

A digital dietary assessment tool may help identify malnutrition and nutritional deficiencies in hospitalized patients

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Abstract

Malnutrition is common among hospitalized patients and associated with longer hospital stays, higher rates of rehospitalization, and increased mortality. Validated questionnaires of varying sensitivity and specificity to help identify patients at risk of malnutrition have been developed, but none has been broadly adopted. Tools to identify patients at risk for malnutrition should be quick, inexpensive, easy to administer and use, not require specialized nutrition knowledge, and provide results which can be entered into an electronic medical record; ideally, the tool should be deployed within 24 hours of admission and repeated if warranted. We hypothesize that a novel digital nutrition assessment tool which uses the Diet Quality Photo Navigation (DQPN) method, can help triage hospitalized patients toward further evaluation of nutritional status. We further propose that micronutrient deficiencies may be identified at the same time as malnutrition and that the reimbursement and cost savings from DQPN will prove substantially greater than the combined costs of its use and triggered dietitian consult. Deploying DQPN upon admission will represent an addition to standard hospital intake procedure that is frictionless for patients and health professionals, and one which may be overseen by clerical rather than clinical staff. The digital format of DQPN, which can be integrated into electronic medical records, will facilitate easier tracking and management of nutritional status over the course of hospitalization and post-discharge. To evaluate the hypotheses, DQPN will be deployed in a hospital setting to a group of patients who will also be seen by a registered dietitian to assess the nutritional status of each patient. Receiver operating characteristic curves will determine the point, or criterion, at which maximal true positivity rate and least false positivity rate for a diagnosis of malnutrition and specific nutrient deficiencies align. The study cohort will also be compared to a matched historical cohort to compare total medical spend and reimbursement between the intervention cohort and matched control. Testing of these hypotheses will thus allow for insight into whether DQPN may be used to identify malnutrition and nutrient deficiencies in

hospitalized patients and, in so doing, improve patient outcomes, reduce healthcare utilization, and bring financial benefit to hospitals.

Keywords

malnutrition; nutritional deficiency; hospital; Diet Quality Photo Navigation; health care costs; digital health

Overview and background

Malnutrition is common among hospitalized patients and associated with longer hospital stays, higher rates of rehospitalization, and increased mortality (Agency for Healthcare Research and Quality 2016b). Historically, between 10% to 60% of hospitalized patients were diagnosed with malnutrition (Elia et al. 2005); more recent estimates put the figure at 7 percent of total non-maternal and non-neonatal hospital stays (Agency for Healthcare Research and Quality 2016b). An additional one third of hospitalized patients are at risk (Sauer et al. 2019). Hospital stays for malnourished patients are up to twice as long (mean: 10.7 vs 4.9 days) and in-hospital mortality up to five times greater compared to patients who are not malnourished (Agency for Healthcare Research and Quality 2016b). Of malnourished patients who are discharged, more than 50 percent are readmitted within 30 days (Agency for Healthcare Research and Quality 2016a).

Despite the health burden, malnutrition remains undiagnosed in up to 70% of patients (Lean and Wiseman 2008), suggesting a total prevalence over 20% in hospitalized patients generally. The missed diagnosis may be in part due to the lack of simple, reliable, and seamless screening protocols, lack of diagnostic laboratory tests, and because biochemical tests for nutritional status are difficult to interpret in the setting of acute illness/inflammation (Lean and Wiseman 2008). Definitions of malnutrition and diagnostic codes used to record it vary (Agency for Healthcare Research and Quality 2016b). As a result, between 70 to 80% of malnourished patients enter and leave the hospital without action being taken to address the malnutrition, and without the diagnosis appearing on a discharge summary (Lean and Wiseman 2008).

Malnutrition is typically defined as any nutrition imbalance that affects both overweight and underweight patients and appears as either “undernutrition” or “overnutrition” (Tappenden et al. 2013). Hospitalized patients, regardless of body mass index (BMI), often suffer from undernutrition because of the propensity for reduced food intake as a result of illness-induced poor appetite, gastrointestinal symptoms, reduced ability to chew or swallow, or nil per os (NPO) status for diagnostic and therapeutic procedures; they may have increased energy, protein, and micronutrient needs from inflammation, infection, or other catabolic conditions (Tappenden et al. 2013). Among outpatients, poverty and food insecurity may play a role too. Malnutrition affects the function and recovery of every organ system and is thus both a cause and consequence of illness, especially in older patients (Lean and Wiseman 2008).

