamics,causing pathophysiologyresponsibleforinadequatenutrientintake,insufficientnutrientabsorption,andincreasedmetabolic demands [2]. Up to one third of infants born with CHD require surgical intervention early in their lives[3]. Postoperative poor outcomes include not only increase overall mortality but also morbidity, such as increased hospital stay, increased intensive care unit (ICU) admissions, delayed wound healing, central line-associated bloodstream infections, surgical site infections, and other infectious complications [4].Nutrition is fundamental for ensuring adequate energy essential for basal metabolism, growth and physical activity. Infants and children possess high metabolic rates and limited reserves for endogenous substrates at baseline, so infants and children are at risk for developing inadequate energy production during episodes of acute or chronic illness [5].There is a general agreement that enteral nutrition is better than Parenteral nutrition. It is no longer controversialthat early postoperative enteral feeding is beneficial, Early enteralnutrition delivery can decrease infectious complications, maintainthe integrity of the gut mucosal border, attenuate the metabolic responseto surgical stress, and decrease mortality [6].The concept of "prehabilitation," essentially preparing the patient for the upcoming insult and major metabolic stress, has gained momentum and is of keen interest in many surgical circles [7]. As part of this prehabilitation concept, the operative team would metabolically assess the patient in some predetermined preoperative setting and offer guidance for optimal glycemic control and begin an individually tailored exercise program to enhance lean body tissue and endurance [8].

II. Aim Of The Work

This study was done to compare the outcome of malnourished congenital heart surgery patients who received nutritional pehabilitation program 2 weeks pre-operatively with those who received nutritional pehabilitationprogram only for 1 week pre-operatively.

III. Patients And Methods

3.1 Patients

This is a prospective study that was carried out on 40 infants underwent open or closed heart surgery for palliative or corrective repairs for congenital heart disease in Pediatric cardiac surgery ofAtfalMasr Hospital.

3.1.1. Inclusion Criteria:

Infants with congenital heart disease, admitted to cardiothoracic unit for either palliative or corrective surgery, suffering from nutritional deficiencies with body weights less than 2 SD.

3.1.2.Exclusion Criteria:

1. Congenital or acquired anomaly of gastrointestinal tract .
2. Metabolic or endocrine disease or any systemic illness.
3. Fever or infection within 5 days before the study entry.

3.1.3.Group Classification:The Avaliable patients will be assigned into one of 2 groups:

Group A: included 20 patients who were scheduled for elective surgery called 2 weeks prior to surgery and received nutritional prehabilitation programs according to the updated guidelines [9].
Group B: included 20 patients who were scheduled for elective surgery called 1 week prior to surgery and received nutritional prehabilitation programs according to the updated guidelines [9].

3.2.Methods

3.2.1.comprehensive history taking:

- **Antenatal history:**Maternal age, chronic diseases, TORCH infection and medications during this pregnancy .
- **Natal history:** Gestational age according to the guidelines of the American Academy of Pediatrics [10], neonatal sex and mode of delivery.
- **Postnatal history:**Respiratory distress and cyanosis.
- **Family history:** Consanguinity, congenital anomalies, previous abortion, sibling death, and still birth .

3.2.2. Clinical examination:

General assessment including:

1. Type of surgery (open or closed).
2. Original diagnosis.
3. Preoperative investigations, intervention or previous surgery.

Specific nutritional assessment:

Anthropometrical assessment was performed using standardized equipment's, and following the recommendations of the International Biological Program [11].

1- Preoperative, early and final postoperative weight (measured on growth curves)
2- Preoperative and postoperative height (measured on growth curves)
3- Body mass index (weight/height)
4- Weight-for-age z score, Height-for-age z score [12].

3.2.3.Laboratory Investigations:

- Complete blood picture using Coulter Counter GEN-S (Coulter Corporation, USA) [13].
- C-reactive protein was estimated by latex agglutination assay using the AVITEX CRP commercial kit [14].
- Coagulation profile.
- Blood sugar.
- Kidney, serum potassium and serum calcium.
- Liver function tests (serum albumin, alanine transaminase and aspartate transaminase). Function tests and electrolytes (blood urea nitrogen, serum creatinin, serum sodium).
- Chest x ray and Echocardiography.

3.2.4.Type of Study:

Prospective study was applied with no blinding. In our study, the parents of the studied infants, data collectors, study nurses, laboratory personnel, the supervisors and attending investigator were aware of the nature of the intervention.

3.2.5 .NutritionalPrehabilitation Program

- **Pre-operative period**: Calculating caloric intake using the recommended dietary allowance (RDA) then increased energy intakes by 30% above RDA with the total caloric intake in the range of 150 to 180 kcal/kg per day [15]. Provide adequate nutrition preferably via enteral feeding (EN) to meet the patient's needs until surgery. Our goal was weight gain of 50 to 60 g per day in order to maintain good nutritional health[16]
- **Post-operative period:**Initiate nutrition support as soon as possible to prevent malnutrition and to support functioning of vital organs. Avoid re-feeding syndrome in the infant with significant malnutrition.Avoid overfeeding, which can cause difficulty in weaning from the ventilator.Reduce unnecessary cessation of EN [17].

3.3The following outcomes was recorded:

3.3.1. Primary outcomes

- The day of successful start of enteral treatment.
- Recording enteral feeding pre and postoperative (volume of increment, frequency, type and method of administration) daily.
- Recording daily intravenous fluids pre and postoperative (type, concentration, volume).
- Recording the total calories taken by the patient daily pre and postoperative.
- Weight gain expressed as g/kg/day. Growth expressed as weight, height and Weight for age z score[18]. All the previous parameters will be recorded at admission and at discharge.
- Feeding complications (overfeeding, underfeeding ability to feed and feeding tolerance (whether good i.e. no distension, no vomiting or diarrhea, no or minimal residual, fair i.e. mild abdominal distension, mild vomiting or colic, small residual volume, bad i.e. marked abdominal distension, hematemesis, marked residual volume more than 60% of the meal)).

3.3.2. Secondary outcomes

- Postoperative complications, wound healing and infective complications
- Length of ICU stay.
- Mortality if present (secondary outcomes).
- Respiratory complications e.g. aspiration, pneumonia, respiratory distress, pneumothorax, atelectasis .
- Mechanical ventilation (duration, extubated, reventilated or not extubated).
- Hemodynamic stability (within the normal average heart rate and blood pressure according to age) and bleeding.
- Neurological complications (convulsions, disturbed conscious level or others).

