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Original Article

Costs of hospital malnutrition

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SUMMARY

Background & aims: Hospital malnutrition has been established as a critical, prevalent, and costly problem in many countries. Many cost studies are limited due to study population or cost data used. The aims of this study were to determine: the relationship between malnutrition and hospital costs; the influence of confounders on, and the drivers (medical or surgical patients or degree of malnutrition) of the relationship; and whether hospital reported cost data provide similar information to administrative data. To our knowledge, the last two goals have not been studied elsewhere.
Methods: Univariate and multivariate analyses were performed on data from the Canadian Malnutrition Task Force prospective cohort study combined with administrative data from the Canadian Institute for Health Information. Subjective Global Assessment was used to assess the relationship between nutritional status and length of stay and hospital costs, controlling for health and demographic characteristics, for 956 patients admitted to medical and surgical wards in 18 hospitals across Canada.
Results: After controlling for patient and hospital characteristics, moderately malnourished patients' (34% of surveyed patients) hospital stays were 18% ($p = 0.014$) longer on average than well-nourished patients. Medical stays increased by 23% ($p = 0.014$), and surgical stays by 32% ($p = 0.015$). Costs were, on average, between 31% and 34% (p-values < 0.05) higher than for well-nourished patients with similar characteristics. Severely malnourished patients (11% of surveyed patients) stayed 34% ($p = 0.000$) longer and had 38% ($p = 0.003$) higher total costs than well-nourished patients. They stayed 53% ($p = 0.001$) longer in medical beds and had 55% ($p = 0.003$) higher medical costs, on average. Trends were similar no matter the type of costing data used.
Conclusions: Over 40% of patients were found to be malnourished (1/3 moderately and 1/10 severely). Malnourished patients had longer hospital stays and as a result cost more than well-nourished patients.

1. Introduction

Hospital malnutrition [1] (inadequate intake of energy, protein and nutrients) has been established as a critical, prevalent, and costly problem for patients and the health care system. Studies in Europe [2–7], Asia [8], and South America [9] have demonstrated increased costs associated with malnutrition during hospitalization. However, our understanding of the costs attributed to malnutrition are limited due to the use of single clinical settings [5,6,8], single clinical populations, such as those with cancer [7], retrospective studies [7,9], or hypothetical samples based on costing and nutritional status estimates from population level data [4]. Few studies to date have been multi-center, limiting the generalizability of prevalence estimates of malnutrition and the costs associated with impaired nutritional states [2,9].

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Additionally, nutritional status designation in these analyses is commonly based on screening tools [2–5], or individual nutrition parameters such as weight loss [7] which do not fully capture nutritional status; use of screening methods specifically which are designed to have a high sensitivity, can inflate costs due to excess prevalence [6]. While there is no gold standard for nutritional assessment, the subjective global assessment (SGA) is a validated nutritional assessment tool demonstrating high sensitivity and specificity and recommended as a predictive tool for clinical outcomes [10–12]. Yet, relatively few reports have used the SGA to assess for malnutrition [6,8,9].

Commonly, length of stay (LOS) is the focus for deriving costs with national or insurance company averages used to cost this care and derive resource utilization estimates [2–4,7–9]. However, it is unclear if these administrative data for costing are consistent with individual hospital data, which have rarely been used to date [5]. Further, not all studies adjust for the effect of co-morbidities on the costs attributed to malnutrition [5,6,8]. For example, one study [9] controlled only for cancer and surgery during admission as markers of morbidity in their analyses and another [2] made no adjustments.

The Nutrition Care in Canadian Hospitals study [13] (NCCHS) provides the opportunity to complete a cost analysis overcoming the deficits noted in prior work. Specifically, this was a multi-center cohort study of more than 1000 patients, where SGA was used at admission to diagnose malnutrition. Patient information collected also included demographic information, comorbidity and length of stay and type of ward admitted and transferred to during their hospitalization. A site questionnaire provided specific hospital information including average daily costs for each type of ward. Finally, costs recorded in a national data base, which holds standardized cost data for specific hospitals across Canada, is used as a comparator for site reported costs. The goals of this study were to determine: how malnutrition and hospital costs are associated; whether adjusting for confounders changed the relationship; whether the relationships were driven by medical or surgical patients or severity of malnutrition; and whether hospital derived cost estimates provided similar information to a standardized national database. To our knowledge, the last two goals have not been previously studied.