All told, malnutrition accounts for nearly 12% of aggregate hospital costs (Agency for Healthcare Research and Quality 2016b). In a fee-for-service health care delivery model, it is a reimbursable diagnosis, coded as either a complication or comorbidity (CC) or major complication or comorbidity (MCC) which increase the relative weighting factor for diagnosis related groups (DRGs) (Doley and Phillips 2019). Identifying and addressing malnutrition also supports providers and health systems working within value-based care contracts (Arensberg et al. 2020). Nutrition interventions that address malnutrition may reduce the length of hospital stay, cost of care, and mortality (Beck et al. 2013, Milne et al. 2009, Somanchi et al. 2011).

Clinicians should be thus able to identify patients with, or at risk for, malnutrition in the hospital - upon admission, during the hospital stay, and at discharge. Tools to identify patients at risk for malnutrition should be quick, inexpensive, easy to administer and use, not require specialized nutrition knowledge, and provide results which can be entered into an electronic medical record (EMR); ideally the tool should be deployed within 24 hours of admission and repeated at intervals as warranted (Tappenden et al. 2013). Seamless integration into prevailing clinical workflows is a requirement that should be met. Validated questionnaires of varying sensitivity and specificity (in the range of 60 to 90%) to help identify patients at risk of malnutrition have been developed (Tappenden et al. 2013). These questionnaires include the Malnutrition Screening Tool (MST) (Ferguson et al. 1999), Mini Nutritional Assessment Short Form (MNA-SF) (Nestle Nutrition Institute 2021), Malnutrition Universal Screening Tool (MUST) (British Association for Parenteral and Enteral Nutrition 2011), Nutritional Risk Screening 2002 (NRS-2002) (Kondrup et al. 2003), and Short Nutritional Assessment Questionnaire (SNAQ) (Kruizenga et al. 2005). Recent reviews have concluded that these tools are generally similar (Neelemaat et al. 2011) and that none have high validity, high reliability, and strong supportive evidence; in addition, there is limited data available to evaluate costs of the screening process (Skipper et al. 2020). Importantly, the tools also do not allow for identification of nutritional disorders other than malnutrition including, for instance, poor diet quality or nutrient deficiencies, which may compromise health and healing (Morze et al. 2020, Abioye et al. 2021).

Objectives

We put forth a set of related hypotheses:

(1) We hypothesize that a novel digital nutrition assessment tool, Diet ID (www.dietid.com), which uses the Diet Quality Photo Navigation (DQPN) method (Fig. 1) (Katz et al. 2020), can help triage hospitalized patients toward further evaluation of nutritional status. In support of this hypothesis, DQPN estimates both energy and protein intake, and low measures of these are associated with higher risk for malnutrition (Fig. 2) (Hengeveld et al. 2019, Fanelli Kuczmarski et al. 2019). In addition, we have seen in initial analyses that with DQPN, of those participants who were underweight (body mass index less than 18.5 kg/m²), nine out of ten participants had protein intake less than recommended (0.8 g protein per kg body weight) with a range of 36 to 77% of recommended. This suggests

that DQPN, with its dietary pattern recognition approach coupled with self-reported height and weight, may be well suited to identify malnutrition.

(2) As a secondary hypothesis, we propose that micronutrient deficiencies may be identified at the same time as other forms of malnutrition and that this more complete picture of nutritional status will allow for a range of dietary interventions (Fig. 3). We have seen in initial analyses that with DQPN, of those participants who were underweight (body mass index less than 18.5 kg/m²), nine out of ten had zinc, calcium, or iron intake less than the daily value recommendation (11 mg for zinc, 1300 mg for calcium, and 18 mg for iron). This suggests that DQPN may be well suited to identify nutritional deficiencies.

(3) As a tertiary hypothesis, we propose that the reimbursement (in this case, money paid by the government, acting as insurer, to the hospital for services provided to a beneficiary) and cost savings from DQPN will prove substantially greater than the combined costs of its use and triggered dietitian consult. In support of this hypothesis, we estimate that the cost of DQPN (as little as \$1 per assessment) and dietitian evaluation (varies by state, payer, and institution but would be expected to be less than \$40 per patient encounter as that is Medicare reimbursement rate for medical nutrition therapy) (Academy of Nutrition and Dietetics. 2020) would be less than the several thousand dollars per patient for reimbursement (Funk and Ayton 1995).

