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Applied nutritional investigation

Nutrition risk profile of 62 408 inpatients based on electronic health records in a tertiary children's hospital

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ABSTRACT

Objectives: This study aimed to evaluate the nutrition risk profile of hospitalized children with electronic health record–based nutrition risk screening. Additionally, this study analyzed the association between high nutrition risk and clinical outcomes.

Methods: Children discharged from Shanghai Children's Medical Center between 2017 and 2018 were enrolled and nutritionally screened. Nutrition risk scores using the Screening Tool for Assessment of Malnutrition in Pediatrics (STAMP), length of stay (LOS), and costs of hospitalization were recorded. Enrolled patients were categorized into two groups: the low and medium nutrition risk (LMNR) group, with scores ranging from 0 to 3, and the high nutrition risk (HNR) group, with scores ≥4.

Results: Out of 62 408 subjects, 17.4% were at HNR. Patients with congenital heart diseases (83.9%), hematology-oncology diseases (26.0%) and gastroenterological diseases (21.4%) were affected most. Infants had the highest HNR rates (35.5%) of any age group. Surgical patients (20.7%) had a higher rate of HNR than non-surgical patients (9.5%). The HNR group had longer LOS (10.0 d versus 3.0 d, $P < 0.001$), higher total hospital costs (53 680.1 Chinese yuan [CNY] versus 8810.1 CNY, $P < 0.001$), and higher costs of antibiotics (441.0 CNY versus 0.0 CNY, $P < 0.001$) compared to the LMNR group. As STAMP score values increased, growing LOS and costs of hospitalization, medications, and antibiotics were observed.

Conclusions: A high prevalence of HNR was found in patients of Shanghai Children's Medical Center. Surgeries, specific disease, and infancy were important HNR risk factors. HNR scores using STAMP might predict prolonged LOS and higher medical costs.

Introduction

Malnutrition in hospitalized children is a prevalent and major concern globally [1,2]. Nutrition risk screening is the key first step in the standard nutrition care process (NCP), followed by nutrition assessment, nutrition diagnosis, nutrition intervention, and follow-up [3]. Clinical guidelines and consensus by the American Society for Parenteral and Enteral Nutrition (ASPEN), European Society of Parenteral and Enteral Nutrition (ESPEN), and Global Leadership Initiative on Malnutrition (GLIM) recommend that all inpatients should be nutritionally screened within 24 h of admission, have weekly follow-ups during the hospital stay, and be monitored after the discharge [3–6].

Since there is no established consensus on the widely accepted nutrition risk screening tool for pediatrics, different needs of medical care settings in practice should be considered when choosing a nutrition risk screening tool [7,8]. The Screening Tool for the Assessment of Malnutrition in Pediatrics (STAMP) is a fast, simple, and reproducible tool and has been widely used in multiple clinical settings with good sensitivity and specificity [9,10]. Furthermore, incorporating nutrition risk screening into electronic health records (EHRs) enables nutrition support teams to take further steps through clinical decision support; however, its worldwide

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application is limited [11,12]. As a result, EHR-based STAMP was chosen as a routine nutrition risk screening tool for the entire hospitalized population in Shanghai Children's Medical Center (SCMCs), a tertiary children's hospital also known as one of the three national children's medical centers in China.

This study aimed to outline the EHR-based nutrition risk profile of all the hospitalized children from 2017 to 2018 in a tertiary pediatric hospital. Possible risk factors for high nutrition risk (HNR) were investigated. This study analyzed the association between nutrition risks and clinical outcomes, including length of hospital stay (LOS) and costs of hospitalization and antibiotics.

Materials and methods

Subjects

Children hospitalized at SCMC between January 1, 2017, and December 31, 2018, were enrolled in the study. Because there is no widely accepted nutrition risk screening tool for newborns and critically ill children, the exclusion criteria were as the follows: 1) a hospital stay of less than 48 h, 2) age younger than 1 mo old at admission, and 3) admission at intensive care units.

Methods

Nutrition risk screening

Each child was nutritionally screened within 24 to 48 h of admission at the hospital by trained nurses using STAMP through our self-designed EHR-based nutrition management system.