2. Methodology

The Canadian Malnutrition Task Force conducted a prospective cohort study [13], NCCHS, from July 2010 to February 2013 which included patients 18 years or older, admitted to surgical or medical wards in one of 18 participating acute care hospitals that had volunteered to participate. All provinces were represented except Newfoundland and Prince Edward Island. Patients were excluded if they were not able to give consent or were admitted directly to intensive care (ICU), obstetric, psychiatry, palliative care or medical day units. Patients were enrolled according to a strict protocol to avoid selection bias [14]. Days of enrollment rotated from Monday to Friday, with Monday capturing the week-end admissions. Consecutive admissions were approached for consent and a maximum of 7 patients were followed at the same time to promote feasibility. The study was approved by all institutions' administration and research ethic's boards (REBs) and all participants or their alternative decision maker, where allowed by the hospital REB, signed a consent form. The final study sample was 1022 patients recruited from community and academic hospitals.

Patient's nutritional status was assessed at admission. SGA [15] was performed by 18 trained coordinators (one in each hospital) to avoid inter-rater variability (SGA A = well-nourished; SGA B = moderately malnourished; SGA C = severely malnourished). Demographic data (sex, age, and education), health information, including number of active diagnoses, the Charlson Comorbidity Index [16] (CCI), and number of medications, were also collected at admission. Length of stay in hospital and on each ward/unit (medical, surgical, mixed medical/surgical, and ICU), and post-admission transfers, including dates of transfers, between units were documented for each participant. Patient charts were reviewed approximately every two days during their hospital stay in order to track transfers and update health information as necessary. Hospital management and administrators completed a standardized questionnaire that included average costs for medical, surgical, and ICU beds.

2.1. Deriving costs

LOS in medical, surgical, mixed medical/surgical, and ICU beds was calculated for each participant by tracking the units patients were admitted to and transferred between. Bed days in each unit were calculated by summing all bed days spent in that type of unit. The average cost of a medical, surgical, mixed medical/surgical, and ICU bed day was provided by each site. In addition, standardized data on hospital per diem expenses and direct expenses for functional units were purchased from the Canadian Institute for Health Information (CIHI) (for comparison to site provided costs (i.e., sensitivity analyses)).

Three costs were derived for each patient in the study; total costs, medical costs and surgical costs. Total cost was the product of the number of bed days each patient spent on a each unit type (medical, surgical, mixed, and ICU) and the average cost of a bed day on that unit type as recorded in a hospital questionnaire. For example, medical bed costs were calculated by multiplying the number of days the patient occupied any medical bed during their hospital stay by the average cost of a medical bed in that hospital. Surgical, mixed ward, and ICU costs were derived in a similar manner. All costs were calculated in 2012 real terms (adjusted for inflation). One hospital ($n = 57$) classified all patient bed days as mixed but provided costs for medical and surgical bed day. These observations were included in total costs by multiplying the number of mixed bed days by the average of the medical and surgical bed cost for that hospital. These observations were excluded when deriving medical or surgical bed days and costs. One hospital ($n = 59$) provided costing information for medical wards only. Surgical ward costs were assumed to be equal to medical ward costs for the hospital. One hospital ($n = 40$) provided all the data needed for the study except for costs. To maintain the observations, and be as conservative as possible, the medical and surgical costs for this hospital were set equal to the minimum medical or surgical costs recorded in the data. Sensitivity analyses were performed around all assumptions and with costing data purchased from CIHI (see online appendix).