Impact

Deploying DQPN upon admission will represent an addition to standard hospital intake procedure that may be frictionless for patient and health professional alike, and one which may be overseen by clerical rather than clinical staff. This is, in itself, a new way of thinking about the role of the hospital intake in collecting health-related information relevant to the admission. The digital format of DQPN, which can be integrated into electronic medical records (EMRs), will facilitate easier tracking and management of nutritional status over the course of hospitalization and post-discharge. This represents a new way of thinking about the role of the EMR, the type of data that should be stored in it, and the importance of nutrition in relation to health. Including a nutrition assessment tool, such as DQPN, as part of hospital admission reflects its evolution from use in the outpatient setting - where it may replace food frequency questionnaires, 24-hour recalls, and food records - to the inpatient one. As such, by deploying DQPN in a hospital setting, we are looking to impact not only patient care but also to transform elements of the health care delivery system.

Implementation

Diet ID technology

Diet ID, powered by DQPN, presents fully formed composite images of established dietary patterns and invites participants, or patients, to select the image most like their own current pattern of intake. The process is repeated until “best possible fit” is achieved. Pattern recognition is the basis for the DQPN method which is described in detail elsewhere (Katz et al. 2020). Diet ID includes the following mainstream dietary patterns: Standard American, Low-fat, Mediterranean, Pescatarian, Flexitarian, Low-carb (low carbohydrate), DASH (Dietary Approaches to Stop Hypertension), AHA (American Heart Association) Heart Healthy, TLC (Therapeutic Lifestyle Changes), MIND (Mediterranean-DASH Intervention for Neurodegenerative Delay), Vegetarian, Vegan, Paleo, and Southern, as well as a growing list of ethnic diets (e.g., Latin, South Asian, etc.). Diet quality is stratified among all diet types and is represented visually as well as quantitatively. Diet quality is objectively measured using the Healthy Eating Index (HEI) 2015, the most robustly researched and validated tool for measuring diet quality that correlates strongly with disease risk and projected healthcare costs (Kirkpatrick et al. 2018, Krebs-Smith et al. 2018, Scrafford et al. 2018, Reedy et al. 2018). A unique nutrient profile for each patient, including estimated energy intake (using the Mifflin-St Jeor equation) is also generated from additional collected data (gender, age, height, weight, activity level, recent weight history).

Preliminary testing

In preliminary testing (Katz et al. 2020), the correlation of diet quality, using the HEI-2010, for Diet ID versus a food frequency questionnaire (FFQ) was statistically significant (Spearman correlation: $r = 0.31$, $p = 0.034$; Pearson correlation: $r = 0.50$, $p = 0.0004$). The correlation of diet quality using the Alternate Healthy Eating Index 2010 (AHEI-2010) was also highly significant versus the FFQ (Spearman correlation: $r = 0.54$, $p = 0.0001$; Pearson correlation $r = 0.52$, $p = 0.0004$). The Pearson correlations pertain to the actual HEI-2010 or AHEI-2010 numerical values while the Spearman correlations pertain to the HEI or AHEI quintile assignments, according to externally validated quintiles. The usual completion time required for Diet ID was approximately one to two minutes.

Evaluation of the hypothesis

To evaluate our hypothesis that Diet ID can screen for malnutrition and nutrient deficiencies in hospitalized patients, we will deploy the Diet ID technology in a hospital setting.

Triaging patients

Screening is by definition a test that look for disease before symptoms appear (U.S. National Library of Medicine: Medline Plus 2021). As malnutrition may contribute to the disease and attendant symptoms that bring a patient to the hospital, a tool to identify malnutrition upon admission may not be considered a *screening* tool per se. Instead, it may be considered a triage tool to help direct patients toward further evaluation. We propose to deploy Diet ID to 100 consecutive beneficiaries of Medicare who are admitted to a hospital general medical ward. The focus on Medicare beneficiaries allows for

Medicare reimbursement rates to be included in cost analyses and for the estimation of potential financial benefit to Medicare. Patients will be identified by the intake coordinator. Any patient whose sight is limited, who is unable to hold the tablet on which the screening tool is administered, who cannot read English, who is not taking food by mouth, or whose medical condition otherwise precludes them from taking the time to complete the screening will be excluded. Prior to initiation of the proposed study, protocol review by the hospital's Institutional Review Board will be requested.

Deploying DQPN upon admission will represent an addition to standard hospital intake procedure that is frictionless for patient and health professional alike, and one which may be overseen by clerical rather than clinical staff. Information gathered during intake for admissions may include one's name, address, telephone number, primary and secondary contact information, insurance and pharmacy information, contact information for one's primary care physician (Johns Hopkins Medicine 2021, Mayo Clinic 2020); intake at the emergency department includes reason for the visit (St. Luke's Health. 2021).