As a Joint Commission International (JCI)-accredited hospital, we initiated nutrition risk screening using STAMP for all hospitalized children in 2010, and thus, SCMC became the first hospital in China to implement nutrition risk screening for all hospitalized children. To improve the efficiency of our routine NCP, an EHR-based nutrition management system was developed in 2013 and implemented in 2016.

According to the STAMP website (stampscreeningtool.org) and the study by McCarthy, et al. [9], this screening tool incorporates three components that are recognized indices or symptoms of malnutrition: namely, the presence of a clinical diagnosis having nutritional implications, estimated current nutritional intake, and weight/height evaluation in growth charts. According the hospital policy, the height and weight of each admitted child were measured by trained nurses and recorded in the EHR. If the patients had special clinical problems (e.g., neurologic impairment), nurses obtained their anthropometric data according to the anthropometric measurement of chapter 25 in Pediatric Nutrition, 7th Edition [13]. The World Health Organization's (WHO) sex-specific weight for age growth standards were used for children between ages 0 and 2 y, whereas the WHO sex-specific body mass index (BMI) growth standards were used for children older than 2 y. Each component carries a score of up to 3, and the total score reflects the nutrition risk. A score of $\geq$4 indicates HNR. Otherwise, the score presents low (0–1) and medium (2–3) nutrition risk (LMNR) [9,14]. A flowchart of EHR-based pediatric NCP during hospital stay was outlined, and nutrition care plans were developed for children with different nutrition risks, as presented in Figure 1 [3,15].

Data collection

In this study, enrolled patients were classified into LMNR and HNR groups based on the highest STAMP scores during their hospitalization. We collected the weight and height data from the EHRs, along with the clinical and demographic data (e.g., clinical diagnosis, LOS, cost of total hospital stay, antibiotics, medication, and surgery). Malnutrition in pediatric patients ages 0 to 2 y was defined as weight for age z score < -2 or > 2, and malnutrition in pediatric patients older than 2 y old was defined as BMI z score < -2 or > 2.

Ethical Consideration

This research was approved by the Ethics Committee of SCMC (SCMCIRB-K2017015). The requirement of informed consent was waived owing to the retrospective use of electronic records.

Statistical analysis

Statistical analysis was performed using SPSS version 25.0 (IBM, Armonk, NY, USA). All the variables were compared for normal distribution using the Kolmogorov-Smirnov test. Categorical variables were expressed as number and percentage and analyzed with the χ^2 test, while continuous variables were expressed as mean $\pm$ SD or median (interquartile range) as indicated. Continuous variables were analyzed between two or more categories with the Mann-Whitney U test. The correlation between STAMP scores, LOS, and hospital cost was performed using Spearman's correlation test. A value of $P < 0.05$ was considered statistically significant.

Results

General characteristics

Out of 72 937 children discharged between 2017 and 2018, 6476 patients were excluded because their hospital stay was fewer than 48 h. Additionally, 3411 patients from neonatology and 642 from the pediatric intensive care unit were excluded. Thus, 62 408 pediatric patients were enrolled in this study (39 028 boys [62.5%] and 23 380 girls [37.5%]). According to distribution by age, patients made up five age groups (11 095 [17.8%, $\geq$1 mo, $<$1 y]; 13 171 [21.1%, $\geq$1 y, $<$3 y); 16 933 [27.1%, $\geq$3 y, $<$6 y]; 16 228 [26.1%, $\geq$6 y, $<$12 y]; and 4981 [7.9%, $\geq$12 y, $<$18 y]). The median age of the participants was 4.1 y (1.5 y, 7.5 y), and median LOS was 3 d (2.0 d, 6.0 d). Regarding the disease groups, the most noticeable were the patients who had undergone general surgery (14 210, 22.8%), followed by patients with hematologic-oncologic diseases (7854, 12.6%), congenital heart diseases (CHD) (6998, 11.2%), pulmonary diseases (4826, 7.7%), cardiovascular diseases (4662, 7.4%), neurologic diseases and endocrinologic diseases (3733, 6.0%), gastrointestinal diseases (1647, 2.6%), and nephrologic diseases (1619, 2.6%). In addition, hospitalized children with other diseases (16 899), such as orthopedic and otolaryngologic diseases, accounted for 27.1% of the total population. Seventy percent of participants were from different parts of the country (not in Shanghai), whereas the local patients accounted for 30%, indicating that the data in our study could represent the nutrition risk profile of the hospitalized children in a national children's medical center of China.