2.2. Nutrition and covariates

Patients with all categories of SGA, well nourished (comparator), moderately and severely malnourished were included in analyses. Previous studies indicate that malnourished patients tend to be: older, more likely to be male, and more likely to suffer from comorbidities [4,8]. Province of residence has been found to be a strong predictor of health status, probability of hospital admission, and/or length of hospital stay [17,18] in Canada, and academic hospitals tend to have higher costs than community hospitals [19]. These variables, which may affect health and/or hospital LOS and costs, regardless of nutritional status, are added as controls when examining the conditional associations between malnutrition and hospital stay and/or hospital costs. Three proxies for health status were included initially; the CCI [16], the number of diagnoses, and the median number of medications prescribed during admission [14]. CCI was missing for 12% of the sample and never approached statistical significance in initial regressions, so it was dropped from the analyses. Diagnoses were categorized as one, two or three or more. Median number of medications is a continuous variable ranging from zero to 35.5 (one patient had zero medications). Age, gender, socioeconomic status, living arrangement, type of hospital, province and year were also added as controls. Age at time of survey is a continuous variable and gender categorical (male = 1, female = 0). Education, classified as less than high school, completion of high school, secondary school completion, and post-secondary education (comparator) proxied for socioeconomic status. Multiple living arrangements were recorded in the survey. These were categorized as living alone, living in residential care or living with someone in the community (comparator).

3. Analysis

Stata/MP 13.1 [20] was used for all statistical analysis. As LOS and corresponding hospital costs were severely skewed and residuals were not normally distributed, linear regression with logarithmic transformation of the dependent variables [21] was undertaken. This type of analysis was possible due to the absence of zero values and correct retransformation [22–24]. As observations were clustered at the hospital level, all standard errors were adjusted for non-independence of observations. Sixty-four observations were excluded from the original study sample (n = 1022) due to missing information in covariates. In hospital mortality resulted in censoring of LOS for 22 patients (2 were well nourished (0.4% of well-nourished patients), 14 were moderately malnourished (4.5% of malnourished patients) and 6 were severely malnourished (5.9% of severely malnourished patients) (differences are significant across groups)). The patients were included in the study with LOS as recorded at time of death as nutritional status is strongly associated with mortality in these data (see online appendix). The odds a moderately (severely) malnourished patient died were 11 (13) times more than the odds a well-nourished patient did within the study period. Other studies have also shown a correlation between malnutrition and mortality [9]. The final estimating sample size is 958.

To illuminate the association between malnutrition and hospital costs, unadjusted analyses and then analyses adjusted for key covariates are presented. Sensitivity analyses (available in online appendix) were performed and indicate inclusion/exclusions and assumptions do not drive study conclusions.

The coefficients, particularly on dummy variables, from the regression model, $\ln(Y) = a + b*N + c*X + e$ (N represents nutritional status, X represents control variables, and e are errors) are not as straightforward as often interpreted. Herein the regression results are presented as marginal effects. The marginal effects provide the correct interpretation of the change (proportional (or percentage change if multiplied by 100)) in Y (not ln(Y)) for a small change in X (dummy variable changes from 0 to 1 or continuous variables are increased by 1) [22,24]. As previously stated, p-values are adjusted for clustering. Finally, given logarithmic transformation of the dependent variable, the appropriate adjusted predicted mean is reported for each regression analysis [25–27].

4. Results

Table 1 presents descriptive statistics for the full sample. Slightly over half of the participants are well nourished while one third are moderately malnourished and just over one tenth are severely malnourished. Males make up almost 52% of the sample and the mean age is 64 years. About one fifth of the sample did not complete high school, 38% did and just over 40% obtained education beyond high school. Over two-thirds of the sample lived with other people before being admitted to hospital, one quarter lived alone, and almost one-tenth lived in a residential setting. The median number of prescribed medications was, on average, close to 13. Just over two-thirds of participants had one diagnosis while 26% had two diagnoses and almost 10% had three or more diagnoses. Just over two-thirds were admitted to academic hospitals.

On average, patients spent almost 10 days (1–117 days) in hospital leading to a total average cost of $6345 ($550–$89,498). A medical bed stay was almost 10 days (1–117 days), on average, costing an average $6214 ($347–$53,536) while a surgical stay was 8 days (1–93 days) costing $5355 ($582–$49,222).

Mean outcomes by nutritional status are presented in Table 2. The average number of days spent in hospital was just over 3.2 (3.3)

Table 1
Survey population descriptive statistics.