3.4.**Ethical Considerations:**Collected data have been used for study purpose only. The mothers of the infants under study were informed about the purpose of the study and of the name of the research institute before agreeing to participate. They provided informed consent before the testing began.

IV. Statistical Analysis

Data were collected, revised, coded and entered to the Statistical Package for Social Science (IBM SPSS) version 20 .Qualitative data were presented as number and percentages while quantitative data were presented as mean, standard deviations and ranges. The comparison between two groups with qualitative data were done by using Chi-square test and/or Fisher exact test was used instead of Chi-square test when the expected count in any cell was found less than 5.The comparison between two independent groups with parametric data were done by using Independent sample t-test while the non parametric data were compared by using Mann-Whitney test. Spearman correlation coefficients were used to assess the relation between two quantitative parameters in the same group.

V. Result

This study was carried out on 40 infants with congenital heart disease admitted to Pediatric cardiac surgery intensive care unit at Ain-Shams University and AtfalMasr Hospital. All of them were fulfilling the selection criteria of the study.The results of the present study are shown in FollowingTables and Figures.

Table (1): Demographic Characteristics Of The 2 Studied Groups

	GroupA (n=20)	GroupB (n=20)	Test	p-value
Malesex,n(%)	13(65.0)	10(50.0)	0.921	0.337
Age(years)				
Range	0.6-7.6	0.5-4.2	1.831	0.067
Median	1.25(0.9–3.34)	0.8(0.55–1.25)		

"Table 1" shows no statistically significant difference as regards sex, age between the 2 studied groups (p>0.05).

Table (2):Pre-Nutrition, Pre-Operative Anthropometric Parameters Of The 2 Studied Groups

		GroupA (n=20)	GroupB (n=20)	Test	p-value
Weight(kg)	Mean±SD	9.72±4.43	6.55±2.74	2.719	**0.010***
Weight-for-agezscore	Median(IQR)	-2(-3--2)	-3(-3--2)	-1.392	0.164
Height(cm)	Mean±SD	86.90±26.06	71.20±14.17	1.915	0.063
Height-for-agezscore	Median(IQR)	0(-1–2)	-1(-2–1)	-1.379	0.168
BMI(kg/m²)	Mean±SD	12.32±2.41	12.59±2.55	-0.346	0.731

BMI: Body mass index; *, p<0.05 (significant). Data were expressed as mean ± SD where Student-t test was applied for comparisons or as median and IQR (interquartile range) where Mann-Whitneytest (z) used for comparison.

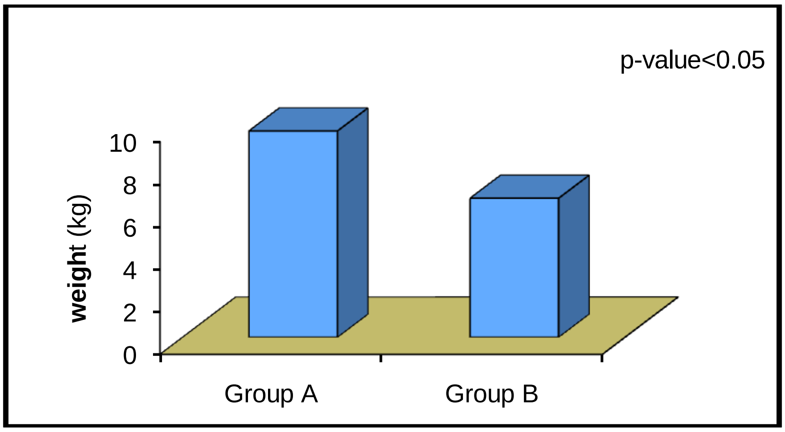

Figure (1): Comparison between the 2 studied groups as regards pre-nutrition, pre-operative weight.

"Table 2" and "fig 1" show pre-nutrition & pre-operative anthropometric parameters in the 2 studied groups. Which significantly higher as regards weight among group A.

Table (3):Post-Nutrition, Pre-Operative Anthropometric Parameters Among The 2 Studied Groups

		GroupA (n=20)	GroupB (n=20)	Test	p-value
Weight(kg)	Mean±SD	11.17±6.75	7.07±2.78	2.512	**0.016***
Weight-for-age zscore	Median(IQR)	1(-1--1)	-1(-2---1)	-3.377	**0.001***
Height(cm)	Mean±SD	87.25±18.81	75.60±14.01	2.221	**0.032***
Height-for-age zscore	Median(IQR)	0(-1--2)	-1(-2--2)	-1.390	0.165
BMI(kg/m²)	Mean±SD	14.80±3.23	12.51±2.68	2.440	**0.019***

BMI: Body mass index; *, p<0.05 (significant). Data were expressed as mean ± SD where Student-t test was applied for comparisons or as median and IQR (interquartile range) where Mann-Whitneytest (z) used for comparison.

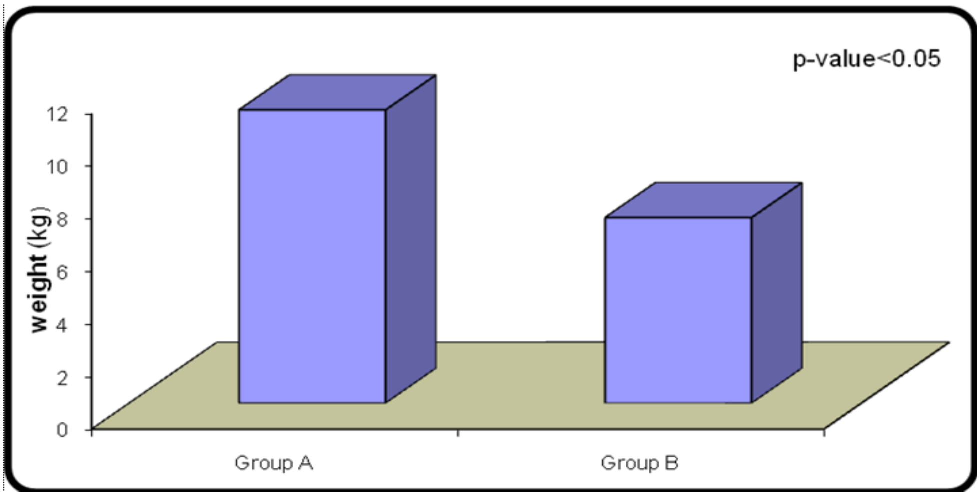

Figure (2):comparison between the 2 studied groups as regards post-nutrition, pre-operative weight.

