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Nutritional status and outcome of surgery: A prospective observational cohort study of children at a tertiary surgical hospital in Harare, Zimbabwe☆

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ABSTRACT

Background: Undernutrition contributes to nearly 50% of all child deaths in the world, yet there is conflicting evidence regarding the association between nutritional status and postoperative complications. The aim was to describe the preoperative nutritional status among pediatric surgery patients in Zimbabwe, and to assess if nutritional status was a risk factor for adverse postoperative outcome of mortality, surgical site infection, reoperation, readmission, and longer length of stay.
Methods: This prospective observational cohort study included 136 children undergoing surgery at a tertiary pediatric hospital in Zimbabwe. Nutritional status was standardized using Z-scores for BMI, length, weight, and middle upper arm circumference. Primary outcomes after 30 days included mortality, surgical site infection, reoperation, and readmission. Secondary outcome was length of stay. Univariate and multivariable analyses with logistic regression were performed.
Results: Of the 136 patients, 31% were undernourished. Postoperative adverse outcome occurred in 20%; the mortality rate was 6%, the surgical site infection rate was 17%, the reoperation rate was 3.5%, and readmission rate was 2.5%. Nutritional status, higher ASA classification, major surgical procedures, and lower preoperative hemoglobin levels were associated with adverse outcome. Univariate logistic regression identified a seven-fold increased risk of postoperative complications among undernourished children (OR 7.3 [2.3–22.8], $p = 0.001$), and there was a four- to six-fold increased adjusted risk after adjustment for ASA, major surgery, and preoperative hemoglobin.
Conclusion: A third of all pediatric surgery patients were undernourished, and undernourished children had a considerably higher risk of adverse outcome. With a positive correlation identified between undernourishment and increased postoperative complications, future aims would include assessing if preoperative nutritional treatment could be especially beneficial for undernourished children.
Levels of Evidence: Level II treatment study.

Despite a decreasing global prevalence of undernutrition, still 13% of the world's population are undernourished today [1]. Children are especially exposed, and undernutrition contributes to nearly 50% of all deaths in young children [2]. Also, it has been estimated that every third child death is due to a surgical condition [5], and there is increasing interest in how preoperative nutritional status impacts surgical outcomes [3]. Undernutrition may contribute to the observed correlation between a country's Human Development Index and the level of avertable postoperative morbidity and mortality seen in adults [4]. Of the estimated 5 billion people without adequate access to surgical care worldwide, a majority lives in poverty in rural or marginalized areas [6], were undernutritional status is endemic [1].

There are several examples of how undernutrition impacts surgery in adults. Undernutrition is a risk factor among elderly surgical patients [7]; nutritional status has been shown to correlate with postoperative complications in patients undergoing pneumonectomy and gastrointestinal operations [8,9]; and undernourished burn-patients have higher complication-rates [10]. In children, undernourished patients with cancer have worse prognosis and clinical outcome [11], however, there is conflicting evidence between nutritional status and postoperative outcome [12,13] and little is known of the role of undernutrition for outcomes after elective and emergency pediatric surgery, and of the relative frequency of postoperative complications among undernourished children.

To address these knowledge gaps, this study was positioned to describe the preoperative nutritional status among pediatric patients at a tertiary surgical hospital in Zimbabwe, and to assess the association

Abbreviations: BMI, Body mass index; MUAC, Middle upper arm circumference.

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between nutritional status and postoperative outcome. Zimbabwe is a sub-Saharan, landlocked country, where 8.8% of all children are underweight [14]. In this setting, it was hypothesized that undernutrition would be an independent risk factor for complications after elective and emergency pediatric surgery.

1. Methods

1.1. Study design and setting

This was a prospective observational cohort study of children undergoing surgery at a tertiary hospital, Harare Central Hospital in Harare, Zimbabwe. The hospital is a public pediatric teaching hospital located in the outskirts of the capital city of Zimbabwe. It is the only dedicated pediatric hospital in the country, with 180 general beds and 30 pediatric surgery beds. Each week, there are ~15–20 surgical procedures during office hours, including day surgery cases, and less than 5 cases during night-time. There are two certified pediatric surgeons, one general surgeon with an interest in pediatric surgery, one senior registrar in pediatric surgery, five junior registrars on a pediatric surgical fellowship, and two to four house officers on a 3-monthly rotation.

