



HEALTH SCIENCES

Congenital Clubfoot Treatment Outcome with Ponseti Method is not Influenced by Nutritional Status

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Abstract: The objective of the study was to evaluate the impact of preoperative nutritional status on the outcome of bilateral congenital clubfoot (CCF) correction using the Ponseti method in infants. A prospective study was carried out between September 2021 and June 2022, including patients aged 0 to 2 years, of both sexes, diagnosed with bilateral CCF treated using the Ponseti method. Anthropometric measurements were collected, a subjective global nutritional assessment questionnaire (SGNA) was applied and complications were identified. The sample consisted of 18 patients (mean age = 3.85 months), predominantly Caucasian (55.5%) and eutrophic (50%) at birth. Regarding preoperative SGNA, two patients were classified as moderately/severely malnourished. Eight patients obtained the same evaluation and nine presented different classifications when comparatively evaluated regarding ideal body weight and body mass index in consultation #1. Of the total number of patients, 22.2% presented recurrence. In conclusion, no significant differences were observed between birth weight and preoperative data, preoperative SGNA and fasting time between patients who had a good or poor outcome after CCF treatment.

Key words: Congenital clubfoot, malnutrition, nutritional status, Ponseti method, treatment.

INTRODUCTION

Congenital clubfoot (CCF) is characterized by an equinus and hindfoot varus, cavus and adduction deformity of the midfoot and forefoot, associated with hypoplasia of the calf muscles and bilateral involvement in 40-50% of cases (Bacino & Hecht 2014, Bertinatto et al. 2020, Dibello et al. 2020, Gray et al. 2012, Maranhão & Volpon 2011, Muzzammil et al. 2021, Werler et al. 2015, 2013). The goal of CCF treatment is to permanently obtain a painless functional plantigrade foot (Dibello et al. 2020, Gray et al. 2012, Maranhão & Volpon 2011, Ponseti & Smoley 2009). The Ponseti method is considered the gold standard in the treatment of CCF (Bertinatto

et al. 2020, Dibello et al. 2020, Gray et al. 2012, Maranhão & Volpon 2011, Muzzammil et al. 2021) and consists of gentle manipulation of the foot associated with the exchange of well-molded and padded plaster casts, followed or not by the Achilles tendon tenotomy (Ponseti & Smoley 2009).

Nutritional status, defined by the difference between nutrient intake and loss (Carvalho et al. 2015), is one of the independent factors that influences postoperative results in elective procedures (Muzzammil et al. 2021). Childhood protein-caloric malnutrition refers to a state of protein-caloric deficiency, resulting from a deficiency of all macronutrients, related to

approximately 45% of child deaths (Pratim Roy 2019).

Establishing a correlation between the nutritional status of pediatric patients and the risk of developing postoperative complications in the treatment of CCF can guide the best preparation of patients for the procedure. Given that, the study aimed to (1) evaluate the impact of nutritional status on the outcome of bilateral CCF correction using the Ponseti method and (2) record the complications rate.

MATERIALS AND METHODS

Data collection

The study was approved by the Research Ethics Committee of the National Institute of Traumatology and Orthopedics (CAAE #36496820.6.0000.5273). Informed consent was obtained from all individual participants included in the study.

A prospective study was carried out, from September 2021 to June 2022. We included patients aged 0 to 2 years old, diagnosed with bilateral CCF and treated using the Ponseti method with Achilles tendon tenotomy in the Pediatric Orthopedics Service, whose parents had authorized the participation in the study with signature of the informed consent form. Patients with chronic or infectious diseases, patients with genetic syndromes and/or encephalopathies, patients undergoing treatment for unilateral or in recurrence of CCF were excluded. Besides, participants were excluded when it was not possible to complete the subjective global nutritional assessment (SGNA) questionnaire.