Variable	Main sample[a] (n = 958) [Standard error[b]]
Well nourish	55.7% [3.25]
Mod malnourish	33.5% [3.32]
Sev malnourish	10.8% [1.58]
Male	51.5% [2.46]
Age	64.05 [0.85]
<High school	21.3% [3.20]
High school	38.1% [2.08]
>High school	40.6% [3.57]
Live with other	65.1% [2.89]
Live alone	26.5% [2.78]
Residential	9.0% [1.79]
Number meds	12.64 [0.64]
One diagnosis	64.0% [3.78]
Two diagnoses	26.2% [2.34]
3+ diagnoses	9.8% [1.71]
Academic hosp	65.9% [11.3]
Total beddays	9.86 [0.71]
Medical days	9.97 [0.95]
Surgical days	7.92 [0.50]
Total costs	$ 6345 [649]
Medical costs	$ 6214 [726]
Surgical costs	$ 5355 [975]

[a] Percent (%) of sample for binary variables and sample mean for continuous variables.
[b] Standard Errors adjusted for clustering.
Source: Author's calculations.

Table 2
Outcome mean by nutritional status.

Outcome	Nourished [Standard error[a]]	Moderately Malnourished	Severely Malnourished
Survey data			
Beddays			
Total (n = 958)	8.43 [0.65]	11.66 [1.17]	11.70 [0.96]+
Medical (n = 632)	8.20 [0.95]	12.05 [1.32]+	12.05 [1.33]+
Surgical (n = 301)	6.98 [0.65]	9.62 [1.39]ǂ	8.75 [1.11]
Costs			
Total (n = 958)	$ 5074 [512]	$ 7931 [766]+	$ 7989 [976]+
Medical (n = 632)	$ 4839 [593]	$ 7825 [849]+	$ 7823 [1042]+
Surgical (n = 301)	$ 4303 [681]	$ 7154 [1660]	$ 6744 [1435]

*, +, ǂ indicates significantly different from well-nourished at 0.00, 0.05, 0.10, respectively. Severely malnourished is never significantly different than moderately malnourished.
[a] Standard errors are adjusted for clustering at hospital level.
Source: Author's calculations.

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days longer for a moderately (severely) malnourished patient, when compared to a well-nourished patient (8.4, 11.7, and 11.7, respectively; $p < 0.05$ indicates significant difference between well-nourished and malnourished, difference between moderately and severely malnourished is n.s.). The association between medical bed days and nutritional status was similar with moderately and severely malnourished patients spending significantly longer in medical beds, conditional on having stayed in a medical bed, (3.9 days; $p < 0.05$) than well-nourished patients. The trend was similar for surgical stays but the difference was only barely statistically significant for moderately malnourished patients. Total cost increased by $2857 when patients were moderately malnourished and by $2915 when severely malnourished (~60%, $p < 0.05$). For medical bed stays, costs were significantly higher ($p < 0.05$), $2986 for moderate and $2984 for severely malnourished patients. The average cost difference between a well-nourished and moderately malnourished surgical patient was $2851 and $2441 for severely malnourished patients but the differences were not statistically significant.

Univariate analyses on the transformed outcomes are presented in Table 3 and multivariate analyses with added controls are presented in Tables 4 and 5. The results shown in Table 3 are the marginal effects of malnutrition, relative to a well-nourished patient, with no adjustment for covariates, the standard errors have been adjusted for clustering at hospital level. The predicted mean LOS (9.3 days) is very close to the sample mean provided in Table 1. Results indicate that nutritional status is strongly and significantly associated with LOS. Moderate malnourishment is associated with a 27% increase ($p = 0.006$), and severe malnutrition with a 44% increase ($p = 0.000$), in total hospital days. Length of stay increases substantially more, on average, for medical stays with a 40% increase for moderate malnutrition ($p = 0.008$) and a 59% ($p = 0.002$) increase for severely malnourished patients. Significance wanes for surgical stays (potentially due to small sample size); malnutrition is associated with 28% ($p = 0.014$) and 29% ($p = 0.067$) increase for moderately and severely malnourished patients, respectively. Moderate malnutrition is associated with a 45% ($p = 0.002$) increase in total costs, a 55% ($p = 0.004$) and 52% ($p = 0.062$) increase, respectively, for medical and surgical costs. Severe malnutrition is associated with a 54% ($p = 0.006$), a 68% ($p = 0.009$) and a 51% (0.066) increase, respectively, for total, medical, and surgical costs.