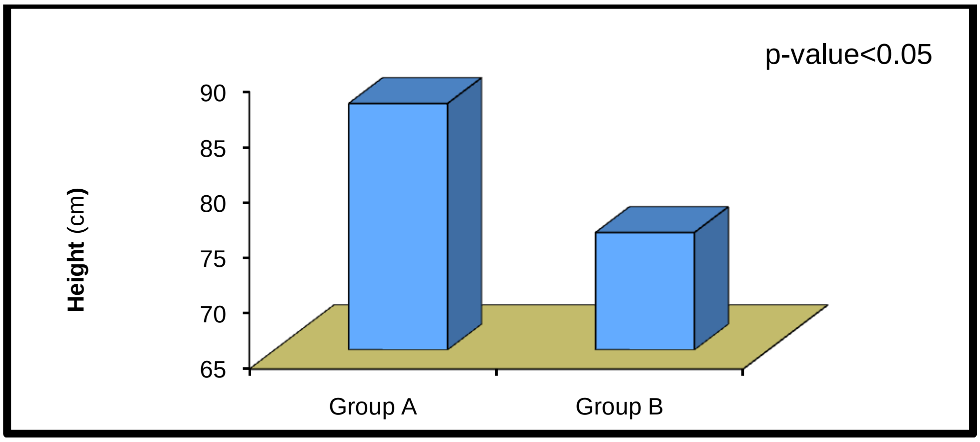

Figure (3):comparison between the 2 studied groups as regards post-nutrition, pre-operative height

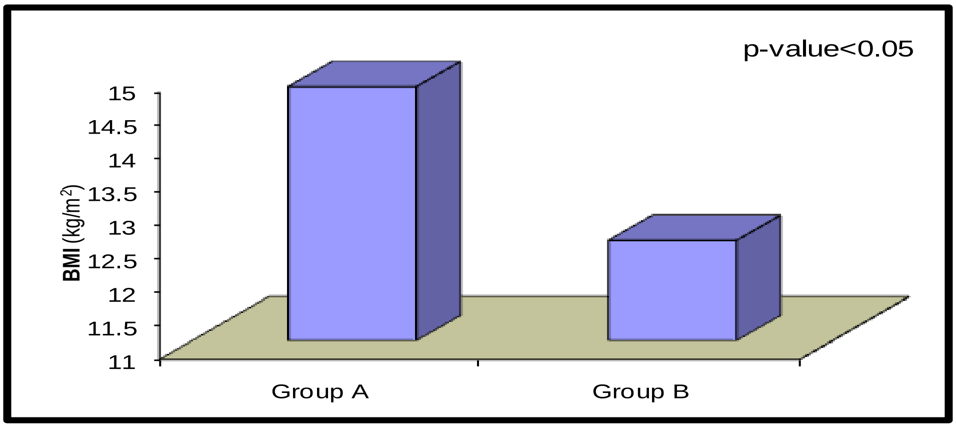

Figure (4):comparison between the 2 studied groups as regards post-nutrition, pre-operative BMI

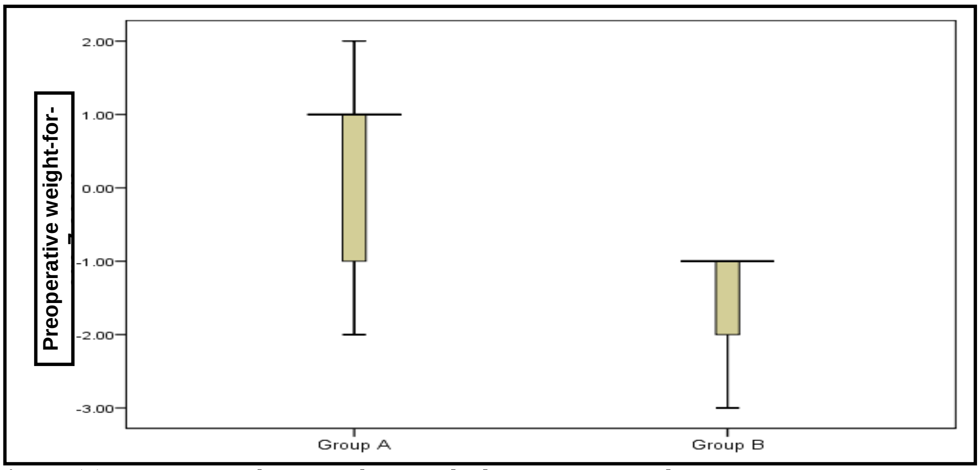

Figure (5): Comparison between the 2 studied groups as regards post-nutrition, pre-operative weight-for-age (z score).

"Table 3" and "fig 2,3,4,5" show post-nutrition, pre-operative anthropometric parameters in the 2 studied groups. A significant increasing weight, weight for age-z score, height and BMI was observed among group A who received nutritional prehabilitation for 2 weeks before surgical interference when compared to group B who received nutritional prehabilitation for 1 week before surgical interference.

Table (4):Post-Operative Nutritional Prehabilitation Of The 2 Studied Groups

		Group A (n=20)	Group B (n=20)	Test	p-value
		n (%)	n (%)		
Timing of start of post-operative enteral feeding (days)	1st	16(80.0)	12(60.0)	2.390	0.303
	2nd	4(20.0)	7(35.0)		
	No	0(0.0)	1(5.0)		
Method of administration of enteral feeding	No enteral feeding	0(0.0)	1(5.0)	3.462	0.177
	Nasogastric	3(15.0)	7(35.0)		
	Oral	17(85.0)	12(60.0)		
Feeding frequency (every hrs)	2	19(95.0)	16(84.2)	1.232	0.267
	3	1(5.0)	3(15.8)		
Volume of post-operative feeding (mL/fed)	mean±SD	37.00±10.31	29.47±10.79	2.228	**0.032***

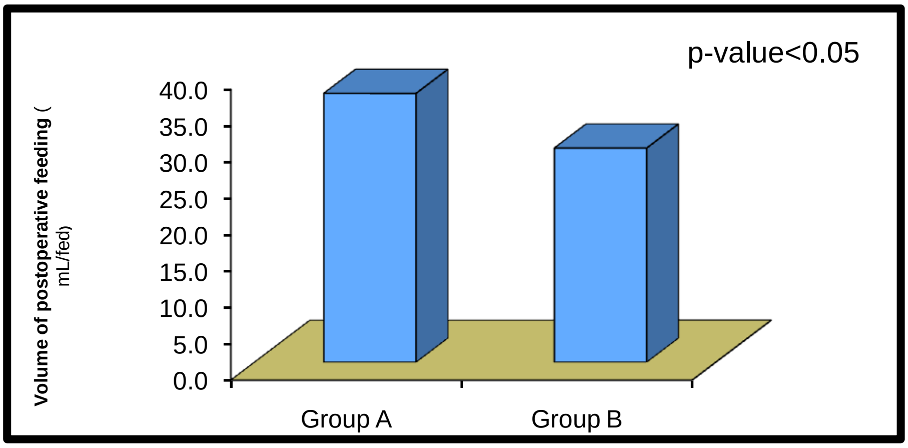

Figure (6): Volume of post-operative feeding in the 2 studied groups

"Table 4" and "fig 6" show no statistically significant difference as regards timing of start of post-operative enteral feeding, method of administration of enteral feeding and feeding frequency while there was statistically significant increase in volume of post-operative feeding in group A who received nutritional prehabilitation 2 weeks before surgical interference compared to group B who received nutritional prehabilitation 1weeks before surgical interference.