Pre-operative planning and preparations are done either in the outpatient department for almost all day-cases and some major cases, or in the ward for all in-patients and most of major surgical cases and emergencies. Intra-operative standards are as internationally, except where there may be variations due to equipment differences. In those cases, surgery is performed as per low and middle-income countries capability. Almost all major surgeries are performed by a senior surgeon or their immediate instruction. The pediatric surgical department prevents surgical site infections by ordering prophylactic antibiotics where indicated, with correct skin preparation, appropriate gowning, use of least tissue traumatizing surgical techniques, and judicious use of drains. Superficial surgical site infections are managed expectantly with dressings and wound swabbing for microbiology, and antibiotics are only used when there is an indication. Treatment for deep surgical site infection is individualized, and typically treatment includes source control, removal of foreign bodies and sometimes drainage. Rarely, patients may require a reoperation as part of infection management.

1.2. Inclusion and exclusion criteria

Included in the study were all consenting patients between 0 and 18 years undergoing major or minor general pediatric surgery and pediatric urology, both elective and emergency procedures (Supplementary Table 1), at Harare Central Hospital between September 2nd and November 1st, 2018. Patients subject to thoracic surgery, orthopedic surgery, neurosurgery, and plastic surgery were not typically admitted to these wards and were therefore not included in the study. During office hours, all patients were included by a single observer. Patients who were admitted after office-hours were eligible for inclusion next morning during rounds. For this reason, some children who were admitted after office-hours and who were discharged during the night may have been missed from inclusion.

1.3. Primary exposure

Primary exposure was nutritional status prior to surgery. Assessment of nutritional status was body mass index for-age (BMI), height-for-age (stunting), weight-for-age (underweight), weight-for-height (wasting), middle upper arm circumference for-age (MUAC), and a composite variable called General nutrition (Supplementary Table 2). BMI, height, weight and middle upper arm circumference were standardized by age and gender to z-score based on WHO's growth reference data using the software WHO Anthro (0–5 years) and WHO Anthro plus (5–18 years) [15–17]. (Supplementary Table 2) General nutrition Z-score was the lowest Z-score of the five anthropometric measurements for each patient. The Z-scores were used both as continuous data and as categorical data with nutritional status groups with cut-off values in accordance with the WHO: severe undernutrition, moderate undernutrition, adequate nutrition and overnutrition. [16] Weight and height were measured in centimeters and kilograms with one decimal. BMI was defined as the patient's weight divided by the square of the patient's height (kg/m^2). Middle upper arm circumference was measured in centimeters with one decimal using a MUAC measuring tape.

1.4. Confounders and independent variables

Confounders and independent variables included gender, age, illness severity (ASA classification), diagnosis, surgical procedure (major vs. minor procedures), surgical priority (elective vs. emergency surgery), and hemoglobin (Hb) (Supplementary Tables 1 and 3). All variables were retrieved from the patients' journals and by directly asking the parents.

1.5. Primary and secondary outcomes

Primary outcomes were mortality, surgical site infection, reoperation, and readmission. These outcomes were analyzed both separately and aggregated to a composite postoperative complication outcome. All outcomes were measured until 30 days postoperatively. Mortality was categorized as either in-hospital or post-discharge, and both the day of death and the cause of death were noted. Surgical site infection was diagnosed by clinical observation in hospital or during the follow-up call after 30 days, and was defined based on CDC guidelines as pain, localized swelling, redness and heat in the incision area or a positive culture from the incision area [18,19]. Reoperation was defined as a new operation within 30 days. Timing of readmission was noted, together with the cause of readmission. Length of stay was considered a secondary outcome, as this variable is sometimes confounded by non-medical circumstances. Length of stay was defined for patients staying at least overnight as days spent in hospital after the primary surgical procedure.

1.6. Lost to follow-up

If still not in hospital, all patients were contacted 30 days postoperatively for a follow-up phone call. If unreachable despite multiple attempts, the patients remained included in the description of preoperative nutritional status but were excluded from the subsequent univariate and multivariable analyses of associations between nutritional status and postoperative outcome.

1.7. Data collection

The clinical data were collected by a single trained observer to promote equal measurement, within 24 h of the operation. All patients were measured anthropometrically using the same technique. In-hospital clinical outcomes were measured daily while in the hospital. At day 30 postoperatively the patients were contacted by a local medical researcher for the follow-up questions.