Data collection was carried out at three different moments: at the first consultation, on the day of the procedure and in the subsequent evaluation. Follow-up data were analyzed through evaluation of the patient's

medical records. In the first two moments, anthropometric measurements were taken and the SGNA questionnaire was administered. In the third moment, information was also collected regarding the procedure, length of hospital stay, fasting time (determined by calculating the difference between the time between fasting and the anesthetic procedure), number of plaster cast changes and complications occurring during hospitalization and up to 30 days after the procedure.

The following anthropometric parameters were evaluated:

a) Weight: measured in kilograms, using a digital scale from the Filizola® Baby brand. Patients were evaluated naked.

b) Height: measured in meters, using the anthropometric ruler scale. Patients were evaluated without shoes.

c) Body mass index (BMI): calculated as the ratio of weight (in kilograms) divided by height (in meters squared).

d) Arm circumference (AC): the midpoint between acromion and olecranon was marked on the right arm, relaxed, at right angles to the forearm. After marking, the patient remained with his arm extended along the body, with the palm of the hand facing the thigh. The arm was outlined in the previously marked location, with an inelastic measuring tape, obtaining the AC measurement.

e) Triceps Skinfold (TSF): at the same point marked for the AC, the skinfold was slightly separated, detaching it from the muscle tissue, and the clinical plicometer was applied.

f) Subscapular Skinfold (SSF): the patient was positioned with relaxed shoulders and arms. The point immediately below the inferior angle of the scapula was marked, with the skin elevated one cm below the inferior angle of the scapula, forming a 45° angle between it and the

spine. At this location, the clinical plicometer was applied.

AC, TSF and SSF measurements were performed on all patients. However, the World Health Organization (WHO) charts used (De Onis 2007) only include measurements for infants over three months of age.

Assessment of complications

Complications were classified as early and late if they occurred, respectively, within 24 hours or up to 30 days after the procedure.

Analysis of results

Data were tabulated in Excel® spreadsheets and analyzed using the MedCalc® program. Frequencies and percentages for categorical variables were calculated. Continuous values were reported as mean and standard deviation. Data were assessed for normality using the Kolmogorov-Smirnoff test. Student's t-test or Chi-square test were used to determine the statistical significance between the different variables. A p-value ≤ 0.05 was considered significant.

The variables analyzed were classified according to the classification below:

a) Maternal gestational age: < 37 weeks: preterm; 37 to 42 weeks: full term; >42 weeks: post-term.

b) Weight: extreme thinness: < p3; thinness: between p3 and p15; eutrophic: between p15 and p85; overweight: p85 – p97; > p97: obesity.

c) Ideal body weight (IBW): obtained through your own calculation (current weight x 100 / ideal weight). Value considered: < 79: severely malnourished; 80 – 89: moderately malnourished; 90 – 100: eutrophic; > 100: obesity.

d) Length: < p3: low height for age; between p3 and p97: eutrophic; > p97: tall stature.

e) Body mass index (BMI): < p3: low BMI for age; between p3 and p 85: adequate or eutrophic; > p85 and p 97: overweight; > 97: obesity.

RESULTS

Sample characterization

Twenty patients diagnosed with bilateral CCF were eligible for the study. Two patients were excluded from the study because they did not undergo Achilles tendon tenotomy, resulting in a sample of 18 patients (36 feet). The average age of the participants was 3.85 months. Of the total number of patients who underwent the procedure, 22.2% had recurrence (n=8 feet). Of this total, 19.4% (n=7 feet) were at full-term gestational age. The average time elapsed between the diagnosis of PTC and surgery was three months Table I and Figure 1 present the characteristics of the sample.

Assessment of preoperative nutritional status

Regarding the preoperative SGNA, most participants were in a normal state (n=14), with two participants classified as moderately malnourished and two as moderately/severely malnourished. The average fasting time was 440 (± 170) minutes, with the shortest fasting time being 250 minutes and the longest fasting time being 805 minutes. The patients, based on the type of food offered, were also classified, comparatively, in relation to their nutritional status through the analysis of the PCI variable in consultations #1 and #2. One patient weight data was not recorded in consultation #1 and another was still wearing a cast in consultation #2, hence only 17 participants data were recorded at Table II.