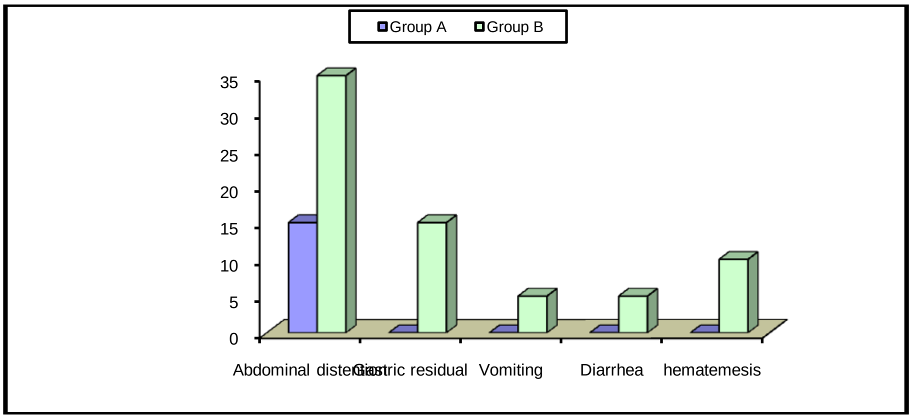

Figure (7):feeding intolerance manifestations in the 2 studied groups

"fig7"show lower incidence of abdominal distention, gastric residual >25%, vomiting, diarrhea and hematemesis among group A patients when compared to group B though not reaching a statistically significant level.

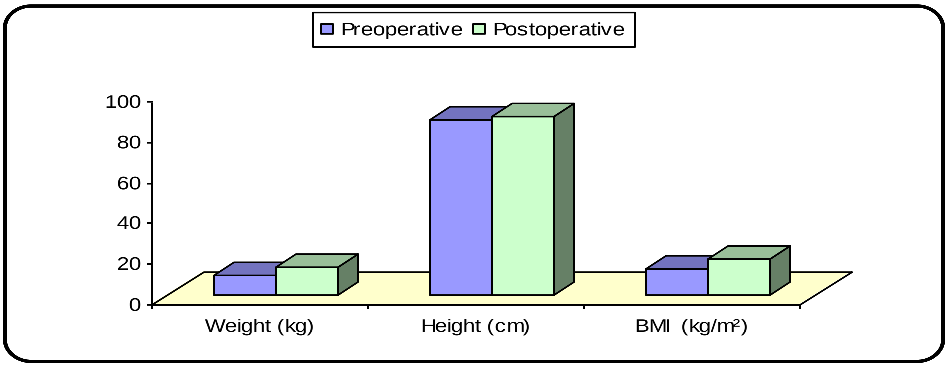

Figure (8):pre-operative and post-operative anthropometric parameters in group a.

"Fig 8"show statistically significant increase in post-operative weight and BMI, weight- fore- age z score and height-for-age z score while there wasno statistically significant difference as regards height in group A.

Table (5)Post-operative anthropometric parameters among the 2 studied groups at discharge

		Group A (n=20)	Group B (n=20)	Test	p-value
Weight (kg)	Mean±SD	13.47±2.84	7.12±2.82	2.636	0.012*
Weight- for- age z score	Median (IQR)	3 (2—3)	1 (1--2)	-3.729	0.000*
Height (cm)	Mean±SD	87.85±18.81	72.10±13.46	3.045	0.004*
Height- for- age z score	Median (IQR)	0 (0—2)	-1 (-1—1)	-1.006	0.314
BMI (kg/m²)	Mean±SD	17.45±3.44	13.42±3.11	2.161	0.047*
Weight gain (Post-operative-pre-operative weight) (gm)	Mean±SD	448.57±148.16	297.78±92.44	2.719	0.013*

"Table5"show post-operative anthropometric parameters in the 2 studied groups. A significant increase in weight, weight-for-age z score, height, BMI and weight gain was observed among group a patients who received nutritional prehabilitation for 2 weeks before surgical interference when compared to group b who received nutritional prehabilitation for 1 week before surgical interference.

Table (6);Pre-operative and post-operative biochemical profile in group B

	Pre-operative Mean±SD	Post-operative Mean±SD	Test	p-value
Na(mEq/L)	139.25±6.59	139.48±6.92	-0.103	0.919
K(mEq/L)	4.33±0.68	4.65±0.80	-1.776	0.092
Ca(mg/dL)	9.77±0.74	9.97±0.66	-0.792	0.438
Urea(mg/dL)	32.10±15.95	39.14±17.36	-1.475	0.157
Creatinine(mg/dL)	0.76±0.31	0.77±0.42	-0.205	0.840
RBS(mg/dL)	104.90±15.13	115.95±21.78	-1.863	0.070
CRP	3.08±1.62	8.35±6.5	3.518	**0.001***

Ca: Calcium;**Na:**Sodium;**K:**Potassium,**RBS:**Randombloodsugar.
Datawereexpressedasmean±SDwhereStudent-ttestwasappliedforcomparisons

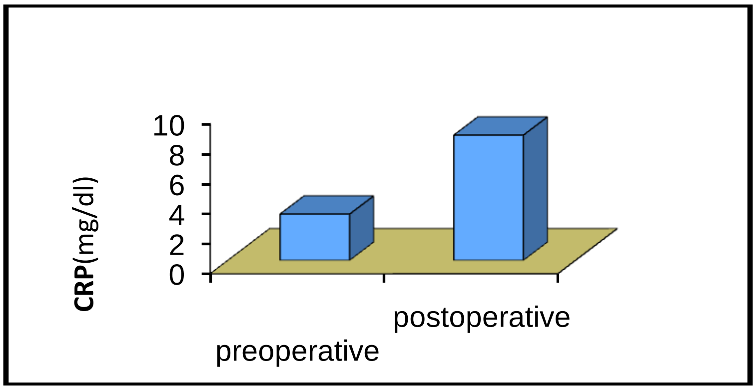

Figure (9): Pre-operative and post-operative CRP in group B.