1.8. Statistical analysis

Normally distributed descriptive data were reported as mean values with 95% confidence intervals. Non-normal data were reported as median values with range or interquartile range, and compared with Mann–Whitney *U* test. Categorical variables were compared with Pearson χ^2 test for categorical data. Associations between independent variables and outcomes were assessed by linear regression for continuous outcome (with beta [95% confidence intervals]) and by logistic regression for binary outcome (with odds ratio (OR) [95% confidence intervals]). Independent variables with statistically significant association on univariate analysis

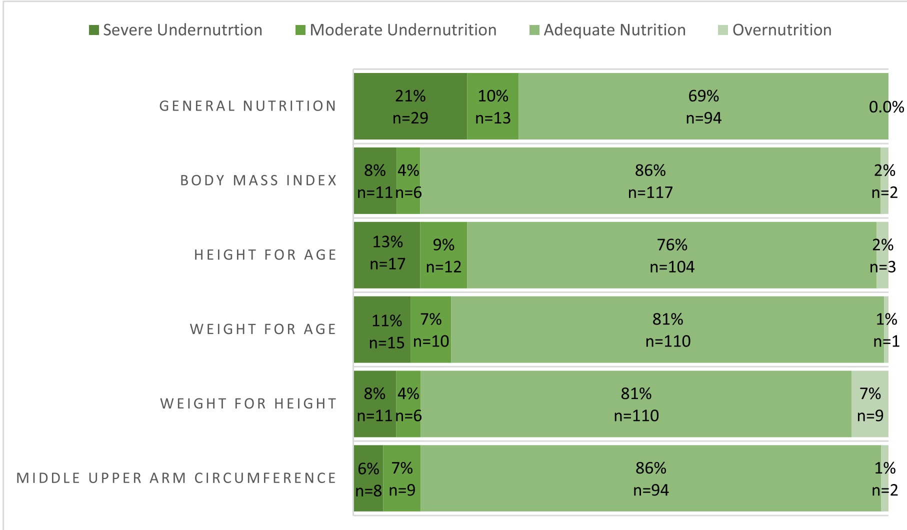


Fig. 1. Nutritional status and different anthropometric measurements (Z-score) of 136 children undergoing surgery at a tertiary pediatric hospital in Zimbabwe.

(*p* value lower or equal to 0.05) were considered for inclusion in multivariable regression models, together with variables of nutritional status. The number of included variables in the multivariable analysis were based on the lowest number of outcomes divided by 10, and the most statistically significant variables were selected for inclusion. Statistical analyses were performed using IBM SPSS Statistics version 25.

1.9. Ethics statement

This study was approved by the Joint Research Ethics Committee, Parirenyatwa Hospital and University of Zimbabwe. Inclusion was contingent on informed parental consent. Patients over 7 years of age could choose to opt out of the study. The manuscript was prepared in accordance with the STROBE statement for observational cohort studies.

Table 1
Independent variables categorized per nutritional group (adequate nutrition vs. undernutrition). ASA: American Society of Anesthesiologists classification. See Supplementary Table 1 for details on the subdivision of major or minor operations, with indication of number of complications per procedure, and surgical priority.

	Adequate nutrition	Undernutrition	p-Value
Total n = 136	94 (69%)	42 (31%)	
Gender n (%)			0.84
Female	33 (35)	14 (33%)	
Male	61 (65%)	28 (67%)	
Age n (%)			
Median [Interquartile range]	4.6 [2.5–7.2]	2.1 [0.2–4.1]	<0.001
0–1 years	11 (12%)	18 (43%)	<0.001
1–5 years	42 (45%)	18 (43%)	
5–18 years	41 (44%)	6 (14%)	
ASA class n (%)			0.001
1	75 (80%)	20 (48%)	
2	9 (10%)	8 (19.0%)	
3	9 (10%)	14 (33%)	
4	1 (1%)	0 (0.0%)	
Surgical priority n (%)			0.54
Elective	84 (90%)	36 (86%)	
Emergency	10 (11%)	6 (14%)	
Diagnosis (ICD 10-chapter) n (%)			0.01
Infectious and parasitic diseases	1 (1%)	1 (2%)	
Neoplasms	6 (6%)	6 (14%)	
Diseases of the digestive system	64 (68%)	18 (43%)	
Congenital malformations	18 (19%)	17 (41%)	
Injuries	5 (5%)	0 (0%)	
Surgical procedure n (%)			<0.001
Major	24 (25%)	24 (57%)	
Minor	70 (75%)	18 (43%)	
Hemoglobin n (%) (total n = 67)			0.27
<100 g/L	10 (30%)	14 (42%)	
>100 g/L	24 (71%)	19 (58%)	

2. Results

A total of 136 pediatric patients between 0 and 18 years were included in the study, and the nutritional status measurements are summarized in Fig. 1. Overall, almost a third of the patients were considered undernourished by any of the measurements (31%), and two thirds of these children were severely undernourished (21%). One in five of all children were stunted (low height-for-age, 21%), one in six children were underweight (low weight-for-age, 18%), one in eight children were wasted (low weight-for-height, 13%), and very few were overweight.

