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ORIGINAL ARTICLE

Implementation of a computerized system in pediatric wards to improve nutritional care: a cluster randomized trial

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BACKGROUND/OBJECTIVES: Malnutrition occurs frequently in hospitalized children. We aimed to assess whether a computerized system could lead to improved clinical practices in malnourished children.
SUBJECTS/METHODS: Healthcare workers (242) from six departments in a pediatric university hospital participated in a cluster randomized trial, studying 1457 malnourished children hospitalized from September 2009 to August 2011. Following a baseline observational pre-intervention period, all departments were randomized into either intervention or control arms. A computerized malnutrition-screening system was implemented in the intervention group to automatically trigger a dietetic referral in real time. Furthermore, the nutrition support team conducted an awareness campaign with healthcare workers and a leadership-based strategy to reinforce the message during the entire study period. Adherence to practice guidelines (daily weights, investigation of etiology for malnutrition, management by a dietitian and application of refeeding protocols) was compared between pre- and post-intervention periods in both the intervention and trial arms.
RESULTS: When compared with the pre-intervention period, the clinical practices were significantly improved within the intervention arm for every outcome ($P < 0.01$), whereas remained unchanged in the control arm. In addition, during the post-intervention period, malnutrition etiology investigation by physicians (adjusted odds ratio (OR) of 4.4, 95% confidence interval (CI) 1.7–11.8, $P = 0.003$) and management by a dietitian (OR 2.7, 95% CI 1.0–6.9, $P = 0.046$) occurred more frequently in the intervention clusters.
CONCLUSIONS: Implementation of an electronic system to detect malnutrition in real time was associated with a rapid improvement in clinical practices for better care of hospitalized children.

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INTRODUCTION

Malnutrition is frequent among hospitalized children, reaching rates of up to 20% in Europe and North America.[1–5] By altering metabolism and organ function, malnutrition increases complications and the length and cost of hospital stays while decreasing the quality of life.[6,7] However, little improvement in nutrition care has been reported in western hospitals during recent decades. There are several explanations for this lack of improvement, including poor interest or lack of education regarding nutrition among healthcare workers and complexity in coordinating the multidisciplinary teams in charge of nutritional care (physicians, nurses and dietitians).[8,9]

In adult populations, implementing nutrition guidelines has improved clinical practices.[10] The introduction of joint nutrition care strategies targeting the identification and treatment of malnourished patients (for example, specific educational modules for nurses, the development of screening tools or changes in food presentation) increases malnutrition screening and dietetic referrals.[11] Computerized systems for reminding and guiding physicians toward the most appropriate care have been shown to improve compliance with recommended guidelines,[12,13] especially for hospital-based prevention.[14] To our knowledge, computerized systems aimed at improving nutritional care were rarely tested. Although acquisition of anthropometric measurements in pediatrics is of utmost importance, assessment of children's nutritional status is complex and requires comprehensive assessment using routine detection tools. The present cluster randomized trial was designed to evaluate the impact of an intervention on recommended practice adherence in caring for malnourished children. In particular, we investigated implementing a pivotal computerized malnutrition screening system to automatically trigger a dietetic referral in real time, including an automatic alert for physicians and dietitians when a patient was undernourished. Because it was our intention to compare healthcare worker behavioral changes, the unit of randomization was the pediatric department (cluster) to minimize the contamination risk between the trial arms, with the intention of analyzing and interpreting data both at the individual and cluster levels.

MATERIALS AND METHODS

Study design and participants

We conducted a prospective parallel cluster randomized trial in the pediatric department of a university hospital in an industrialized country (Figure 1).