Diagnosis

All 100 patients will be seen by a registered dietitian who will assess the nutritional status of the patient. Malnutrition is commonly diagnosed using either the American Society for Parenteral and Enteral Nutrition (ASPEN) (White et al. 2012) or Global Leadership Initiative on Malnutrition (GLIM) (Jensen et al. 2019) criteria, while nutrient deficiencies may be by clinical exam and laboratory testing. Diagnosis by ASPEN criteria requires that two of the following six criteria be present: insufficient energy intake; weight loss; loss of muscle mass; loss of subcutaneous fat; localized or generalized fluid accumulation that may sometimes mask weight loss; diminished functional status as measured by hand-grip strength (White et al. 2012). Diagnosis by GLIM criteria requires the presence of at least one phenotypic criteria (non-volitional weight loss; low body mass index; reduced muscle mass) and one etiologic criteria (reduced food intake or assimilation; disease burden/inflammatory condition) (Jensen et al. 2019). There is no standard diagnostic criteria used across healthcare systems.

Statistical approach

To evaluate our primary and secondary hypotheses, we will undertake the following steps. From Diet ID and the formal evaluation, receiver operating characteristic (ROC) curves will be generated to determine the point, or criterion, at which maximal true positivity rate and least false positivity rate for a diagnosis of malnutrition and specific micronutrient deficiencies align, including iron, zinc, thiamine, vitamin B12 and vitamin C. These points may be constructed using single outcome measures of interest from Diet ID, such as estimated energy intake, protein intake, or diet quality, or a combination. We expect that a combination 'trigger' of data can be identified that will have a sensitivity of 80% or higher and a specificity of 70% or higher. Separate ROC curves may be generated for prediction of micronutrient deficiencies. The following performance measures will also be assessed after determining the positivity criterion, as they depend

on the selected criterion: sensitivity, specificity, positive predictive value, negative predictive, and false negative rate.

The sensitivity determination will be impacted by fact that there is no gold standard for a malnutrition diagnosis – health systems may independently choose to adopt ASPEN or GLIM criteria or a different criterion. The sample of consecutive patients chosen will impact sensitivity determinations; other sample populations may lead to different values and thus repeat assessments will be needed in other populations. A test with low reliability will generally not be very sensitive or specific (Rothman and Greenland 1998).

To evaluate our third hypothesis, our study cohort will be compared to a matched historical cohort, similarly defined at the same institution, to determine the prevalence of diagnosed malnutrition in the historical control group. We anticipate that while malnutrition will be at a comparable prevalence in the matched controls, it will have gone completely overlooked. We will then compare total medical spend, and reimbursement between the intervention cohort and matched control using parametric or non-parametric tests as appropriate.

Discussion

In September of 2020, the American Heart Association issued a statement noting that It is “critical that diet quality be assessed and discussed at the point of care with clinicians and other members of the healthcare team to reduce the incidence and improve the management of diet-related chronic disease” (Vadiveloo et al. 2020). Their statement builds upon the evidence supporting the critical role of diet in the prevention and treatment of disease (Vadiveloo et al. 2020). The importance of assessing and discussing diet at the point of care with hospitalized patients and tracking assessment results in electronic health records (EHRs) is particularly important given that malnutrition in hospitalized patients is associated with impaired recovery, extended length of stay, and increased likelihood of early readmission (Agency for Healthcare Research and Quality 2016b). Malnutrition has also become a common, but overlooked, financial liability, adding costs to the health care system along with a missed opportunity for reimbursement based on reliable capture of a relevant complicating diagnosis.

Since 1995, the Joint Commission has mandated universal screening and assessment of hospitalized patients for malnutrition (Patel V et al. 2014). Although recent survey data demonstrate broad compliance with completing a nutrition screen, and most hospitals appear to have a process to perform a nutrition assessment once a screen is completed, opportunities exist to identify ideal practices for these processes in hospitalized patients (Patel V et al. 2014).

Current questionnaires deployed to identify malnutrition have failed to enter ‘standard of practice’ for reasons perhaps related to their performance, or more likely, challenges with integration into established workflow. A highly efficient, digital assessment amenable to patient use overseen by clerical rather than clinical staff, and integrated into an EHR,

offers promise to overcome such impediments. Simple cohort studies can establish the clinical and economic benefits of such a system, while providing pilot data to make the case for randomized intervention trials. The goal of this line of inquiry would be to show that routine assessment and reliable identification of malnutrition, as well as possibly nutrient deficiencies, among hospitalized patients benefits both patients and healthcare systems.