Overall, the median age was 3.7 years (range 4 days to 11 years, interquartile range 1.6–6.1) and the most common diagnoses were inguinal hernia, umbilical hernia and anorectal malformation (Table 1). The undernourished group was younger ($p < 0.001$) and more severely ill (higher ASA classification) ($p = 0.001$), but the gender distribution showed no statistical significance ($p = 0.841$). There was no statistical difference in surgical priority ($p = 0.542$) (elective vs emergency operations), but the undernourished group had a different disease panorama ($p = 0.012$) and was more often subject to major surgical procedures ($p < 0.001$). Hemoglobin levels for the nutritional groups were comparable ($p = 0.267$).

To assess the association between nutritional status and postoperative outcome, a total of 86 (63%) patients were reached for a 30-day postoperative follow-up (Fig. 2). A fifth of these patients had any of the evaluated postoperative complications (20%). During follow-up, 50% of the undernourished patients had any complication, compared

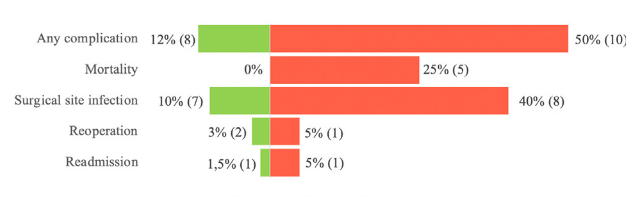
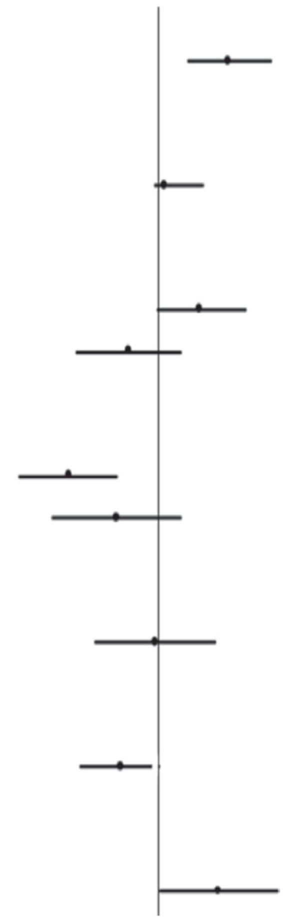


Fig. 2. Incidence of any postoperative adverse outcome; mortality, surgical site infection, reoperation and readmission, comparing patients with adequate nutrition and undernutrition.

Table 2
Frequency and unadjusted odds ratio for any postoperative complication (mortality, surgical site infection, reoperation, readmission) per independent variables among the 86 follow-up patients. The forest plot shows odds ratio with p-value and 95% confidence interval compared to the indicated reference variable.

	No complication n (%)	*Complication n (%)*	*Odds ratio [95% CI]*	*P-value*
Nutritional status				
Undernutrition	10 (50%)	10 (50%)	7.25 [2.3-22.8]	0.001
Adequate nutrition (ref)	58 (88%)	8 (12%)		
Gender				
Female	24 (77%)	7 (23%)	1.17 [0.9-3.4]	0.78
Male (ref)	44 (80%)	11 (20%)		
Age				
0-1 years	10 (56%)	8 (44%)	3.3 [0.96-11.5]	0.06
1-5 years	29 (91%)	3 (9%)	0.43 [0.1-1.8]	0.25
5-18 years (ref)	29 (81%)	7 (19%)		
ASA class				
1	57 (89%)	7 (11%)	0.08 [0.02-0.3]	<0.001
2	6 (67%)	3 (33%)	0.31 [0.05-1.8]	0.2
3&4 (ref)	5 (39%)	8 (61%)		
Surgical priority				
Elective	61 (78%)	16 (21%)	0.92 [0.2-4.8]	0.92
Emergency (ref)	7 (78%)	2 (22%)		
Surgical procedure				
Minor	52 (85%)	9 (15%)	0.31 [0.1-0,9]	0.04
Major (ref)	16 (64%)	9 (36%)		
Hemoglobin (total n=35)				
<100 g/L	3 (33%)	6 (67%)	5.43 [1.1-27.8]	0.04
>100 g/L (ref)	19 (73%)	7 (27%)		