The height, weight, and BMI z scores of the enrolled patients were calculated using the WHO Anthro software. There were 4949 patients (7.9%) with an age-specific z score of < -2 and 4600 patients (7.4%) with an age-specific z score of > 2. In total, 9549 (15.3%) hospitalized children were malnourished, according to the malnutrition definition in our study.

Distribution of high STAMP scores among SCMC patients with different diseases and ages

Enrolled hospitalized children were classified as LMNR group (n = 51 527, 82.6%) and HNR group (n = 10 881, 17.4%). HNR rates varied among the patients with different diagnoses and ages. The highest HNR rate was found in patients with CHD (83.9%), followed by patients with hematologic-oncologic diseases (26.0%), and then by patients with gastroenterological disease (21.4%) ($P < 0.001$) (Fig. 2A). Considering the age factor, younger children were more likely to have HNR. Infants older than 1 mo (35.5%) had the highest HNR rates compared to older age groups ($P < 0.001$ (Fig. 2B). Thus, significant differences in HNR proportions existed among different disease and age groups.

Comparison of LOS and hospital costs in hospitalized children with different nutrition risks

The HNR group had longer LOS (10.0 d versus 3.0 d, $P < 0.001$), more total hospital costs (53 680.1 Chinese yuan [CNY] versus 8810.1 CNY, $P < 0.001$) and more costs of antibiotics (441.0 CNY versus 0.0 CNY, $P < 0.001$), medication (17 231.3 CNY versus 2013.6 CNY, $P < 0.001$), and surgery (16 788.0 CNY versus 1815.0 CNY, $P < 0.001$) than those in the LMNR group. When surgery costs were excluded, the total non-surgery hospital costs of HNR children (32 499.3 CNY) remained higher than those in the LMNR group (5241.7 CNY). Similar results were found regarding daily average costs (Table 1).

As approximately 70% of hospitalized children in SCMC underwent surgeries, it was important to know the prevalence of HNR in surgical and non-surgical patients and the related clinical