Assessment of CCF treatment outcome

One participant presented an episode of bronchospasm after orotracheal intubation as

Table I. Characteristics of the study population at birth and before procedure. g: grams; IQR: Interquartile Range; n: total number of individuals included in the sample; p: percentile; SD: standard deviation; WHO: World Health Organization.

Variable		n
Age	0-3 months	11
	4-6 months	3
	7-9 months	2
	Months	1
	> 12 months	1
Sex	Male	15
	Female	3
Ethnicity	Caucasian	10
	Non caucasiano	8
Gestational age	Pre term	1
	At term	16
	Post term	1
Birth weight	<2500 g	2
	>2500 g to <3500 g	9
	>3500 g to <4500 g	6
	>4500 g	1
Birth weight percentile (WHO)	<p3	2
	p3-p15	1
	p15-p50	5
	p50-p85	8
	>p97	2
Preoperative weight (g)	Average $\pm$ SD	8050 $\pm$ 3315
	Median (IQR)	7100 (5850-9000)
Preoperative weight percentile (WHO)	<p3	2
	p3-p15	3
	p15-p50	6
	p50	1
	p50-p85	3
	>p97	3

an immediate postoperative complication. No late complications were observed. Regarding the outcome, six patients (five MBF and one PBF) had a poor outcome, with disease recurrence. Regarding the number of plaster cast changes, there was no difference between the groups ($p=0.7$). Eight patients had less than ten plaster

cast changes and ten had more than ten changes, of which two had more than twenty changes. When patients were categorized in relation to the outcome, it was not possible to observe significant differences between the groups in relation to birth weight, preoperative weight, preoperative SGNA, fasting time (Figure 2).

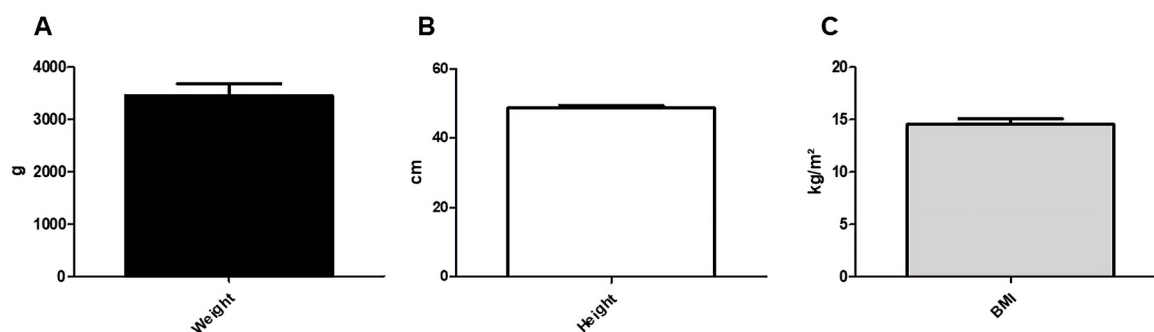


Figure 1. Sample preoperative a) weight (g), b) height (cm) and c) BMI (kg/m²). Sample weight, height and BMI graphical representation in mean and standard error. BMI: body-mass index g: gram; kg/m²: kilogram per square meters; cm: centimeter.

Table II. Analysis of nutritional assessment using ideal body weight (IBW) in consultations #1 and #2 and the type of food offered (n=17*). CF: complementary feeding; EBF: exclusive breastfeeding; MBF: mixed breastfeeding; and PBF: predominant breastfeeding. * One patient weight data was not recorded in consultation #1 and another patient was still wearing a cast in consultation #2.

Consultation	Food offered	Eutrophic	Obesity	Malnutrition
#1	EBF	1	4	1
	PBF	1	2	0
	MBF	1	1	3
	CF	1	1	1
#2	EBF	3	2	1
	PBF	1	2	0
	MBF	2	1	2
	CF	1	1	1

The association between sex, preoperative weight percentile and BMI, ideal weight and treatment outcome was also evaluated, with no association found for any of the evaluated parameters (Table III).