to 12% among the adequately nourished patients ($p < 0.001$), and several patients had more than one complication at the same time. All deaths occurred among undernourished patients, 80% of which were severely undernourished ($p < 0.001$). Perioperative mortality was 6%, and mortality occurred primarily among the younger children, and after major procedures. Surgical site infection rate was 17%, and occurred most commonly after hernia repairs and laparotomy. Of the undernourished patients, 40% had a surgical site infection, compared with 10% among adequately nourished patients ($p = 0.002$). Reoperation rate was 3.5% and was most frequent after laparotomy or colostomy fashioning. The readmission rate was 2.5%, most commonly due to surgical site infection or small bowel obstruction. For reoperation and readmission rates there were no statistical difference between the nutritional groups. Patients available for follow-up were generally older ($p = 0.036$), had a minor procedure ($p = 0.013$), and differed in terms of diagnosis ($p = 0.047$), but not regarding gender ($p = 0.75$), ASA class ($p = 0.31$), surgical priority (elective vs. emergency procedures) ($p = 0.57$), or hemoglobin levels ($p = 0.052$).

Univariate logistic regression identified a seven-fold increased risk of postoperative complications among undernourished children (OR 7.3 [2.3–22.8], $p = 0.001$) (Table 2). Also, a higher ASA class (OR 0.08 [0.02–0.3], $p < 0.001$), lower hemoglobin level (OR 5.43 [1.1–27.8], $p = 0.04$), and major procedures (OR 0.31 [0.1–0.9], $p = 0.04$) were univariately associated with an increased risk of postoperative complications. When adjusted in a multivariable analysis for ASA classification, the adjusted odds ratio for undernutrition was 4.5 [1.43–24.4] ($p = 0.018$), and when adjusted for surgical procedure, the adjusted odds ratio was 5.9 [1.7–19.9] ($p = 0.005$). When adjusted for hemoglobin level, the adjusted odds ratio for undernutrition was 4.0 [0.84–18.7] ($p = 0.08$).

Over half of the patients returned home the same day as the operation. The mean length of in-patient stay after operation was 3 days [range 1–25]. There was a negative correlation between nutritional status and length of stay. For every unit increase in nutrition the length of stay decreased by 3 days ($p = 0.03$, $R^2 = 0.14$). For every standard deviation increase in middle upper arm circumference the length of stay decreased by 1.3 days ($p = 0.004$, $R^2 = 0.57$) (Fig. 3).

3. Discussion

This prospective observational cohort study described the preoperative nutritional status among pediatric patients in Zimbabwe and

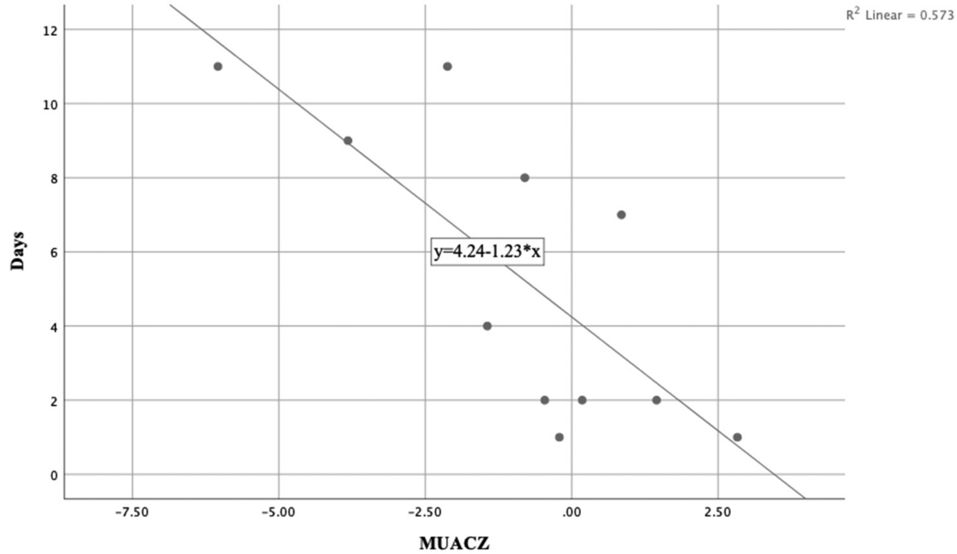


Fig. 3. Length of stay after surgery related to nutritional status measured by Middle upper arm circumference Z-score (MUACZ). $p = 0.004$, $R^2 = 0.57$.