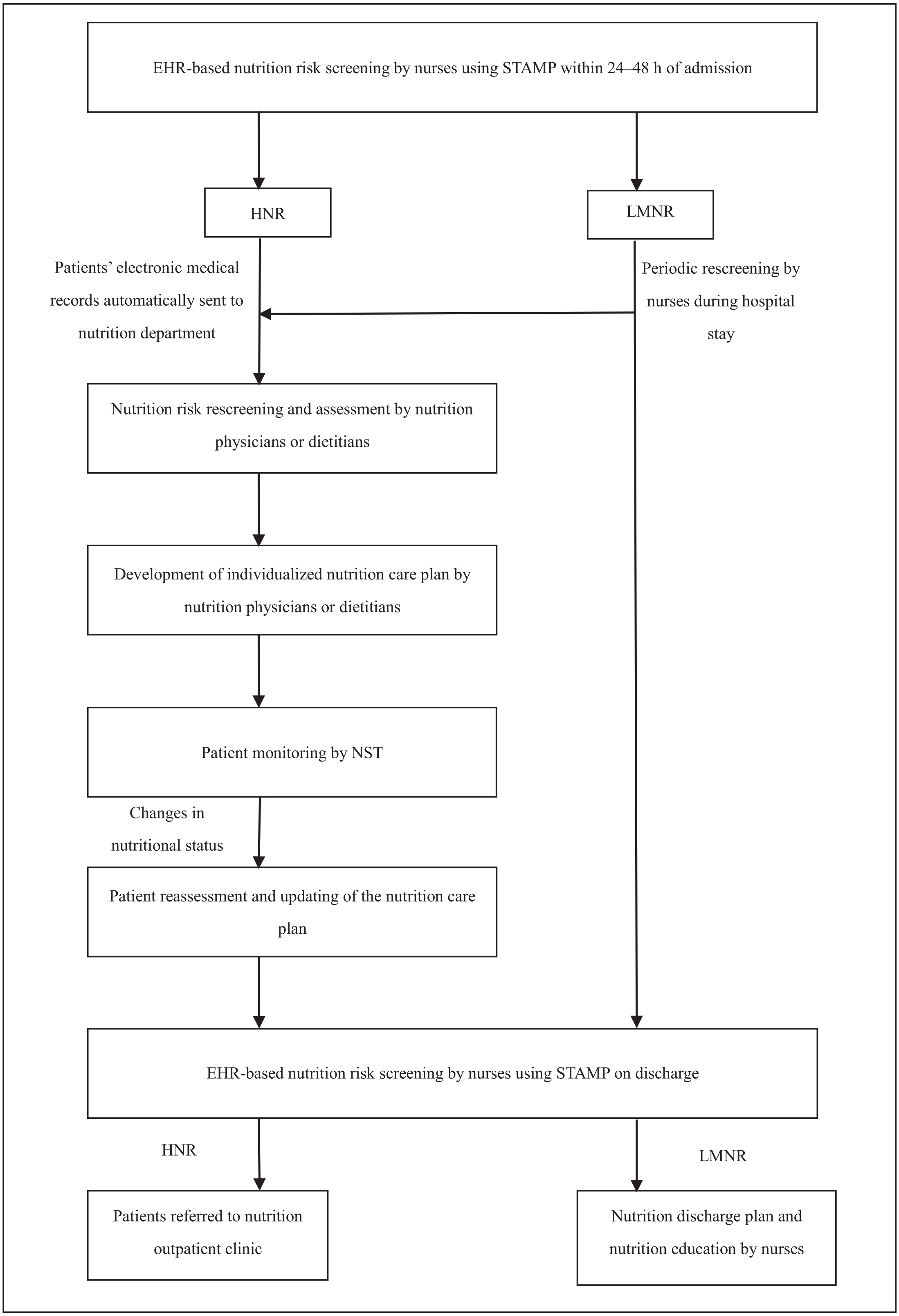

Fig. 1. Flowchart of electronic health record (EHR)-based pediatric nutrition care process with nutrition risk screening using STAMP. The STAMP scores of all the hospitalized children were documented in EHRs. Children whose scores were less than 4 were rescreened weekly until discharge. Regular rescreening was performed if there were any changes in clinical conditions, surgeries during the hospital stay, or transfer of patients. Those with scores of at least 4 were electronically referred to nutrition physicians or dietitians for rescreening and, if confirmed, further nutrition assessment was provided, followed by individualized nutrition intervention. In addition, at the time of discharge, patients were rescreened, and if the score indicated high nutrition risk, they were referred to the nutrition outpatient clinic and were provided with nutrition care during the follow-up period.

HNR, high nutrition risk; LMNR, low and medium nutrition risk; NST, nutrition support team; STAMP, Screening Tool for Assessment of Malnutrition in Pediatrics.