Table 3
Loglinear regression univariate results.

	Total (n = 958) Marginal Effect [p-value]*	Medical (n = 632) Marginal Effect [p-value]*	Surgical (n = 301) Marginal Effect [p-value]*
Bed days			
Mod malnourish	0.272 [0.006]+	0.399 [0.008]+	0.284 [0.014]+
Sev malnourish	0.438 [0.000]*	0.594 [0.002]+	0.294 [0.067]ǂ
Predicted mean	9.344	9.251	7.668
R-squared	0.0346	0.0549	0.0353
Costs			
Mod malnourish	0.450 [0.002]+	0.553 [0.004]+	0.524 [0.062]ǂ
Sev malnourish	0.543 [0.006]+	0.678 [0.009]+	0.514 [0.066]ǂ
Predicted mean	6157	6030	5164
R-squared	0.0475	0.0628	0.0682

*p-value adjusted for clustering at hospital level.
*, +, ǂ indicates significantly different from well-nourished at 0.00, 0.05, 0.10, respectively.
Source: Author's calculations.

Table 4
Loglinear regression results for bed days.

	Total (n = 958) Marginal Effect [p-value]*	Medical (n = 632) Marginal Effect [p-value]*	Surgical (n = 301) Marginal Effect [p-value]*
Mod malnourish	0.184 [0.014]+	0.229 [0.014]+	0.316 [0.015]+
Sev malnourish	0.342 [0.000]*	0.527 [0.001]+	0.167 [0.236]
Male	0.001 [0.492]	−0.062 [0.122]	−0.019 [0.423]
Age	0.005 [0.014]+	0.006 [0.009]+	0.004 [0.048]+
<High school	0.062 [0.245]	−0.060 [0.250]	0.056 [0.299]
High school	−0.002 [0.475]	−0.100 [0.018]+	0.035 [0.328]
Live alone	0.013 [0.376]	0.074 [0.137]	0.042 [0.333]
Residential	0.253 [0.010]+	0.253 [0.005]+	0.237 [0.188]
Number meds	0.019 [0.002]+	0.013 [0.011]+	0.013 [0.068]
Two diagnoses	0.229 [0.007]+	0.268 [0.006]+	0.093 [0.235]
3+ diagnoses	0.568 [0.000]*	0.548 [0.002]+	0.536 [0.102]
Academic hosp	0.116 [0.065]ǂ	0.053 [0.300]	0.046 [0.324]
Predicted mean	9.407	9.537	7.768
R-squared[a]	0.1860	0.2046	0.1778

*p-value adjusted for clustering.
*, +, ǂ indicates significantly different from well-nourished at 0.00, 0.05, 0.10, respectively.
[a] Results control for province and year.
Source: Author's calculations.

Table 5
Loglinear regression results for costs.

	Total costs (n = 958) Marginal Effect [p-value]*	Medical costs (n = 632) Marginal Effect [p-value]*	Surgical costs (n = 301) Marginal Effect [p-value]*
Mod malnourish	0.312 [0.003]+	0.285 [0.004]+	0.336 [0.022]+
Sev malnourish	0.378 [0.002]+	0.550 [0.003]+	0.269 [0.145]
Male	0.012 [0.412]	−0.024 [0.338]	−0.066 [0.243]
Age	0.005 [0.011]+	0.006 [0.009]+	0.007 [0.011]+
<High school	−0.022 [0.405]	−0.149 [0.065]	−0.013 [0.460]
High school	0.024 [0.384]	−0.087 [0.034]+	−0.013 [0.431]
Live alone	−0.059 [0.067]	0.035 [0.299]	0.055 [0.434]
Residential	0.263 [0.067]ǂ	0.288 [0.007]+	0.105 [0.311]
Number meds	0.012 [0.031]	0.007 [0.085]	−0.004 [0.290]
Two diagnoses	0.134 [0.035]+	0.168 [0.028]+	0.051 [0.334]
3+ diagnoses	0.435 [0.002]+	0.400 [0.006]+	0.438 [0.115]
Academic hospital	0.360 [0.100]ǂ	0.198 [0.104]	1.144 [0.001]+
Predicted mean	6195	6219	5208
R-squared[a]	0.2930	0.3375	0.3409

*p-value adjusted for clustering.
*, +, ǂ indicates significantly different from well-nourished at 0.00, 0.05, 0.10, respectively.
[a] Results control for province and year.
Source: Author's calculations.