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[7]Members of the PREDIRE Study Group are listed in the Acknowledgements section.
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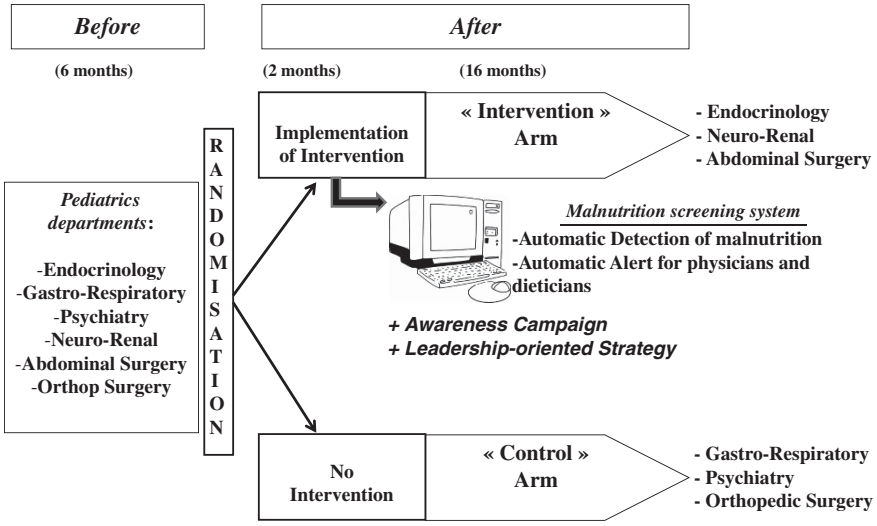

Figure 1. Study design.

The methodology was described in detail previously.[15] In brief, following a 6-month pre-intervention observational, baseline period, the departments were randomized into two cluster arms. An intervention was then implemented in one arm (that is, the departments of endocrinology, neurology, nephrology and abdominal surgery) over the next 18 months to compare its outcomes with the control arm (that is, the departments of gastroenterology, pneumology, psychiatry and orthopedic surgery) in both the pre- and post-intervention periods.

Medical and surgical departments in this institution participated in the trial except the neonatal, intensive care and emergency units. Healthcare workers in charge of care for malnourished children were targeted by our intervention. All children aged 1-month to 18-year old who were admitted to the hospital between 1 September 2009 and 31 August 2011 were eligible for inclusion. In keeping with national pediatric guidelines for the screening and care of malnutrition, the Algoped nutritional risk score was used to assess the nutritional status of every child based on the weight and height as measured at admission; and then on a daily basis for weight and a weekly basis for height.[16] The detection of malnourished children was dependent upon the combination of two ratios. First, to detect acute malnutrition, the weight/height ratio (W/H) was calculated, in which the child's measured weight was divided by the expected weight as related to his/her actual height.[17] Second, to detect chronic malnutrition, the height/age ratio (H/A) was calculated by dividing the child's measured height by the expected height as related to his/her age. When the W/H $>$ 90% and/or H/A $>$ 94%, there was no malnutrition. When the W/H was 80–90% and/or H/A was 85–94%, there was moderate malnutrition. At last, a W/H $<$ 80% and/or H/A $<$ 85% indicated severe malnutrition.[5,18] We used the national growth curves. Patient exclusion criteria consisted of hospital stay of $<$ 2 days, a first weighing at $>$ 2 days after admission, a first height recorded $>$ 15 days after admission or participation refusal.

Intervention

An innovative computerized malnutrition-screening system was implemented in the intervention group only. This computerized system aimed to (1) detect automatically the malnourished patient by calculation of W/H and H/A ratios from the weight, height and age of children noted in the information system at admission of each child and (2) alert automatically physicians, residents and dietitians when the patient was below the normal level of these ratios. This alert was provided to the physicians and residents as a red flag in their screen when drugs were electronically prescribed; and to the dietitians by a monitoring dashboard updated daily, allowing them to independently intervene without a clinician's call.

Furthermore, within clusters of the intervention arm, the nutrition support team coordinated a healthcare worker awareness campaign and a leadership-based strategy. These components were designed to support the implementation of the pivotal electronic-screening system and were specifically targeted to healthcare workers involved in caring for malnourished children. They consisted of (1) educational symposiums, (2) training sessions and (3) regular outreach visits, including information about malnutrition frequency and severity among hospitalized children in their department and case reviews. In particular, the message for nurses was focused on systematic screening by weight and height measurements for increasing the performance of the computerized malnutrition-screening system. Physicians and dietitians were sensitized to evidence-based care and the need to comply with the guidelines, once they were alerted about the malnutrition status of a child by the hospital information system. The nutritional management was standardized in the intervention group. A computerized protocol was developed for the enteral nutrition depending on the severity of the malnutrition (moderate and severe).

Normal care was provided in the control clusters. No specific intervention was implemented to improve malnutrition management, and dietitians only intervened in response to physician calls.