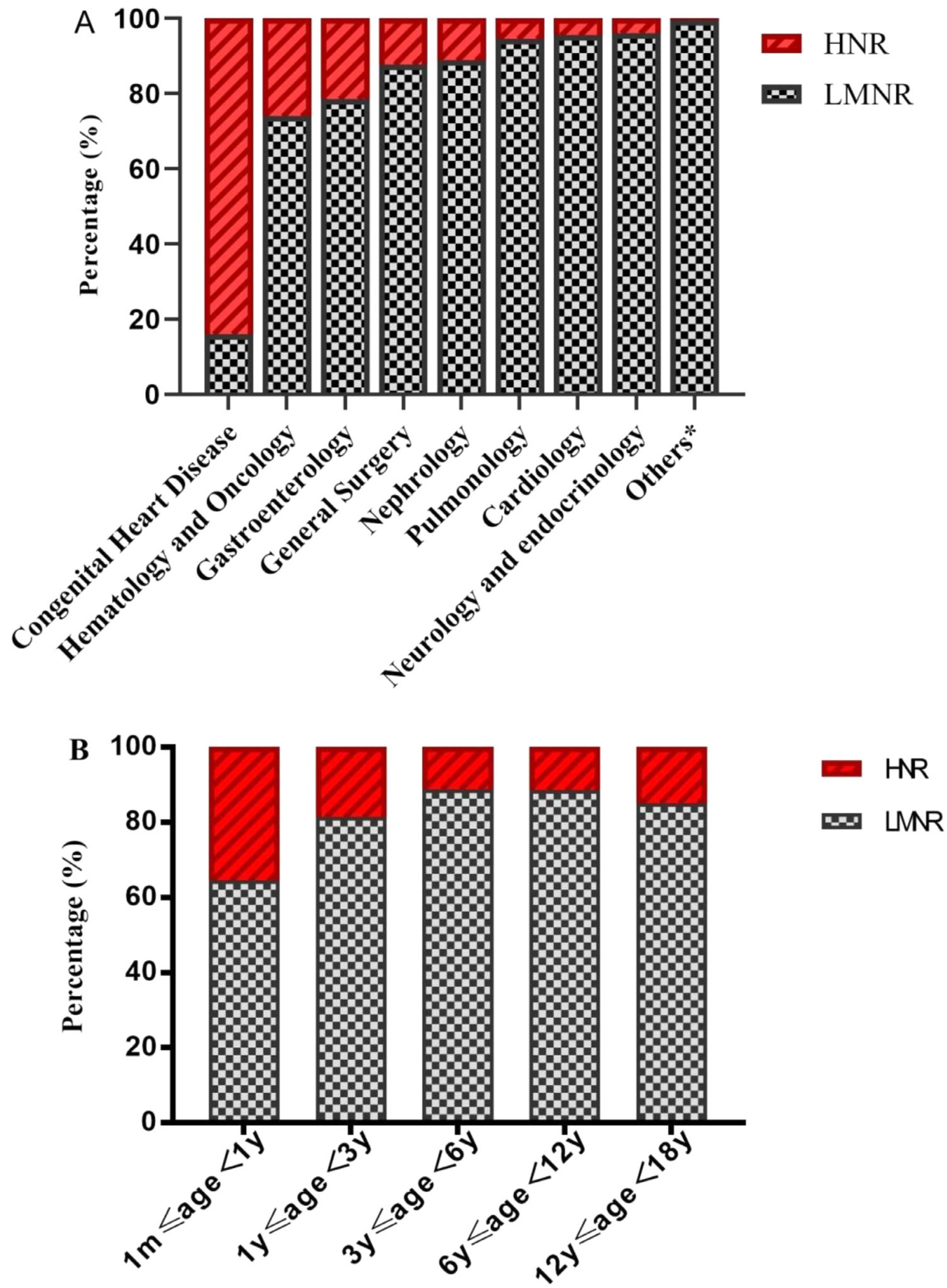

Fig. 2. Distribution of nutrition risk proportion in hospitalized children with different diseases and ages. (A) Distribution of nutrition risk proportions in hospitalized children with different diseases. Others include osteology, otorhinolaryngology, etc. (B) Distribution of nutrition risk proportions in hospitalized children with different ages.

HNR, high nutrition risk (STAMP score ≥4). LMNR, low and medium nutrition risk (STAMP score <4); STAMP, Screening Tool for Assessment of Malnutrition in Pediatrics.

outcomes. In contrast to 9.5% of the non-surgical patients (n = 18 771) with HNR, 20.7% of the surgical patients (n = 43 937) were at HNR. Regardless of the surgical or non-surgical group, LOS and costs in the HNR group were significantly higher than those in the LMNR group. Moreover, greater differences of LOS and costs of hospitalization between the surgical HNR and LMNR groups were found compared to the non-surgical HNR and LMNR groups (Table 2).

Association of STAMP scores with clinical outcomes

Medians for LOS, cost of hospitalization, cost of medication, and cost of antibiotics in hospitalized children of SCMC were calculated for each STAMP score value ranging from 0 to 9 (Fig. 3). With an increase in STAMP score values, there were significant rising trends mostly in LOS (r = 0.596, $P < 0.001$), followed by cost of hospitalization (r = 0.395, $P < 0.001$), cost of medication (r = 0.564, $P < 0.001$), and cost of antibiotics (r = 0.317, $P < 0.001$).