"Table 6 "and "figure 9" show no statistically significant difference as regards post-operative laboratory characteristics, except significant post-operative CRP rise showed between the 2 studied groups.

Table (7): Primary outcomes of the 2 studied groups

		Group A (n=20) n (%)	Group B (n=20) n (%)	Test	p-value
Length of ICU stay (hrs)	Median (IQR)	24 (24 – 48)	60 (38 – 108)	3.184	**0.001***
Duration of post-operative mechanical ventilation (hrs)	Median (IQR)	8 (6 – 18)	18 (13 – 47)	2.914	**0.003***
Extubation	Early	18(90.0)	15(75.0)	2.273	0.518
	late	1(5.0)	3(15.0)		
	notextubated	0(0.0)	1(5.0)		
	re-intubated	1(5.0)	1(5.0)		
Wean of ventilator	No	0(0.0)	1(5.0)	1.026	0.311
	yes	20(100.0)	19(95.0)		
Inotropes withdrawal	No	0(0.0)	1(5.0)	1.026	0.311
	yes	20(100.0)	19(95.0)		
Clinical evidence of respiratory or other infections	No	20(100.0)	18(90.0)	2.105	0.147
	Yes	0(0.0)	2(10.0)		
Bleeding	No	20(100.0)	20(100.0)	NA	NA
Neurological complications	No	20(100.0)	20(100.0)	NA	NA

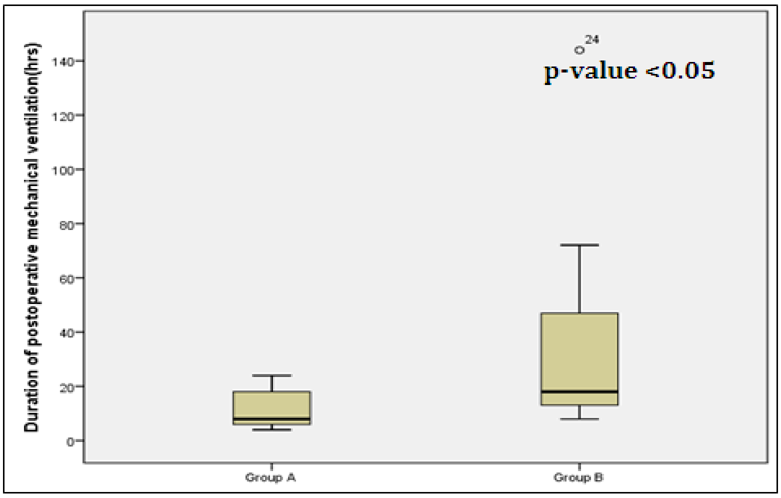

Figure (10): Duration of post-operative mechanical ventilation in the 2 studied groups.

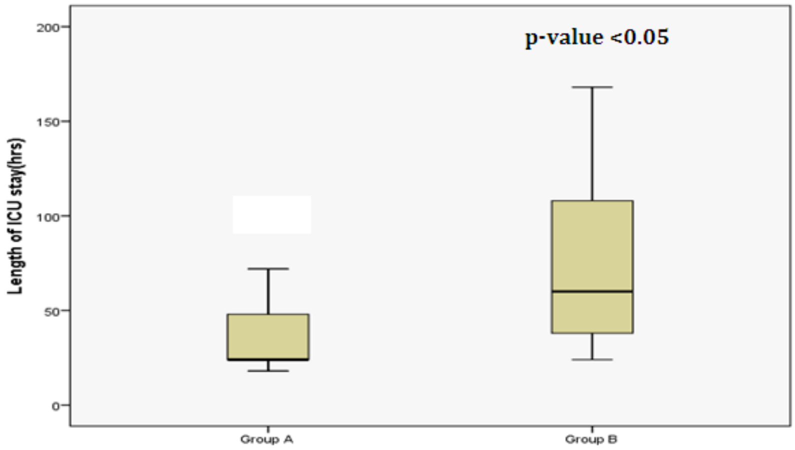

Figure (11): Post-operative ICU stay in the 2 studied groups.

"Table 7" and "fig 11-12" show no statistically significant difference as regards clinical evidence of respiratory or other infections, post-operative bleeding, neurological complications, cause of death, successful Weaning of ventilator, extubation, inotropes withdrawal, but there was statistically significant decrease in duration of post-operative mechanical ventilation and length of CICU stay was observed among group A who received nutritional prehabilitation for 2 weeks before surgical interference when compared to group B who received nutritional prehabilitation for 1 week before surgical interference.

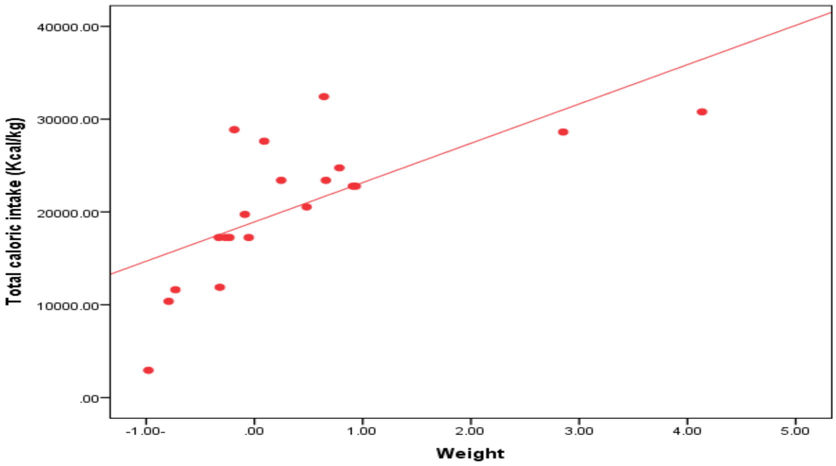

Figure (12): Positive correlation between total caloric intake and post-operative weight in group A.