Outcomes and data collection

Outcomes were chosen for their ability to assess the quality of care on the basis of healthcare worker adherence to clinical practice guidelines.[18] They included (1) the number of daily weighings during hospitalization (as the total number of weighings/length of stay), (2) the frequency of investigation of malnutrition etiology (a detailed analysis of malnutrition causes as presented in the medical record) and (3) the frequency of malnutrition management by a dietitian and the introduction of a refeeding protocol (oral, enteral or parenteral).

Following each child's admission, a patient's report form was completed by external research assistants using medical records. Among the set of collected variables, the comorbidities included inflammatory bowel disease, severe intestinal failure, liver disease, renal failure, genetic syndromes, chronic pulmonary disease, heart failure, anorexia, caloric intake deficiency, encephalopathy, cancer, immunodeficiency, severe infection, cystic fibrosis, diabetes, epilepsy, gastroesophageal reflux and other chronic diseases.

Ethical statement

Because the intervention and randomization were targeted at the cluster level and outcome data were routinely collected, national review boards waived the requirement for individual consent.[19] Responsible authorities from all the departments provided written consent without incentives for their participation. Printed information about personal data utilization was given to the children's parents at admission, and their potential refusal to share hospitalization data was considered. The Research Committee for the Protection of Persons (CPP) allowed the study in accordance with ethical directives of the country. Further agreement was obtained from the National Advisory Committee on Information Processing in Material Research in the Field of Health (CCTIRS) regarding the anonymous processing of personal health information.

Sample size and randomization

The trial was conducted in 11 pediatric units that were eligible for participation. To reduce the risk for contamination bias, these units were

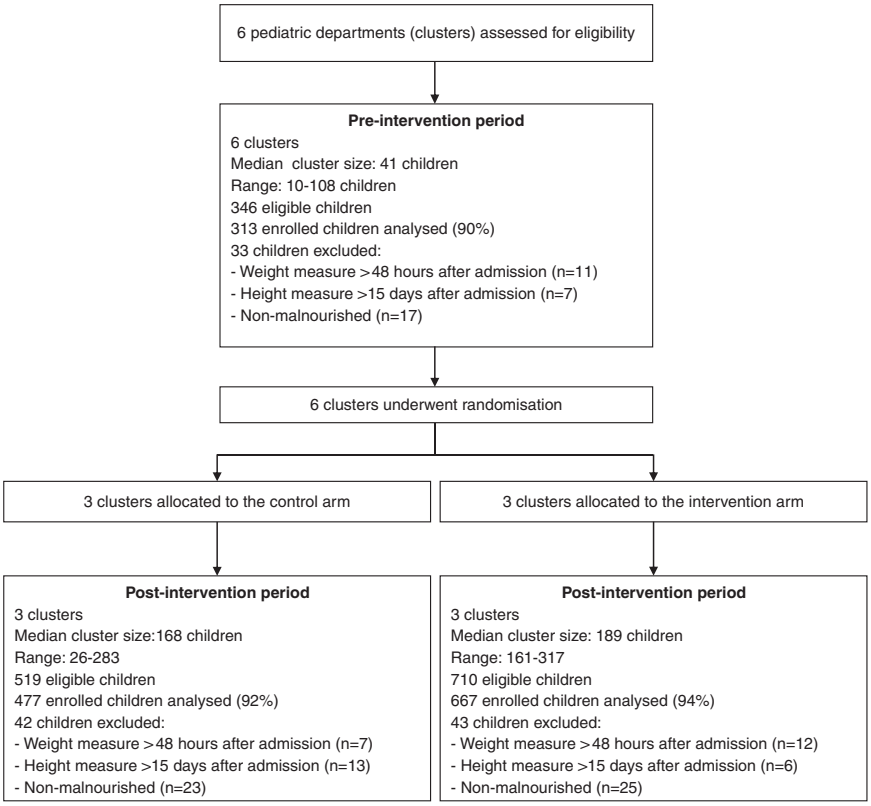

Figure 2. Flow diagram of progress in clusters and individuals from enrollment to analysis. The same child may have presented with one or more exclusion criteria.

geographically clustered in six departments (clusters) depending on their location in the hospital and the mobility of nursing staff across units. We anticipated a power of 80% to detect a difference of 25% in the rates between the two arms with $\alpha = 0.05$ and three clusters for each trial arm.