Discussion

NCP with nutrition risk screening as the first step guarantees standardization of nutrition support in pediatric patients and avoids diagnostic omission errors in hospitalized children with HNR or undue nutrition intervention for those with low nutrition

Table 1
Comparison of LOS and costs between low and medium nutrition risk group and high nutrition risk group

Variable	LMNR (n = 51 527) Median (IQR)	HNR (n = 10 881) Median (IQR)	*P* value
Length of stay (day)	3.0 (2.0, 6.0)	10.0 (7.0, 15.0)	< 0.001
Total hospital cost (CNY)	8810.1 (45 07.4, 15 596.0)	53 680.1 (18 931.6, 74 429.7)	< 0.001
Cost of antibiotics (CNY)	0.0 (0.0, 113.9)	441.0 (0.0, 1615.2)	< 0.001
Cost of medication (CNY)	2013.6 (1155.0, 3557.4)	17 231.3 (9242.0, 27 827.8)	< 0.001
Cost of surgery (CNY)	1815.0 (0.0, 6830.0)	16 788.0 (516.0, 26 315.0)	< 0.001
Total non-surgery cost (CNY)	5241.7 (2479.0, 10 452.4)	32 499.3 (13 199.7, 50 225.6)	< 0.001
Average daily cost of hospitalization (CNY)	2712.0 (1332.0, 5068.6)	4573.1 (1989.6, 6852.6)	< 0.001
Average daily cost of medication (CNY)	681.1 (390.7, 1124.4)	1790.6 (970.3, 2371.2)	< 0.001

CNY, Chinese yuan; HNR, high nutrition risk; IQR, interquartile range; LMNR, low and medium nutrition risk; LOS, length of stay.

Table 2
Comparison of LOS and costs between surgical and non-surgical groups with different nutrition risks

Variable	Non-surgical patients			Surgical patients		
	LMNR (n = 16 997) median (IQR)	HNR (n = 1774) median (IQR)	*P* value	LMNR (n = 34 830) median (IQR)	HNR (n = 9107) median (IQR)	*P* value
Length of stay (day)	4.0 (2.0, 6.5)	6.5 (4.5, 10.0)	< 0.001	3.0 (2.0, 5.5)	10.0 (7.0, 16.0)	< 0.001
Total hospital cost (CNY)	5109.3 (1957.1, 8270.0)	7530.2 (4079.3, 13 689.3)	< 0.001	11 319.4 (6546.9, 19 993.0)	58 285.8 (38 401.4, 80 252.2)	< 0.001
Cost of antibiotics (CNY)	0.0 (0.0, 206.4)	18.2 (0.0, 961.6)	< 0.001	0.0 (0.0, 69.2)	475.7 (0.0, 1709.1)	< 0.001
Cost of medication (CNY)	1636.9 (209.1, 3952.2)	4192.0 (1565.4, 11 206.0)	< 0.001	2101.3 (1423.7, 3373.8)	18 629.2 (13 579.3, 30 195.1)	< 0.001
Average daily cost of hospitalization (CNY)	1293.0 (915.3, 1630.0)	1127.9 (788.9, 1620.1)	< 0.001	4071.8 (2407.5, 6354.3)	5301.9 (2933.2, 71 86.2)	< 0.001
Average daily cost of medication (CNY)	370.8 (68.6, 695.9)	625.2 (306.4, 1351.8)	< 0.001	816.2 (540.0, 1265.5)	1925.4 (1292.6, 2436.3)	< 0.001
Cost of surgery (CNY)	N/A	N/A	N/A	4927.0 (1735.0, 7612.0)	19 983.5 (7187.0, 27 505.0)	< 0.001
Total non-surgery cost (CNY)	N/A	N/A	N/A	5376.2 (2604.6, 12 312.9)	35 689.2 (24 556.8, 55 651.6)	< 0.001

CNY, Chinese yuan; HNR, high nutrition risk; IQR, interquartile range; LMNR, low and medium nutrition risk; LOS, length of stay; N/A, not applicable.