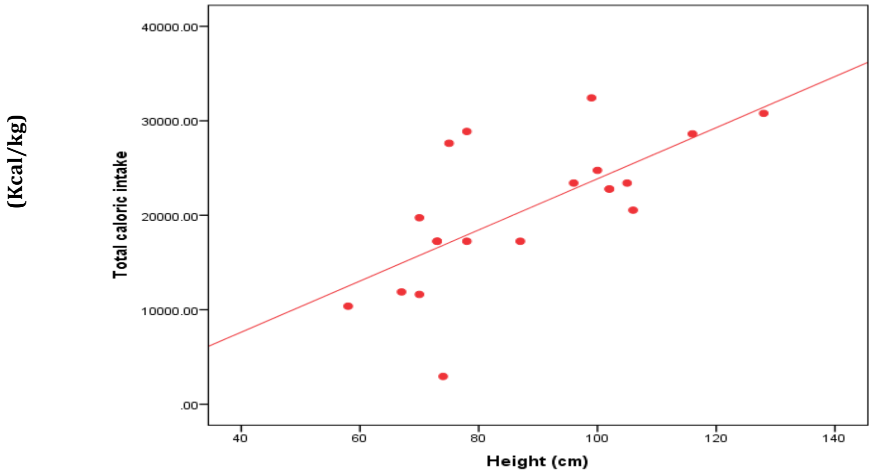

Figure (13): Positive correlation between total caloric intake and post-operative height in group A.

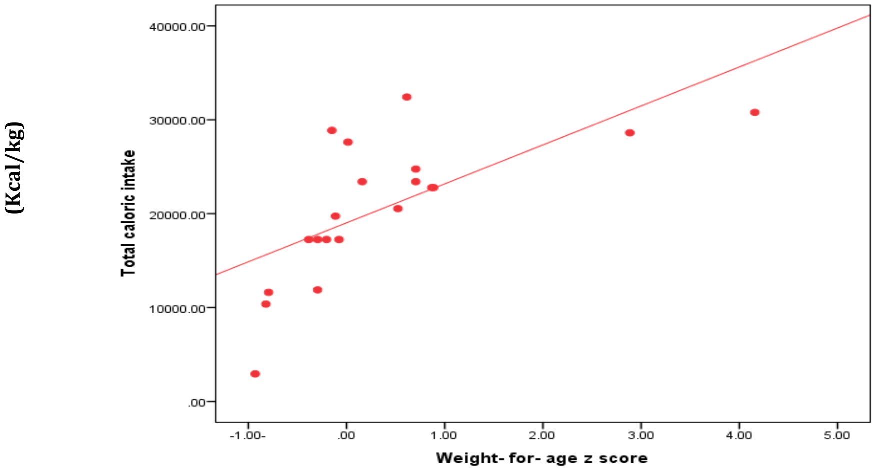

Figure (14): Positive correlation between total caloric intake and post-operative weight-for-age z score in groupA.

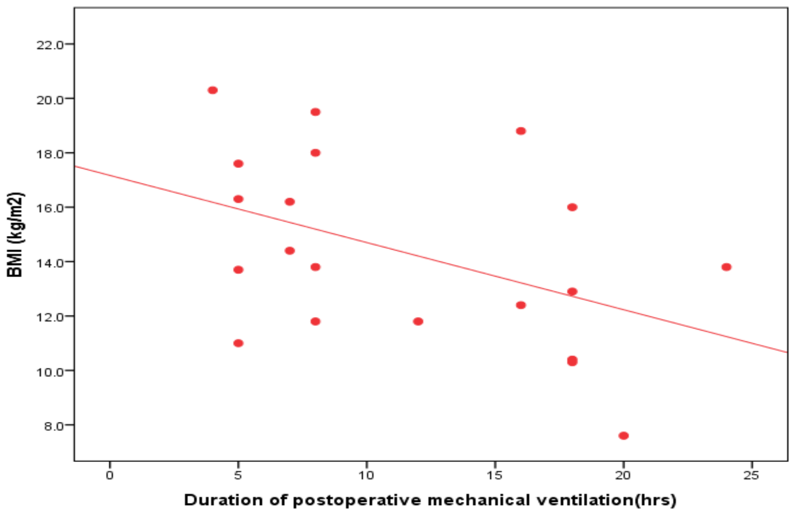

Figure (15): Negative correlation between post-operative BMI and duration of mechanical ventilation in group A.

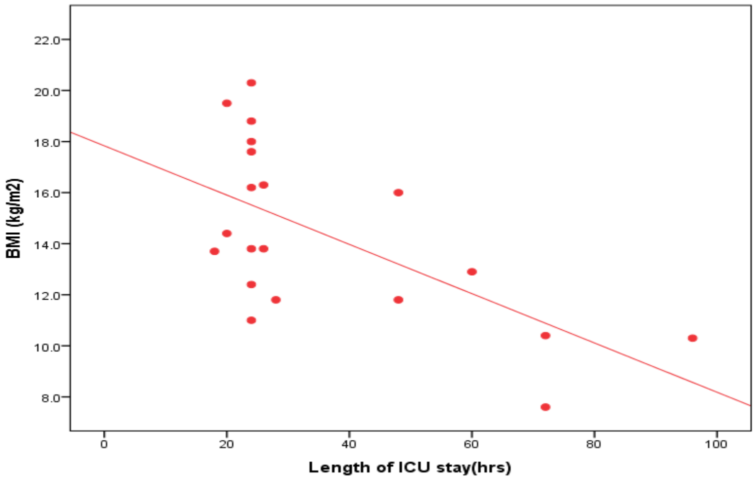

Figure (16): Negative correlation between post-operative BMI and length of ICU stay in group A.

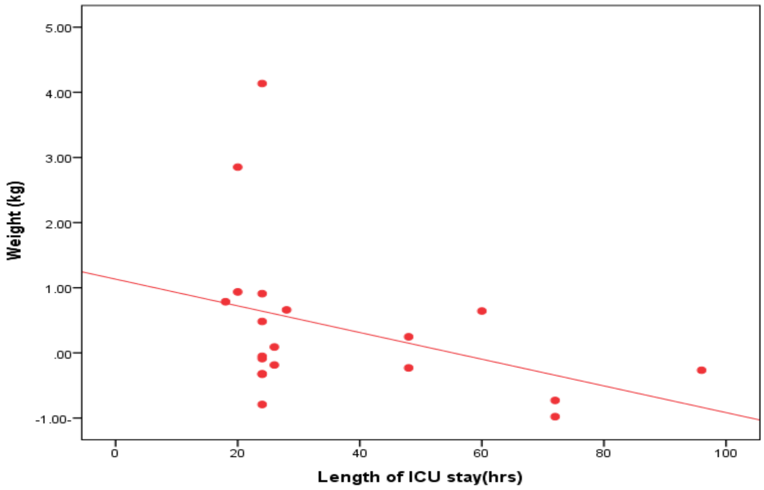

Figure (17): Negative correlation between post-operative weight and length of ICU stay in group A.