An allocation scheme for randomly assigning interventions to these clusters was computer generated at a central location. Randomization was guided using pre-intervention data with a view to obtain two comparable groups in terms of frequency and severity of malnutrition. Three clusters were allocated to the intervention arm (Neurology–Nephrology–Rheumatology, Endocrinology-Metabolic Diseases and Digestive Surgery), whereas the others were assigned to the control arm (Gastroenterology–Nutrition–Pulmonology, Pediatric psychiatry and Orthopedic Surgery).

Statistical considerations

Statistical analyses were performed using Statistical Analysis System software version 9.2 (SAS Institute, Cary, NC, USA) according to the intention-to-treat principle. All malnourished children who were screened in all clusters and allocated to the intervention or control arm were included in the analysis.

The generalized estimating equation method was performed to analyze the impact of our intervention on the outcomes, allowing for the clustered nature of the data with children nested in pediatric departments.[20] First, comparisons were made within each arm regarding outcome changes between pre- and post-intervention periods using a multivariate generalized estimating equation regression model. The period following the beginning of the intervention was the predictor, while individual level characteristics for which the results were adjusted included age, severity of malnutrition, presence of comorbidities, occurrence of complications and length of hospital stays. Immediate changes and quarterly trends in clinical practices following the implementation of the intervention were also estimated. Second, the difference between the arms in the outcomes during the post-intervention period was quantified using the multivariate generalized estimating equation regression model. Pediatric department was the clustering variable, whereas all the potential confounders listed above were considered in the final models. Models were fitted using PROC GENMOD. The intervention effect was given as the adjusted odds ratio (OR) with a 95% confidence interval (95% CI) and overall Intracluster Correlation Coefficient.

RESULTS

Study population

The population consisted of 242 healthcare workers in six pediatric departments. All the workers were randomly assigned and received the intended intervention. Primary outcomes between three interventions and three control clusters (Figure 2) were compared. Among 1575 eligible malnourished children, a total of 1457 (92.5%) were ultimately included in the analysis over 2 years, including 313 during the pre-intervention period and 1144 during the post-intervention period.

Table 1 shows the characteristics of the intervention and control arms pre- and post-intervention at the individual and cluster levels. The child nutritional status and the presence of comorbidities were similar between arms during the post-intervention period. The prevalence of malnutrition was 21.0% (1144/5445 hospitalized children, 95% CI 19.3–22.7%, including 6% with severe malnutrition), and was equivalent between the intervention (21.1%, 667/3154, 95% CI 19.0–23.3%) and control arms (20.8%, 477/2291, 95% CI 18.3–23.4%). There were 122 and 120 participating healthcare workers in the intervention and control arms, respectively, including 76 and 76 nurses, 43 and 41 physicians and three dietitians in each arm.

Outcome comparisons between the pre- and post-intervention periods

Compared with the pre-intervention period, the post-intervention practices were significantly improved in the intervention arm for every outcome, whereas they remained unchanged in the control

Table 1. Baseline information for each arm before and after intervention at the individual and cluster levels

Variables	*Pre-intervention period*	*Post-intervention period*	
		Intervention arm	*Control arm*
Individual level	*(n = 313)*	*(n = 667)*	*(n = 477)*
Mean (s.d.) age (years)	4.6 (5.7)	4.2 (5.0)	6.9 (6.0)
Female (%)	182 (58.1)	386 (57.9)	241 (50.5)
Mean (s.d.) BMI (kg/m^2)	15.0 (2.4)	15.0 (2.8)	15.6 (3.0)
Weight/height ratio (%)	82.3 (7.6)	82.9 (6.4)	83.2 (6.2)
Height/age ratio (%)	88.3 (5.5)	89.13 (5.2)	88.1 (6.0)
Malnutrition status—moderate (%)	218 (69.6)	499 (74.8)	351 (73.6)
Severe (%)	95 (30.4)	168 (25.2)	126 (26.4)
Malnutrition etiologies evaluated (%)	157 (50)	434 (65)	354 (74)
Anorexia (%)	3 (2)	19 (4)	17 (5)
Caloric intake deficiency (%)	1 (0.6)	3 (0.7)	2 (0.6)
Inflammatory bowel disease (%)	8 (5)	3 (0.7)	15 (4)
Severe intestinal failure (%)	2 (1)	2 (0.5)	7 (2)
Liver disease (%)	5 (3)	4 (1)	20 (6)
Renal failure (%)	5 (3)	42 (10)	7 (2)
Chronic pulmonary disease (%)	28 (18)	44 (10)	72 (20)
Heart failure (%)	7 (4)	10 (2)	21 (6)
Genetic syndromes (%)	10 (6)	33 (8)	36 (10)
Encephalopathy (%)	17 (11)	70 (16)	31 (9)
Cancer (%)	0 (0)	8 (2)	6 (2)
Immunodeficiency (%)	1 (0.6)	3 (0.7)	3 (0.9)
Severe infection (%)	1 (0.6)	0 (0)	1 (0.2)
Diabetes (%)	22 (14)	0 (0)	62 (14)
Other chronic diseases (%)	118 (75)	297 (68)	283 (80)
Cluster level	*(n = 6)*	*(n = 3)*	*(n = 3)*
Median (min–max) no. of beds	26 (15–43)	30 (20–30)	22 (15–43)
Median (min–max) no. of physicians	14 (7–20)	13 (10–20)	14 (7–20)
Median (min–max) no. of nurses	24 (23–29)	24 (23–29)	24 (23–29)
No. of dietitians	6	3	3