Limitations

DQPN has been designed to reflect the general composition, objective quality, and approximate nutrient levels of a given diet, not to match exactly at the level of every food and nutrient (Katz et al. 2020). Moreover, the tool is limited to the dietary patterns in its library and thus may not reflect the dietary habits of all patients: the initial map for the U.S., for example, includes all of the most prevalent diets but does not include particular rare, fad, or fringe diets (Katz et al. 2020). Consequently, it is possible that DQPN may not capture the dietary pattern, and thus not identify malnutrition or nutrient deficiencies, of a hospitalized patient who is consuming a rare, fad, or fringe diet. These instances are expected to occur infrequently; additionally, more dietary patterns are constantly being added to the Diet ID library, including for instance, the ketogenic diet.

It is possible that hospitalized patients may not have the interest, patience, motivation, or ability to use the DQPN tool as a result of their acute condition. As the tool is to be deployed at the same time as other admission paperwork, this too is expected to occur infrequently, and hospital staff will determine appropriateness of deploying the tool given each individual patient's acuity. It is possible that patients may have questions or technological difficulties using DQPN; to date, this has occurred rarely and, importantly, when testing the hypothesis, the tool will be deployed in such a way as to not increase clinician time, burden, or workload.

Additionally, although malnutrition is a reimbursable diagnosis, coded as either a CC or MCC, with Medicare, it only takes one to shift the DRG to "with CC" or "with MCC" and therefore adding just one MCC will maximize reimbursement (Giannopoulos et al. 2013). Patients who enter the hospital with malnutrition may have other comorbidities and therefore not gain additional reimbursement from the malnutrition diagnosis. Our anticipation is that even if only a few patients merit additional reimbursement (that is, if malnutrition is the sole comorbidity), the low cost of identifying it across the patient population will prove the intervention cost-effective.

Conclusion

We have previously put forth evidence for pattern recognition through DQPN as an entirely new way to assess diet (Katz et al. 2020). Here, we present additional arguments that DQPN may be used to identify malnutrition and nutrient deficiencies in hospitalized patients and, in so doing, may improve patient outcomes, reduce healthcare utilization, and bring financial benefit to hospitals.

Ethics and security

Consent statement/Ethical approval: Not required.

Author contributions

AMB drafted the initial version of this manuscript and edited subsequent versions. DLA and LQR participated directly in the development of the Diet ID platform and reviewing/editing drafts of the manuscript. RSM is a board member of Diet ID and reviewed/edited drafts of this manuscript. DLK invented diet quality photo navigation and reviewed/edited drafts of this manuscript.

Conflicts of interest

AMB, LQR, DLA, and DLK are employees of Diet ID and own options or stock in the company. RM owns stock in Diet ID.

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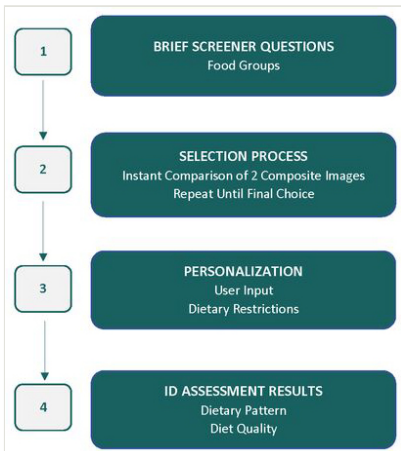


Figure 1.
Diet ID user experience via laptop, tablet, or mobile phone.

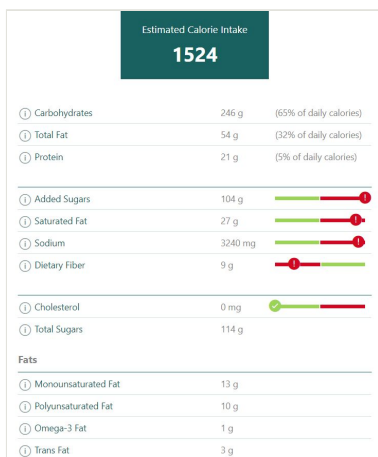


Figure 2.

Results illustrating a select macronutrient profile which may be within or out of range for a sample patient with the following characteristics: *70 years old, male, height 5 foot 6 inches, weight 125 pounds, minimal physical activity, losing weight, following restrictive diet.*



Figure 3.

Results illustrating a select micronutrient profile which may be within or out of range for a sample patient with the following characteristics: *70 years old, male, height 5 foot 6 inches, weight 125 pounds, minimal physical activity, losing weight, following restrictive diet.*