DISCUSSION

This study aimed to evaluate the relationship between nutritional status and the outcomes of CCF treatment. The majority of patients in the sample were male, accordingly to other studies (Maranho & Volpon 2011, Ponseti & Smoley 2009, Werler et al. 2013). Age at the time

of the first consultation was 3.85 months. Hu and colleagues (Hu et al. 2022) received their patients after an average of 2.5 months, while Muzzammil et al. (2021) reported children between 1 week and 3 years, with the majority of the population between 0 and 3 months of age. CCF treatment should occur as early as possible to take advantage of the natural flexibility and elasticity of the infant's foot, in addition to ligament flaccidity for better positioning of the feet during construction of the plaster cast, lowering the chances of recurrences (Ponseti & Smoley 2009). In the present study, patients who presented recurrences were less than 4 months

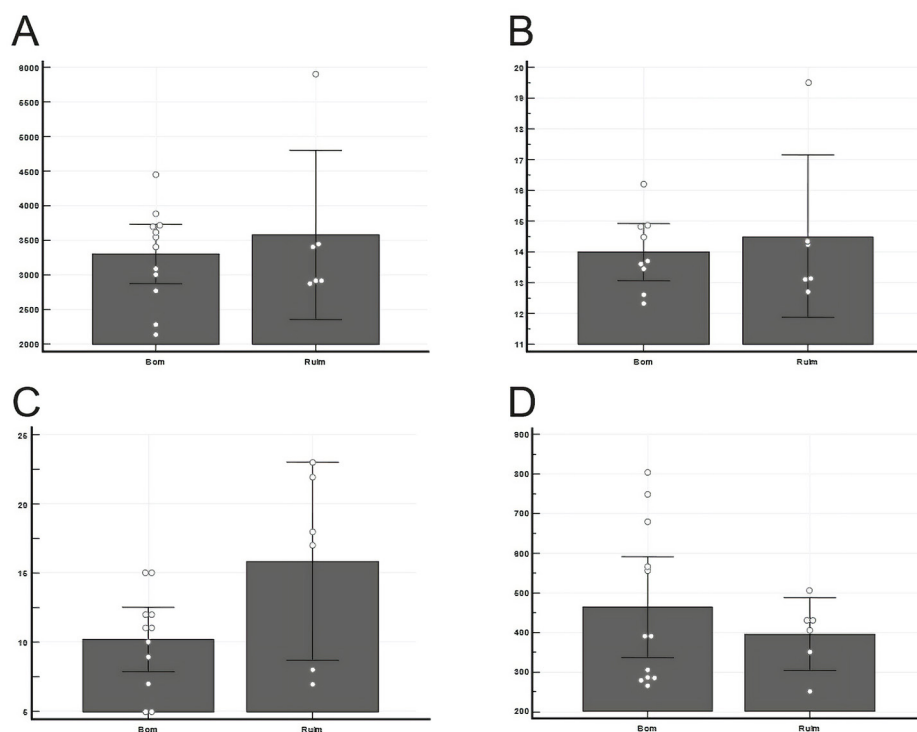


Figure 2. Comparison between groups with good and poor outcome from CCF treatment. a) Birth weight, b) BMI at birth, c) number of plaster cast changes, d) fasting time.

old when started treatment using the Ponseti method.