Abbreviation: BMI, body mass index.

arm (Table 2). The adjusted mean of daily weighing in particular increased from 0.65 to 0.71 ($P = 0.004$), as did the rates for malnutrition etiology investigation (from 12.3 to 43.0%, $P < 0.001$), dietitian management (from 33.5 to 46.1%, $P < 0.001$) and the introduction of a refeeding protocol (from 23.4 to 34.9%, $P = 0.003$). Interestingly, the mean number of daily weighings was higher in the control clusters when compared with the intervention clusters prior to implementing the intervention (0.79 vs 0.65), as well as the rate of the prescribed refeeding protocol (33.7 vs 23.4%).

Furthermore, an exploration of the outcome trends in the intervention arm (Figure 3) revealed a 13.9% increase immediately after intervention for the investigation of malnutrition etiology (adjusted rate, 95% CI 8.4–19.4%, $P < 0.001$), followed by a sustained increase of 5.8% per quarter (95% CI 2.1–9.6%, $P = 0.002$). Dietitian management also increased immediately after intervention by 7.4% (95% CI 1.1–13.8%, $P = 0.02$).

Outcome comparisons between the intervention and control arms

Outcomes comparison between the arms is presented in Table 3. An investigation of the malnutrition etiology (with an adjusted OR of 4.4, 95% CI 1.7–11.8) and management by a dietitian (OR 2.7, 95% CI 1.0–6.9) occurred significantly more frequently in the intervention clusters than in the control clusters. No effect was observed regarding the repetition of weighing during the stay (OR 1.1, 95% CI 0.5–2.6) and the introduction of a refeeding protocol (OR 1.0, 95% CI 0.3–3.5).

Table 2. Multivariate comparison of outcomes before and after intervention by arm

Primary and secondary outcomes	*Pre-intervention period*[a] (n = *313*)	*Post-intervention period*[a] (n = *1114*)	P-*value*
No. of daily weighings (adjusted mean)			
Intervention arm	0.65	0.71	0.004
Control arm	0.79	0.73	0.48
Investigation of malnutrition etiology (adjusted rate)			
Intervention arm	12.3	43.0	< 0.001
Control arm	12.6	21.6	0.19
Management by a dietitian (adjusted rate)			
Intervention arm	33.5	46.1	< 0.001
Control arm	32.5	34.1	0.85
Refeeding protocol[b] *(adjusted rate)*			
Intervention arm	23.4	34.9	0.003
Control arm	33.7	39.3	0.42

The period following the implementation of the computerized system was the predictor, whereas individual level characteristics for which the results were adjusted included age, severity of malnutrition, presence of comorbidities, occurrence of complications and length of hospital stays. [a]The adjusted outcomes were calculated based on a multivariate generalized estimating equation (GEE) regression model, taking into consideration the clustering of malnourished children by pediatric department. [b]Including the prescription of oral, enteral or parenteral refeeding.