R^2s are low for all regressions but this is not unusual for health utilization studies [17].

Table 4 demonstrates that nutritional status remains significantly associated with LOS after adjusting for individual and hospital characteristics, which may drive LOS independently of nutritional status. Moderate malnourishment is independently associated with an average increase of 18% in hospital days ($p = 0.014$), 23% increase in medical days ($p = 0.014$), and 32% increase in surgical stays ($p = 0.015$) when compared to a well-nourished patient. Severely malnourished patients stay 34% longer ($p = 0.000$) in hospital and approximately 53% longer ($p = 0.001$) in medical beds than do well-nourished patients with similar characteristics. Adding covariates eliminates the significance of the relationship between severe malnutrition and surgical

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bed days (17% longer but $p = 0.236$). Patient covariates independently associated with longer LOS are: increasing age, living in residential settings, more medications prescribed, and having more diagnoses during their hospital stay. Education is not significantly related to LOS except that high school graduates have, on average, fewer medical bed days than do those with post-secondary educations ($p = 0.018$). The only hospital characteristics independently associated with longer LOS are academic ($p < 0.10$) and province (results not shown).

Cost results are presented in Table 5. Adjusting for covariates diminishes the relationship slightly but the independent effect of malnutrition on hospital costs remains large in magnitude and strongly significant. Moderately malnourished patients cost, on average, between 31% and 34% more than well-nourished patients (p-values < 0.05). Severe malnourishment is associated with higher total and medical costs, on average; 38% higher total costs ($p = 0.003$), 55% higher medical costs ($p = 0.003$), but surgical costs are not significantly higher for malnourished patients. The only patient covariates independently associated with costs were increasing age, number of medications, and number of diagnoses. Academic hospitals were associated with higher hospital costs and particularly higher surgical costs.

Sensitivity analyses (presented in online appendix) were completed to test changes in samples (excluding one Quebec hospital recording only 'mixed beds' ('limited sample' $n = 900$) and dropping all Quebec hospitals ('No Quebec' $n = 787$)), assumptions, and costing data.

Online Appendix Table 1 documents mean outcomes for different samples and Table 2 shows outcomes by nutritional status. Results are very similar to Tables 1 and 2 of the main analyses. The only differences worthy of note are the average costs depending on source of costing data. Average costs calculated with CIHI Direct Expenditure data were close to $1000 lower than average costs using comparable data provided by the hospitals while average costs calculated using CIHI Per Diem costs are almost double the average costs using the comparable hospital data. This demonstrates that costing definitions/inclusions differ depending on the data source and sensitivity analyses are required to assure results are generalizable.

Online Appendix Tables 3 and 4 present the regression coefficients on our variables on interest (coefficients on control variables are not reported) to test sensitivity to sample specifications (Table 3) and costing assumptions (Table 4). Although significance between severe malnutrition and surgical costs are insignificant in most cases (similar to our full-sample results), the relationships between moderate and severe malnourishment hold strong in alternate samples and for alternate costing data sources. The conclusion that malnourished patients' hospital stays cost significantly more than well-nourished patients with similar characteristics holds.

5. Discussion

This study identified that almost half of hospital patient participants in the Nutrition Care in Canadian Hospitals study were malnourished at admission as measured by the SGA; one third were moderately malnourished and just over one tenth were severely malnourished. Malnourished patients stay in hospital longer (approximately three days longer, on average than well nourished) and, as a result, cost substantially more, on average, per hospital stay. The strong univariate relationship, adjusting for non-normal distribution of residuals and clustering of observations, between malnourishment and hospital stays/costs held after adjusting for patient and hospital characteristics. Malnutrition at admission increases total costs by 31% (moderate) to 38% (severe), on average, which translates to about $1500 to $2000 (2012 dollars) after controlling for characteristics that may influence the cost of hospitalization and the likelihood of being malnourished. The significance in the relationship wanes when examining surgical stays but this may be due to the small sample size for surgical bed stays or the possibility that some severely malnourished patients may not be candidates for some surgical procedures.