When analyzing the gestational and anthropometric data at birth of the patients, we observed that 19.4% of the patients who presented with recurrence were classified as having a full-term gestational age. We have not identified studies that correlate CCF and maternal gestational age. However, in contrary to what was initially thought, CCF is a malformation that occurs at the beginning of pregnancy, starting in the ninth and ending in the fourteenth week of pregnancy, when the feet assume the anatomical position characteristic of adults (Werler et al. 2013). Previous studies are in agreement regarding the still unknown/undefined etiology of CCF (Hu et al. 2022, Maranhão & Volpon 2011, Ponseti & Smoley 2009, Werler et al. 2013), although some risk factors have been pointed out (Werler et al. 2013, 2015) as oligohydramnios, breech birth, bicornuate uterus, smoking and maternal diabetes, presence of multiple pregnancies,

genetic factors, obesity and maternal BMI. In the present study, there was a predominance of patients with birth weight between 2500g and 3500g. When these data were plotted on the WHO weight/height graphs for boys and girls separately, it was noted that two patients were below p3, one between p3 and p15, and thirteen patients were between p15 and p85. To date, no studies have been found corroborating the relationship between birth weight and worse results in the treatment of CCF using the Ponseti method. Maternal malnutrition is related to low birth weight, a condition that favors the appearance of acute diseases and worsening of chronic diseases, especially resulting from the metabolic stress arising from the malnutrition itself (Muzzammil et al. 2021). Malnutrition leads to hampered wound healing due also to the delay in tissue regeneration, raises infection risk, leading to an increase in the length of hospital stay, generated by decreased immune response (Leite et al. 2011). Obesity, like malnutrition, is considered a global health problem (Leite et

Table III. Association between preoperative variables and treatment outcome. BMI: body mass index; CF: complementary feeding; EBF: exclusive breastfeeding; MBF: mixed breastfeeding; and PBF: predominant breastfeeding. Significant p-value when <0.05 . *One patient weight was not recorded at birth, hence it was not possible to calculate BMI.

Parameter		Good outcome	Poor outcome	P-value
Sex	Male	10	5	$>0,99$
	Female	2	1	
Preoperative BMI*	Low	3	2	0,6
	Eutrophic	8	4	
Preoperative weight percentile	p0-p15	2	3	0,1
	$>p15$	10	3	
Ideal weight	Eutrophic	9	5	$>0,99$
	Malnourished (any degree)	3	1	
Food type	EBF ou PBF	8	1	0,1
	MBF of CF	4	5	

al. 2011, Weihrauch-Blüher & Wiegand 2018). The increase in childhood obesity exceeds the increment in adult obesity in several countries (Weihrauch-Blüher & Wiegand 2018), and there is a 3.19 times greater risk of a child developing overweight if the mother was also overweight (Engstrom & Anjos 1996).

The time elapsed between the first consultation and the surgical procedure was an average of 3 months, and no studies were found to support the association between this interval and worse outcomes. Among the five patients who presented relapse in treatment using the Ponseti method, the difference varied between one and six months, with all those greater than one month ($n=4$) coinciding with high numbers of plaster cast changes, ranging between 16 and 23 exchanges. Maranhão & Volpon (2011) presented treatment time varying between two and four months in their study.

Regarding the analysis of the classification of patients using the SGNA questionnaire, the majority of them were categorized as eutrophic in detriment of those who were moderately or moderately/severely malnourished. Pimenta et al. (2018), observed as a negative point of their study that the SGNA did not differentiate eutrophic patients from those with overweight/obesity, which could lead to error. To date, there are no studies that compare the results of SGNA with the per-, pre- or post-operative results for Achilles tendon tenotomy surgery or during treatment with plaster casts.

When compared respectively, in relation to IBW and BMI in the first consultation, it can be observed that the majority of patients ($n=9$) presented divergent classifications regarding nutritional status. Although nutritional assessment measures are easy to acquire, low cost and simple to handle, they are unable to detect early nutritional disorders, as well as

micronutrient deficiencies (Carniel et al. 2015). Hence, there is a need to combine subjective nutritional assessment indicators with objective parameters, seeking the best and most appropriate nutritional classification for patients (Pimenta et al. 2018).