DISCUSSION

We have conducted a cluster randomized trial over 2 years to assess the impact of a computerized system on healthcare worker adherence to recommended practices in children's nutritional care. When compared with the pre-intervention period, all clinical practices were significantly improved in the intervention arm, whereas they remained unchanged in the control arm after the intervention had been implemented. Large effect sizes were highlighted when comparing outcomes between the intervention and control arms related to the investigation of malnutrition etiology and specialized dietitian management. No difference was found in the frequency of daily weighings and the introduction of refeeding protocols, mostly as a consequence of unbalanced outcomes between the arms at baseline.

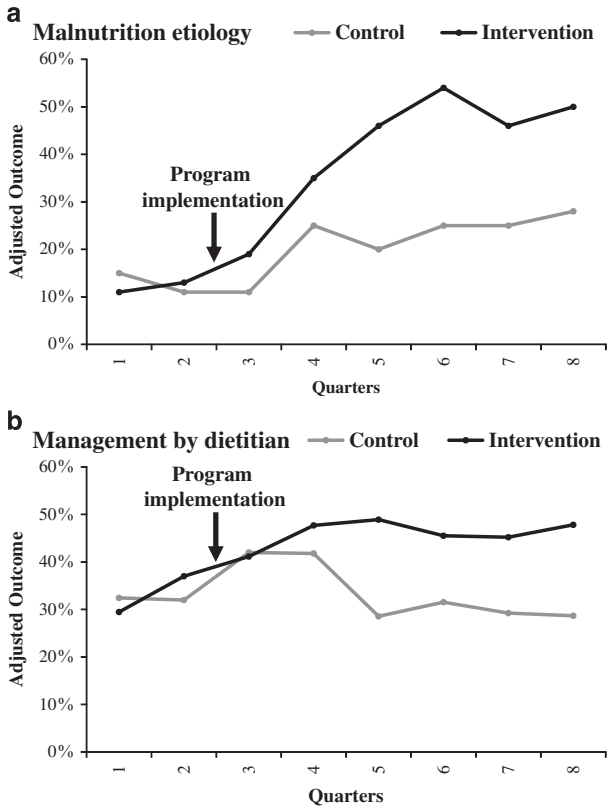

Figure 3. Outcome trend comparison before and after intervention by arm. (**a**) An immediate increase in the adjusted investigation rate for malnutrition etiology was observed after the intervention ($P < 0.0001$), followed by a gradual and sustained quarterly increase until there was a plateau in the intervention arm ($P < 0.01$). At the same time, no significant change was observed in the control arm. (**b**) An immediate increase in the adjusted rate for dietitian management was observed after the intervention ($P < 0.05$), which was decreased in the control arm ($P < 0.05$).

This experimental investigation revealed changes in professional practices in response to the use of computerized tools for screening all malnourished children at the hospital. The prevalence of malnutrition in the study population was comparable to the observed rates in other university hospitals of ~20%.[3–7] Despite being rapid and feasible in a clinical setting,[21] the use of computerized systems for nutrition screening (that is, the type that automatically generates at-risk patient notification based on established criteria without human intervention) are rarely used.[22] To date, most efforts to improve nutritional care have focused on the implementation of automated screening tools for malnutrition-related complications[23] or Computerized Prescriber Order Entry systems.[24,25] The Computerized Prescriber Order Entry systems are assumed to enhance the safety of parenteral nutrition for pediatric patients.[26] By calculating the nutritional requirements and automatically producing daily patient menus, computerized systems may improve work efficiency[27] by decreasing time spent on menu planning and prescription errors.[28]

We didn't use a malnutrition-screening tool such as PYMS, STRONG kids or STAMP on admission to raise the awareness of the medical team because our aim was to detect children with malnutrition at admission and because it would be more time consuming than the automatic alert based on W/H and H/A ratios.