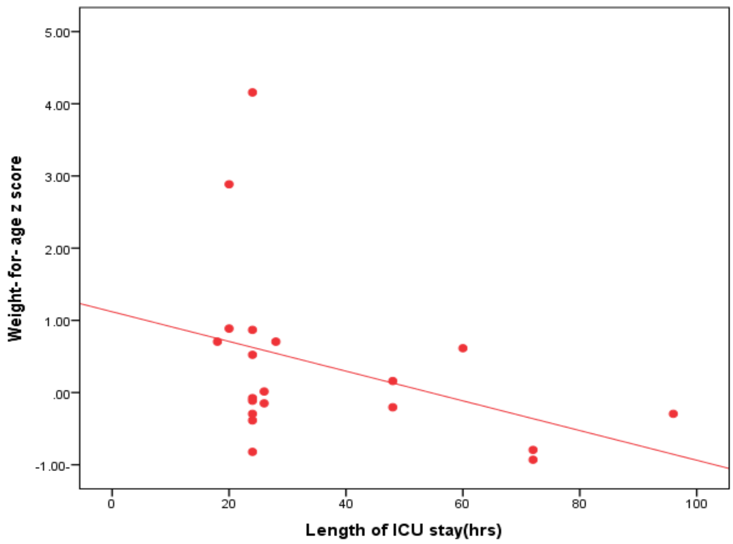

Figure (18): Negative correlation between post-operative weight-for-age z score and length of ICU stay in group A.

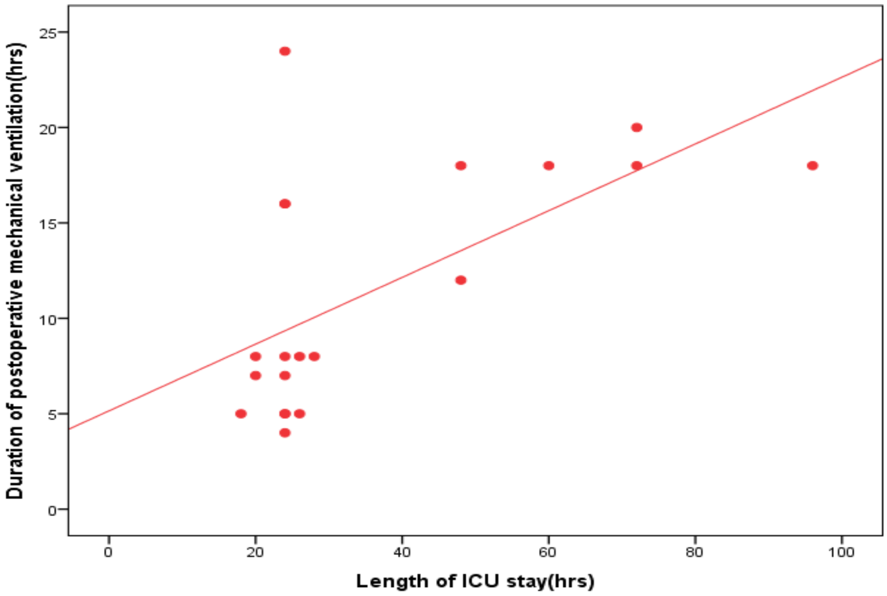

Figure (19): Positive correlation between duration of post-operative mechanical ventilation and length of ICU stay in group A.

"fig"12-18 Show a significant positive correlation between total caloric intake and each of weight, height and weight-for-age z score (p<0.01) for all. Furthermore, length of ICU stay shows a significant negative correlation with weight, weight-for-age z score (p<0.01) for all. In addition, duration of mechanical ventilation shows a significant negative correlation with BMI (p<0.01).

Table (7):Linear regression analysis for total caloric intake in prediction of length of stay

	Unstandardized Coefficients		Standardized Coefficients	T	Sig.
	B	Std.Error	Beta		
(Constant)	89.655	11.029		8.129	**0.000***
Totalcaloricintake(Kcal/kg)	-0.002	0.001	-0.502	-3.579	**0.001***

Beta=R=-0.502

Linear regression analysis was used to assess the correlation between total caloric intake and length of CICU stay. Length of stay calculated from the equation; length of stay (hrs) = (89.655 – 0.002) x total caloric intake (Kcal/kg).

Table (10): Secondary outcomes of the studied groups:

	Group A (n=20)	Group B (n=20)	Test	p-value
	n (%)	n (%)		
Discharge	20(100.0)	20(100.0)	NA	NA
Death	0(0.0)	0(0.0)	NA	NA
Sepsis	0(0.0)	2(10.0)	2.105	0.147

Data were expressed as number and percentage using Chi-square (X^2) test for comparison.
"Table 10" shows no statistically significant difference as regard secondary outcomes between the 2 studied groups (p>0.05).

VI. Discussion

Congenital heart defects have a high priority in public health illnesses, representing the most common congenital malformations present at birth with an impact on childhood morbidity and mortality. They are responsible for 6-10% of the total of 20-40% of infant deaths caused by congenital malformations [19]

Most CHDs require surgical correction at some point, and the timing of the surgery depends not only on the type of the cardiac lesion, but also on the child's weight. Surgical correction is performed in most cases as soon as possible, after the child reaches ideal weight[20].

Malnutrition in the pediatric intensive care unit (ICU) population is a widely acknowledged problem that may intensify underlying illnesses, increase the risk of complications and affect growth and development. Nutritional assessment upon admission to the ICU is necessary to identify children at risk and to guide nutritional support during ICU stay [21].

The repertoire of routine laboratory parameters includes several markers (e.g., albumin, urea, electrolytes) that can provide useful and easily obtainable information regarding nutritional status and requirements. Abnormalities in these parameters reflect derangements in several metabolic pathways and may represent the severity of depletions occurring during critical illness[22].

In the current analysis, both groups were comparable as regard baseline demographic, clinical and laboratory characteristics measured before implementation of any nutritional prehabilitation or surgical interference. In an earlier study, Hansen and Dorup [23]recorded that caloric intake in patients with CHD was 76% that of normal age-matched controls. Fatigue upon feeding may represent a possible cause to explain the decreasedintake and chronic hypoxia leads to both dyspnea and tachypnea during feeding, causing the child to tire easily and thus reduce the quantity of food consumed.