Regarding preoperative fasting time, all patients experienced more than four hours of fasting, with ten patients fasting for more than eight hours. As described by Bergantini et al. (2021), the American Society of Anesthesiology (ASA) has been proposing modern protocols guiding the 6-4-2 scheme, which consists of abstaining from solid food, breast milk and clear liquids, respectively for six, four and two hours after the surgical or contrast procedure. Prolonged fasting acts as a metabolic stress factor increasing surgical stress, which can lead to unwanted surgical results or a greater risk of complications (Carvalho et al. 2017). The provision of clear liquids two hours before the procedure is already accepted by several anesthesiology societies around the world (Carvalho et al. 2017), preserving the intravascular volume, offering hemodynamic improvements, and facilitating the obtention of venous access, reducing the child's hunger, thirst and anxiety, making them more cooperative with pre- and post-anesthetic procedures.

The SGNA questionnaire (Detsky et al. 1987) helps classifying patients according to the type of food offered. In this study, the classification based on WHO definitions (Ministério da Saúde 2015) found six in exclusive breastfeeding (EBF, offering only breast milk, whether direct from the mother's breast or expressed, but without offering other liquids, with the exception of drops, vitamins, oral rehydration salts or medicines); three in predominant breastfeeding (PBF, receives water, water-based drinks or juices, in addition to breast milk); six in mixed breastfeeding (MBF, receives both breast milk

and other types of milk); and finally, three in complementary feeding (CF, complementary feeding with solid foods). The WHO's global public health recommendation is that EBF should last six months, followed by complementary breastfeeding until two years of age (Agostoni et al. 2009, Meneses et al. 2021), highlighting that the early introduction of other foods (before the sixth month) may be associated with a greater risk of malnutrition (Ministério da Saúde 2011, 2015). Bortolini et al. (2013) demonstrated that cow's milk was consumed by 62.4% of children under six months of age, 74.6% of those between six and twelve months and in approximately 80% of older children (over twelve months). In another survey, in the first month of life, 13.8% of children received water, 15.3% received teas and 17.8% received milk other than breast milk (Ministério da Saúde 2011). It is noteworthy that, in this study, of the children on complementary feeding (n=3), two were under the age of one and were not breastfed, and one, under the age of two, was breastfed. mother's breast for a short period. All children in CF consumed full cow's milk, and in two cases there was an addition of flour or sugar, thus generating a dietary error from a very early age.

Regarding complications, this study demonstrated that a single child presented an episode of bronchospasm after orotracheal intubation. Muzzammil et al. (2021) described minimal complications as soaking of the plaster with blood and pressure ulcers caused by the plaster and skin problems. Due to the conservative characteristic of the Ponseti method, there are few complications compared to extended surgery (Hu et al. 2022), most related to inadequate technique and/or excess force used in making the plaster, bearing in mind that excess force on the articular surface can lead to stiffness and local deformity (Maranho & Volpon 2011). However, complications following

percutaneous tenotomy of the tendon have also been reported, such as injury to the posterior tibial artery or the small saphenous vein, as well as the formation of pseudoaneurysms (Maranho & Volpon 2011).

When looking at the outcomes, 27.7% of the total cases treated surgically had an unfavorable outcome. Hu et al. (2022) obtained a recurrence rate of 21.6%, in contrast to Muzzammil et al. (2021) who demonstrated an early relapse rate of 10.22% and 16.02%, respectively, in well-nourished and malnourished patients. Moreover, the study showed a correlation between malnutrition and an increase in the rate of Achilles tenotomy and greater recurrence or treatment failure using the Ponseti method. Hu et al. (2022) had 5.71 plaster changes and, when recurrent cases were individualized, this number rose to 7.15 plaster changes. Muzzammil et al. (2021) observed that a group of malnourished patients had higher rates of average number of plasters per patient

per week (7 in those with malnourishment and 5 in those with good nutritional status) and changed more than 6 plasters, compared to those who were well nourished (45.45% for those who were malnourished and 21.42% for those who were well nourished). We found that eight patients had less than ten plaster cast changes and ten had more than ten changes, but it was not possible to observe significant differences between the groups in relation to birth weight, preoperative weight or preoperative SGNA.