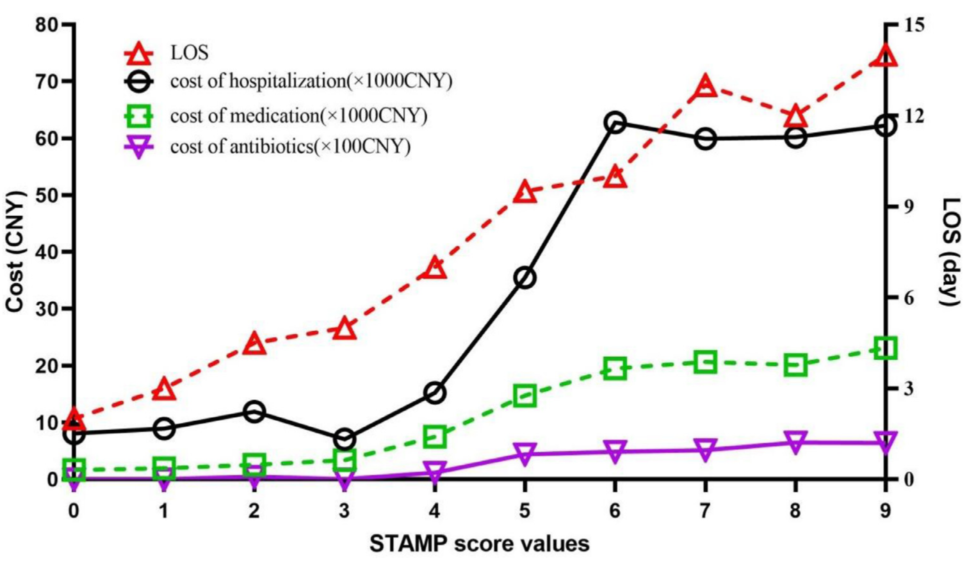

Fig. 3. Association of STAMP scores with LOS and hospital expenditure. Medians for LOS and costs of hospitalization, medications, and antibiotics were calculated for all the hospitalized children for each STAMP score value ranging from 0 to 9. A trend test ($P < 0.001$) showed a positive correlation of STAMP score values with median LOS, cost of hospitalization, costs of medication, and cost of antibiotics ($P < 0.001$).
LOS, length of stay; STAMP, Screening Tool for Assessment of Malnutrition in Pediatrics.

risk. To the best of our knowledge, this is the first study to analyze the prevalence of HNR in such a large population of hospitalized children in China. Overall, 17.4% of the enrolled pediatric patients were at HNR. Seventy percent of participants were from different parts of the country (not in Shanghai), whereas the local patients accounted for 30%, indicating that the data in our study could represent the nutrition risk profile of the hospitalized children in a national children's medical center of China. These results were consistent with the international findings that prevalence of pediatric HNR during hospital stay ranged from 6.1% to 25% in North America, Europe, and Australia and 13.4% to 54% in Asia, Latino world [16], and Africa [17–22]. Evidence indicates that the growth and development of pediatric patients may be retarded in the long run because of the unrecognized nutrition risk or malnutrition on admission and insufficient nutritional support during hospital stay and after discharge [4,11]. Therefore, there is an urgent need for routine nutrition risk screening for pediatric patients worldwide, followed by nutrition assessment and intervention to prevent the development of iatrogenic malnutrition

Moreover, a large sample of hospitalized children in our study strongly supports the association between HNR and specific diseases. In our study, the majority of the HNR hospitalized children were diagnosed with CHD (83.4%) and hematologic and oncologic diseases (26.0%), followed by gastrointestinal diseases (21.4%). In an Egyptian study by Hassan et al. [23] 84.0% of children with CHD had a poor nutritional status before surgery, and 74.1% were diagnosed with severe malnutrition. Unfavorable nutritional conditions in pediatric hematology-oncology patients were also reported in another international medical center [24]. A high proportion of children with inflammatory bowel disease was found at HNR in the study by El Mouzan et al. [25]. These specific diseases altered nutrient metabolism, leading to increased nutritional needs, nutrient malabsorption, and nutrient loss. Combined with metabolic stress caused by surgeries or other treatments, nutrition risk was consequently increased. SCMC is the largest CHD surgery center globally (n = 5810 per year) and the largest hematology-oncology center in China (n = 3927 per year). As CHD and hematologic-oncologic diseases are the top-ranking diseases associated with HNR, these pediatric patients benefit in terms of treatment and recovery from timely nutrition risk screening followed by nutrition intervention.