Moreover, we found a negative correlation between the baseline pre-operative pre-nutritional anthropometric measurements including weight and height of all the studied patients with CHD and duration of hospitalization and mechanical ventilation. Similarly, Bozzetti [24] reported that in pre-operative patients with protein energy malnutrition, the incidence of post-operative adverse events is reported to be higher than in patients with normal nutrition status. Moreover, Tokel et al [25]stated that pre-operative severity of malnutrition is indeed related to the pre-operative and post-operative events.

In the view of the effect of pre-operative nutritional prehabilitation on the anthropometric features of the 2 studied groups, we observed a highly significant increase in weight, height, BMI and weight-for-age z score in group A who received nutritional prehabilitation for 2 weeks pre-operatively compared to group B who received nutritional prehabilitation for only 1 week pre-operatively.

In an earlier study, Potter et al [26] reported that most trials included in his review concluded that nutritional supplementation improves body weight and anthropometry. Furthermore, aretrospective study conducted by Schuurmans et al [27]observed low pre-operative mean weight-for-age and height-for-age z-scores in 18 Dutch children with Tetralogy of Fallot, which improved after the introduction of adequate nutritional rehabilitation therapy.

As regard height-for-age Z score, the current study showed no significant change in height post-nutritional prehabilitation. This could be explained by the fact that changes in height known to be secondary to chronic changes that take longer time to show the difference than acute change of weight [25].This was further supported by the positive change in weight-for-age z score and height-for-age z score post-operatively in both groups.Our nutritional prehabilitation protocol includes not only pre-operative nutritional support, but also post-operative increased enteral feeding goal rates, in order to allow our patients to receive their goal nutrition requirements in a 24-hour period post-operatively.

As regards post-operative nutritional outcomes, no significant difference was found between both groups as regard type of enteral feeding, timing of start, method of enteral feeding and frequency of feeding. However, group A showed significant high volume per fed post-operatively compared to group B. Furthermore, this nutritional prehabilitation protocol was easily tolerated by patients of both groups with lower manifestations of feeding intolerance among group A though not reaching statistically significant level.

These results agree with the results recorded by Binnekade[28] who studied the tolerance to enteral feeding after application of post-operative nutritional protocol in pediatric CICU and concluded that tolerance was significantly improved after application of such protocol.

Upon comparing pre-operative and post-operative anthropometric features, highly significant increase in post-operative weight-for-age z score and height-for-age z score in both groups. Furthermore, group A showed a highly significant increase in post-operative weight and BMI. Moreover, length of ICU stay was negatively correlated with post-operative anthropometric parameters including weight, weight-for-age z score and BMI, however didn't reach significant levels in group B.

In an additional assessment of the effect of nutritional prehabilitation program, a highly significant increase in weight, height, BMI, weight-for-age z score and weight gain in group A compared to group B, post-operatively with a significant positive correlations between post-operative anthropometry and total caloric intake.The previous findings support those of Beattie et al[29]who studied the application of dietary supplementation in patients following surgery where weight was slow to recover in the control group compared with the group receiving post-operative nutritional supplementation. However, we found it unethical to use a control group that has no pre-operative nutritional support, instead we randomly assigned patients into one of 2 groups receiving pre-operative nutritional prehabilitation for either one or 2 weeks pre-operatively and continued post-operatively till discharge.

In agreement with our findings, Anderson et al [30] who examined infants with single ventricle at Cincinnati Children's Hospital Medical Center reported that optimal nutritional practices after the Norwood operation led to improve in weight gain. Moreover, Sables-Baus et al [31]carried out retrospective review of infants admitted with congenital cardiac disease over a period of 1 year and concluded that enteral feeding was associated with greater weight gain.

Upon comparing post-operative hemodynamic data between both groups, we found no significant difference as regard heart rate, respiratory rate, systolic blood pressure, diastolic blood pressure, body temperature, central venous pressure, urinary output and oxygen saturation.

Upon comparing pre-operative and post-operative hematological and biochemical features of both groups we found no significant difference except for CRP which showed significant post-operative rise in group B. However, comparing pre-operative and post-operative hematological and biochemical features between both groups, we found no significant difference except for post-operative CRP which significantly lower in group A compared with group B.

This is in concordance with Nakamura et al [32]who studied influence of pre-operative nutritional state on inflammatory response after surgery and reported that among patient receiving nutritional intervention, the malnourished group having higher CRP levels than those who were not malnourished .

Upon studying the effect of longer pre-operative enteral nutritional intervention on the primary outcome measures, a significant decrease of the duration of mechanical ventilation and duration of hospitalization in group A compared with group B was found. Furthermore, we observed that post-operative weight, BMI, weight-for-age z score were negatively correlated with the length of the intensive care stay, and that post-operative BMI was negatively correlated with the duration of mechanical ventilation in group A, while group B showed no significant correlations with the measured outcomes.

In agreement with our results Corkins[33], Yiet al [34], White et al [35] demonstrated that early pre-operative enteral nutrition decreases infection rates, length of stay and duration of mechanical ventilation. Moreover, Dong et al [36]reported that duration of mechanical ventilation and length of ICU stay were significantly reduced in the nutritional rehabilitation group compared with the control group. In this regard, McClave et al [36]reported improved patient outcomes when a protocol to deliver the caloric and protein goal is implemented. Furthermore, Deitch et al [38]stated that proper adequate nutritional support may help in achievement of the balance between the calories, proteins and electrolytes delivered to the patients and the nutritional requirements needed for proper functions of the liver, kidney, brain and heart, improved resistance to infections, shortened length of hospital and ICU stay, good function of the lungs and early weaning from the ventilator. Additionally, Somanchi et al [39] observed in their analysis on malnourished hospitalized patients at the Johns Hopkins Hospital that nutrition screening involving a team approach to address malnutrition and earlier intervention reduced the length of hospital stay by an average of 3.2 days in severely malnourished patients.As regards secondary outcomes, all of the included patients were discharged and none of our patients died during the study.

The limitation of our study includes examining a heterogeneous group of patients of different ages with diseases of different complexity scores and different types of surgery.

VII. Conclusions and recommendations

- Early enteral nutrition and adequate preoperative energy intake is correlated with the length of the intensive care therapy, duration of mechanical ventilation and number of postoperative complications and infections.
- Pre-operative nutritional support improves post-operative anthropometric measurements and clinical outcomes in the undernourished CHD patient.
- The nutritional and other clinical outcomes as well as fate of the patients were markedly improved after application of the prehabilitation nutritional program.
- We recommend that nutrition delivered to the patients in the ICU should be guided by prehabilitation program and that the regular assessment of the nutritional status of the patients clinically and laboratory in pre- operative and post operative period.

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