As a strength of the study, it is highlighted that we discussed the nutritional impact on the outcome of minor procedures as CCF treatment with the Ponseti method, which are sometimes neglected in the routine evaluation. On the other hand, as the present study was carried out in the post-pandemic period, some procedures had to be postponed, reducing sample size. Moreover, there was difficulty in obtaining maternal and paternal height to calculate the genetic target,

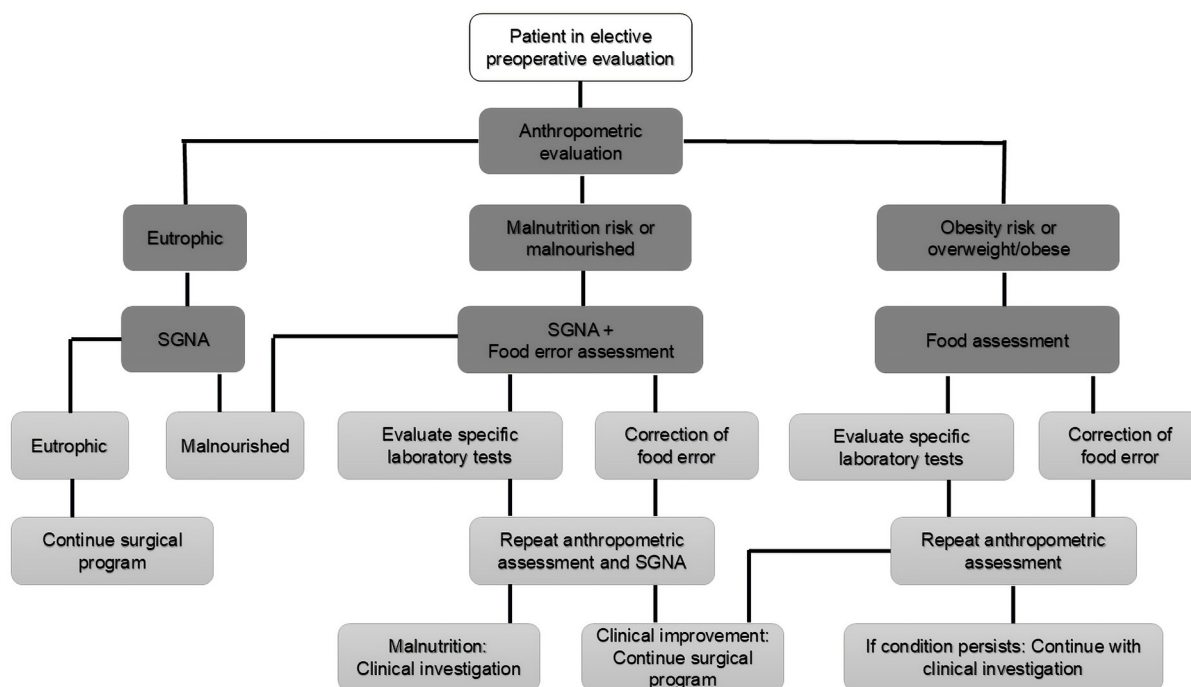


Figure 3. Flowchart for guidance on nutritional assessment of children in the preoperative period of elective surgeries. SGNA: subjective global nutritional assessment.

since in most cases, children were accompanied only by the mother.

Finally, we propose in Figure 3 a flowchart to guide the nutritional assessment of children in the preoperative period of elective surgeries.

CONCLUSIONS

Regarding clinical-demographic characteristics and assessment of nutritional status, no significant differences were observed between data on birth weight, preoperative weight, preoperative SGNA, and fasting time among patients who had a good or bad outcome after the treatment of CCF. No late complications were observed and only one patient presented a complication during surgery.

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ALCCV: Study conception and design, material preparation, data collection, analysis of results and manuscript final draft. AECL: data collection and analysis of results. EBS: Study conception and design, material preparation, data collection, analysis of results and manuscript final draft. ACLO: Study conception and design, material preparation, data collection, analysis of results and manuscript final draft.