The results of this study are consistent with prior work [3,4,9] however what is unique about this study is the adjustment of diverse patient and hospital characteristics as well as the clustering effect of hospital. Prior work has not adjusted for as an extensive set of covariates or recognized that LOS and costs are dependent on the individual hospital setting. It is striking that the effect of malnutrition is more important than any covariate, excepting age and the number of diagnoses which are also strong drivers of hospital costs.

In addition, most work to date does not differentiate on the severity of malnutrition. Prior work has demonstrated that the moderately malnourished group is not readily identified in referral procedures in Canadian hospitals [28]. Current results indicate that moderately and severely malnourished patients have similar outcomes and, as such, all malnourished patients should be identified on admission so that appropriate nutritional care can be instituted as early as possible.

Sensitivity analyses determined that the independent effect of malnutrition on hospital costs derived from LOS holds while using a variety of costing information providing a notion of generalizability across studies with different costing data. Future studies should add to this study by focusing on counting patient level costs incurred by malnourished as compared to well-nourished patients during their hospital stay (e.g., added costs of nutritional supplements, nutritionist and other therapists visits, nutrition related pharmaceutical costs, etc.) rather than using aggregate costs per bed day.

Finally, analyzing medical and surgical patients separately provided the opportunity to identify differences among the two groups of patients. The association between malnutrition and LOS/costs waned for surgical patients, especially the severely malnourished. However, it should be noted that sample size was small and, in some cases, patients were transferred between units. There were 14 patients who transferred between ICU and medical beds, 8 patients who transferred between ICU and surgical beds, 14 patients who transferred between ICU and both medical and surgical beds, and 19 patients who transferred between medical and surgical beds. While this study is the first, that we are aware of, to point out the differences between medical and surgical stays, the small sample of surgical patients and the extremely small samples of transfer patients (disallowing further sub-population analyses), make it difficult to draw any strong conclusions regarding differences across patients that inhabit specific types of hospital beds. Future research with larger sample sizes would be necessary to ascertain whether the conclusions are generalizable.

Although this work overcame many of the weaknesses seen in prior research, there are some limitations in additions to those already discussed. As is typical in any cohort study, there were some missing data on covariates, which reduced the sample in analyses to 958 from the original participant pool of 1022. Multicollinearity may also be an issue, particularly for surgical bed days, given the marginal effects and R^2 are similar to the other regressions but standard errors are substantially larger. We did not test for potential interactions among variables used to adjust the association between malnutrition and LOS/costs as this would have increased the effects of multicolinearity.

In conclusion, moderate and severe malnutrition are individually and independently associated with LOS and costs in Canadian hospitals. The results were particularly strong for patients who spent at least one night in a medical bed. The results indicate that approximately 40% of patients were malnourished at admission and they cost between $1500 and $2000 more per hospital stay than a well-nourished patient. Hospital discharge data that come from CIHI [29] indicate that approximately 2.6 million adults were discharged from Canadian hospitals in 2012/2013. A very rough 'back of the envelope' analysis using these figures indicates the total additional cost to the health care system that may be attributed to malnutrition at hospital admission is substantial at approximately $1.56 to $2.1 billion per year. This figure may only be a starting point as hospital costs may poorly capture the total economic impact of malnutrition. The repercussion of malnutrition on a patient's ability to return to work or to require additional outpatient care was not addressed. Future work needs to determine if improved care practices, as suggested in the Integrated Nutrition Pathway for Acute Care [30] can divert any additional costs and improve patient outcomes.

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Conflict of interest

Dr. Curtis reports no conflicts of interest for this study.

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LC designed the methodology, amalgamated and cleaned the data, carried out the analyses, and was the primary writer of the original and revised papers. HK worked in close collaboration with LC during analysis and writing. KJ and PB provided conceptualization of the analysis during early stages and reviewed a draft of the paper. JA, DD, LG, ML coordinated data collection at their sites, provided guidance to other sites for data collection, provided some guidance on direction of the paper and reviewed a draft of the paper.

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