We also found that surgery significantly affected nutrition risk scores and clinical outcomes. The HNR rate in the surgical group was significantly higher than that in the non-surgical group. Noticeably, we found greater differences in LOS and hospital costs between the surgical HNR and LMNR groups than those between the non-surgical HNR and LMNR groups, indicating more adverse influence of surgery-related HNR on clinical outcomes. Lim, et al. [26] reported that preoperative nutritional status was strongly associated with 30-d mortality, LOS, and mechanical ventilation. According to the study by Ladd et al. [27], worsening degrees of malnutrition directly correlated with increasing risk of 30-d complications in children undergoing major bowel surgery. Surgery-related nutrition risk might be caused by injury, stress from surgery and anesthesia, perioperative complications (e.g., infections), and delayed recovery after surgery.

Another finding in this study was that HNR was age-related (i.e., infants older than 1 mo had the highest HNR rate). Our results were supported by the early research by Beser et al. [28] in Turkey, who reported that children between 31 d and 0.9 y had the highest rate of HNR. Similar research results were also found in Australia, not just in developing countries and regions. A more recent study demonstrated that infants were more vulnerable to malnutrition than the older age groups [29]. Infants have a significantly higher metabolic rate and energy requirement per unit of body weight than older children. Moreover, inadequate feeding because of gastrointestinal intolerance caused by preterm labor or low birth weight increases energy needs. Inadequate nutrient intake, digestive disorders, and malabsorption as a result of birth defects (e.g., CHD, biliary atresia, gastrointestinal malformation) contribute to an increased nutrition risk.

Our study indicated that specific diseases, surgeries, and infancy were important risk factors for HNR. Therefore, special attention to the nutrition risk and status of these populations was needed not only during the hospital stay but also before admission and after discharge. To avoid deterioration in nutritional status and unfavorable clinical outcomes including prolonged LOS and increased medical expenditure, we should give more priority to timely nutrition risk screening, nutrition assessment, and personalized nutrition intervention. If pediatric patients had more than one risk factor mentioned above (e.g., preoperation infants with CHD) it was important to perform nutrition risk screening as integrative part of nutrition management from hospital to home.

Furthermore, we found an association of higher STAMP scores with more unfavorable clinical outcomes (i.e., longer LOS and higher costs of hospitalization, medication, and antibiotics), which is supported by several previous studies [30–32]. However, regardless of the nutrition screening tools used, few of them focused on large samples. Our study was the first to establish a correlation between STAMP score values and clinical outcomes on a large number of hospitalized children, thus setting an evidence base for the prediction of clinical outcomes using STAMP and its validation as a widely used nutritional screening tool for pediatrics.

The strengths of this study were as follows. Firstly, based on a large sample of 62 408 hospitalized children, a nutrition risk profile of a national children's medical center in China was presented. HNR was prevalent in this tertiary teaching hospital, a finding corresponding with other research worldwide and providing strong support for the awareness and attention of health care authorities to HNR hospitalized children. Second, based on the large amount of data in our study, we found that specific diseases, surgeries, and infancy were important HNR factors, implying that more emphasis should be given to the nutrition risk screening and the nutrition care pathway for these populations. Third, we also found that HNR scores using STAMP tools might be a strong predictor of longer LOS and growing hospital expenditure.

There were several limitations in this study. The hydration status of special pediatric populations was considered when qualified nurses measured these patients' weights/heights on admission, but this was not specifically analyzed in this study. This study mainly focused on the nutrition risk profile and it relation with clinical outcomes. The association of nutrition risk with malnutrition types could be addressed in future studies. As there is no gold standard for nutrition risk screening in pediatrics, we used STAMP to nutritionally screen hospitalized children aged older than 1 mo according to the hospital policy. The sensitivity and specificity of STAMP among children younger than 2 y requires further research.

Conclusions

EHR-based nutrition risk screening showed an HNR rate of 17.4% in 62 408 hospitalized children in this national children's medical center in China. These children the needed complete attention of the nutritional support team with improved interdisciplinary cooperation for high-quality nutrition care. Moreover, surgeries, specific diseases, and infancy were important risk factors for HNR. Our study indicated that HNR scores might predict prolonged LOS and higher costs, including hospitalization and antibiotics. In future research, more emphasis should be placed on the association of specific diseases with nutritional status and clinical outcomes. With appropriate individualized nutritional intervention following nutrition risk screening, further studies could be conducted on the cost-effectiveness of nutrition care in pediatric patients.

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