assessed the association between nutritional status and postoperative outcomes. Almost a third of all children were undernourished before surgery, and after adjustment for differences in ASA class or major surgery, undernourished children had at least a four-fold higher risk of any complication compared to adequately nourished children. Low nutritional status was an independent risk factor for perioperative mortality, surgical site infection and longer hospital stay, and the risk of death increased with malnutrition severity.

The association between nutrition and postoperative outcome has been studied in adults [7–9,23–25], but less frequently in children. A review of nutritional assessment and clinical outcomes found a lack of high-quality evidence to support that undernutrition correlates to postoperative outcome and highlights the wide variety of nutritional assessment and study design [13]. A recent study included 24 thousand children from the American National Surgical Quality Improvement Program (NSQIP) and found that stunting increases the risk of any postoperative complication (OR 1.16, [1.0–1.3], $p = 0.036$) [26]. These findings are congruent with the present study results, even if the demographic differs considerably, with lower prevalence of undernutrition and much higher prevalence of overnutrition. A study that assessed nutritional status in pediatric cancer patients in Central America using similar methods as in the present study, as well as serum-albumin and triceps skin fold thickness, found an even higher rate of undernutrition and that it clearly increased complications, in accordance to this study [11].

The findings must be interpreted in the context of our study design. The present study includes anthropometric measurement, often used by UNICEF and WHO [27], yet, there are many ways to measure and evaluate nutrition in children and this somewhat reduces the comparability to previous studies [13]. We are also mindful of the possibility of selection biases. A national survey report funded by UNICEF in Zimbabwe described the 2018 nutritional status among children below 5 years [14], and compared to the present study, stunting, a marker for long term undernutrition, was slightly more prevalent, while underweight and wasting, markers for acute undernutrition, were much less prevalent. This could indicate a selection bias, or could mean that pediatric surgery patients in general tend to be more acutely undernourished, possibly due to the current surgical disease. All respondents accepted inclusion in the study, which reduce a bias of inclusion. During office hours, all patients were included by a single observer without any structural bias, and all the anthropometric measurements were measured exactly the same way, using the same technique, scale, height board and MUAC measuring tape. However, we anticipate a slight selection bias towards major surgery, since it is possible that some patients with very minor emergency procedures performed after office-hours were discharged from hospital before being enrolled during next morning's rounds. A third potential selection bias relates to the follow-up process, even if a 63% follow-up rate could be considered reasonable for this kind of study, especially considering that patients lost to follow-up did not differ in terms of ASA classification, surgical priority or surgical procedure. It is possible that length of stay, in this study setting, is confounded by financial factors, which is why it was considered a secondary outcome. Finally, all patient's parents were asked for comorbidities such as HIV, but future studies in the field must more reliably examine these factors further, with the inclusion of even more potential confounders.

Based on the results of the study, it can be hypothesized that adequate preoperative nutritional status can prevent complications and deaths, and that preoperative nutritional management might be especially beneficial to undernourished surgical patients. It would also be of interest if further studies would evaluate Hb-levels as a predictor for postoperative complications, as this could be a quick and economical tool in low-resource hospitals to evaluate the risk to operate. Anemia can be considered both a marker for adverse outcome as well as a marker for undernutrition and the present study found that low Hb-values are associated with the risk of complication.

4. Conclusion

A third of all children before surgery were undernourished and undernutrition was a strong risk factor for complications after surgery. Undernourished children had a 4 to 6 times higher adjusted risk of complications, compared to adequately nourished children. It was only undernourished children that died during the study period. The hospital length-of-stay increased with increasing undernourishment. Future studies could assess the role of anemia and if preoperative nutritional treatment could avert postoperative complications among undernourished children.

Supplementary data to this article can be found online at https://doi.org/10.1016/j.jpedsurg.2020.09.020.

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