On the basis of a quasi-experimental design, O'Flynn *et al.* suggested improvements in clinical practices following the introduction of a nutrition education program and routine screening for inpatient adults.[13] In pediatrics, a higher educational level among healthcare workers is assumed to increase the probability of specific nutritional support for children. Those hospitalized in pediatric versus non-pediatric wards may benefit more frequently from dietitian care.[29] However, more than half of malnourished children may not be identified or gain access to specialized dietitian care, even in pediatric hospitals. Moreover, a poor preoperative nutritional status is associated with a higher risk of complications,[30] and admitted malnourished children are at a higher risk of a deteriorating nutritional status during their hospital stay.[1]

Although an experimental trial design is supposed to provide the strongest level of scientific evidence, we advise cautious interpretation of these study findings. Population representation was limited by the monocentric context of the pediatric department in a university hospital. As a consequence of the small number of clusters, assigning the intervention was challenging in terms of evenly distributing population characteristics between the trial arms.[31] Randomization did not assure a similar starting point between the arms for all measured outcomes, as evidenced by the higher frequency of daily weighings and

Table 3. Multivariate comparison of outcomes between the arms during the post-intervention period

Primary and secondary outcomes	*Intervention arm (n = 667 malnourished children in 3 departments)*	*Control arm (n = 477 malnourished children in 3 departments)*	*ICC*[a]	*Adjusted odds ratio (95% CI)*[a]	P-*value*
Mean no. of daily weighings	0.71	0.73	0.491	1.10 (0.46–2.65)	0.83
Investigation of malnutrition etiology (*n*)	284	102	0.081	4.42 (1.66–11.78)	0.003
Management by a dietitian (*n*)	305	161	0.051	2.66 (1.02–6.92)	0.046
Refeeding protocol[b] (*n*)	230	186	0.111	1.02 (0.30–3.49)	0.97

Pediatric department was the clustering variable, whereas individual level characteristics for which the results were adjusted included age, severity of malnutrition, presence of comorbidities, occurrence of complications and length of hospital stays. The intervention effect is given as the adjusted odds ratio with a 95% confidence interval (95% CI) and overall Intracluster Correlation Coefficient (ICC). [a]The difference between the arms in the outcomes during the post-intervention period was quantified using a multivariate GEE regression model. [b]Including the prescription of oral, enteral or parenteral refeeding.

refeeding protocols in the control arm during the pre-intervention period. This discrepancy in the two groups at baseline may be explained by the gastro-respiratory cluster, which improved the baseline scores in the control group as these medical specialties have great interest and experience in management of diseases with a high prevalence of malnutrition (Crohn's disease, short bowel syndrome, cystic fibrosis and so on). Such unbalanced baseline metrics have reduced our capacity to highlight potential differences between the arms during the post-intervention period. This distinction was even harder to make in light of the unexpectedly high intracluster correlation coefficients and unequal sample sizes across clusters. However, the control group didn't reveal any significant change during the study, which is an important point. Furthermore, despite the fact that the intervention was appropriately randomized at the cluster level, we cannot exclude contamination across clusters. This eventuality is supported by a non-significant trend toward improvement in the control arm relating to the investigation of malnutrition etiology and a tendency of improvement for the frequency of etiology investigation and dietitian management during the first quarters of the post-intervention period. However, in contrast to the intervention arm, this tendency was not sustained for the control group during the entire study period, as illustrated in Figure 3.

Our study was designed to evaluate the evolution of professional practices after an intervention, but not clinical outcomes, such as the rate of complications or their duration. A larger cohort would be required to evaluate such clinical end points.

The recent development and implementation of integrated hospital information systems offer the opportunity to gain substantial improvements in the quality of care delivery. With the increasing availability of detailed clinical data, there is now a markedly greater ability to automate electronic tools to help hospital staff in managing specific patient conditions. Based on a limited set of routinely collected variables, we have demonstrated the feasibility and efficacy of implementing in real time a computerized malnutrition-screening system that would not be achievable by human action alone. This automated tool, which combines a malnutrition index calculation with an electronic alert for physicians and a monitoring dashboard for dietitians, is easily reproducible by institutions with integrated information systems. Its performance requires that nurses comply with systematic weighings and height measurements for every admitted child to allow sensitive screening and to trigger dietitian intervention at the bedside.

The hospital information system is supposed to reflect work organizations within institutions to facilitate high-level consistent care. Because it cannot substitute for human behavior, other components of our multifaceted intervention (an awareness campaign directed toward healthcare workers and a leadership-based strategy) necessitate improving coordination and teaching skills of a nutrition support team. Gaining a common 'nutritional culture' is pivotal to facilitating information sharing and collaboration between the various healthcare workers involved in the nutrition care process. This coordination requires time and may explain why, despite rapid improvements, there is still substantial room for improvement in achieving better screening and management of malnourished hospitalized children.

CONFLICT OF INTEREST

The authors declare no conflict of interest.

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