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PREFACE

The VA Evidence Synthesis Program (ESP) was established in 2007 to conduct timely, rigorous, and independent systematic reviews to support VA clinicians, program leadership, and policymakers improve the health of Veterans. ESP reviews have been used to develop evidence-informed clinical policies, practice guidelines, and performance measures; to guide implementation of programs and services that improve Veterans' health and wellbeing; and to set the direction of research to close important evidence gaps. Four ESP Centers are located across the US. Centers are led by recognized experts in evidence synthesis, often with roles as practicing VA clinicians. The Coordinating Center, located in Portland, Oregon, manages program operations, ensures methodological consistency and quality of products, engages with stakeholders, and addresses urgent evidence synthesis needs.

Nominations of review topics are solicited several times each year and submitted via the ESP website. Topics are selected based on the availability of relevant evidence and the likelihood that a review on the topic would be feasible and have broad utility across the VA system. If selected, topics are refined with input from Operational Partners (below), ESP staff, and additional subject matter experts. Draft ESP reviews undergo external peer review to ensure they are methodologically sound, unbiased, and include all important evidence on the topic. Peer reviewers must disclose any relevant financial or non-financial conflicts of interest. In seeking broad expertise and perspectives during review development, conflicting viewpoints are common and often result in productive scientific discourse that improves the relevance and rigor of the review. The ESP works to balance divergent views and to manage or mitigate potential conflicts of interest.

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Operational Partners

Operational partners are system-level stakeholders who help ensure relevance of the review topic to the VA, contribute to the development of and approve final project scope and timeframe for completion, provide feedback on the draft report, and provide consultation on strategies for dissemination of the report to the field and relevant groups.

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Technical Expert Panel

To ensure robust, scientifically relevant work, the technical expert panel (TEP) guides topic refinement; provides input on key questions and eligibility criteria, advising on substantive issues or possibly overlooked areas of research; assures VA relevance; and provides feedback on work in progress. TEP members included:

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The findings and conclusions in this document are those of the author(s) who are responsible for its contents and do not necessarily represent the views of the Department of Veterans Affairs or the United States government. Therefore, no statement in this article should be construed as an official position of the Department of Veterans Affairs. The final research questions, methodology, and/or conclusions may not necessarily represent the views of contributing operational and content experts. No investigators have affiliations or financial involvement (eg, employment, consultancies, honoraria, stock ownership or options, expert testimony, grants or patents received or pending, or royalties) that conflict with material presented in the report.

Main Report

Evidence Synthesis Program

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ABBREVIATIONS TABLE

Abbreviation	Definition
AND	Automated nutrition delivery
BCMA	Barcode medication administration
CDS	Clinical decision support
CMS	Centers for Medicare and Medicaid Services
CPOE	Computerized provider order entry
ISMP	Institute for Safe Medication Practices
MAR	Medication administration record
NICU	Neonatal intensive care unit
PICU	Pediatric intensive care unit
PN	Parenteral nutrition
TPN	Total parenteral nutrition

BACKGROUND

Optimal nutrient intake is crucial for patients' health during a hospital stay.[1,2] Yet hospital malnutrition is a common condition that often goes undiagnosed and untreated.[3] It is estimated that 40% of patients are malnourished during their hospitalization, which may lead to muscle loss, delayed wound healing, increased risk of infection, prolonged hospitalization, and mortality.[1,4]

The provision of optimal nutrition support during hospitalization is challenging due to variability in timing, delivery route, dose, and type of nutrients provided. Also, many patients at nutritional risk suffer from multiple comorbidities that need to be accounted for when implementing a nutrition support plan that maximizes patient safety. Patient experiences with hospital nutrition also influence overall perception of care and satisfaction during hospitalization.[1,4] Yet the provision of inpatient nutrition supports is not without risk. Several studies have documented common errors and safety events related to the provision of inpatient nutrition supports.[5,6] To address the delivery of optimal nutrition support, many health care organizations have adopted automation technology as a promising practice to improve patient safety and satisfaction with care, nutrition support accuracy, and delivery efficiency.[3,7,8]

Inpatient nutrition support includes screening and assessment, ordering appropriate nutrition supports, preparation of products, delivery and administration, monitoring, and termination of nutrition supports. The automation of nutrition delivery can target 1 or several of these steps, and conceivably, automated tools could be integrated into a comprehensive computerized system encompassing ordering through administration at the patient's bedside. Key examples of nutrition delivery innovations include computerized provider order entry (CPOE), clinical decision support (CDS), or barcode medication administration (BCMA) and electronic Medication Administration Record (eMAR).[9,10] CPOE refers to a variety of computer systems for ordering medications that ensure standardized, legible, and complete orders. A CDS system can vary in complexity but often includes suggestions or default values for nutrient doses, routes, and frequencies. Some CDS provides reminders for corollary orders (*eg*, glucose checks before nutrition intake) and clinical guidelines (*eg*, decision trees for amount of nutrient at time of ordering). More complex CDS can check for allergies, laboratory values, interactions, and contraindications.

The third example, BCMA and eMAR, employs patient-specific wristbands and barcodes to electronically ensure the "five rights of medication administration": the right medication, right dose, and right route at the right time for the right patient.[9,11] These eMAR barcode systems have the ability to automatically document the administration of medication into a patient's electronic health record. The US Food and Drug Administration (FDA) has mandated barcodes for thousands of medications and products.[12] While these barcodes are mandated only for products produced by drug suppliers, the FDA ruling has encouraged technological advancements like BCMA for other products like delivery of nutrition supports.[13]

While the main goals of automating nutrition delivery are to improve patient safety and maximize delivery efficiency and nutrition support accuracy, the shift to automated nutrition innovations may have unintended impacts on hospital staff. Specifically, introducing automation may alter or even hinder the routines of the health care staff. Consequently, staff may adapt their decision-making processes and activities to comply with new technology systems.[9,14] Although evidence indicates that automation technology can improve patient safety,[15-18] automation also has the potential to cause patient harm.[19-21] Favorable outcomes in nutrition support depend on several factors, including an

implementation process that facilities the integration of the innovation into existing workflows.[22,23] When hospital staff experience workflow conflicts between their standard duties and new innovation implementation tasks, staff may develop implicit or explicit procedures to reject the innovation (*eg*, develop workarounds).[9,10,24]

Using automation processes to deliver nutritional supports to hospitalized patients has the potential to address many aspects of the Quintuple Aim for health care improvement.[25] Recently, several national profession societies and institutions, such as the Institute for Safe Medication Practices,[26] have advocated for innovations to support the provision of nutritional products to hospitalized patients to reduce errors and maximize the safety and quality of care.[27-29] Yet it is unknown which forms of automation are optimal and to what degree automation optimizes key clinical and patient outcomes. Also, it is unknown how hospital staff implementing and delivering nutrition supports added by automation experience such innovations. To address these questions, we conducted a systematic review of quantitative and qualitative peer-reviewed literature evaluating the impact of automated nutrition delivery systems in the context of inpatient care. The VHA Nutritional Field Advisory Board requested this review to inform clinical guidance and implementation methods to optimize nutrition delivery to hospitalized Veterans.

METHODS

REGISTRATION AND REVIEW

A preregistered protocol for this review can be found on the PROSPERO international prospective register of systematic reviews (CRD42022347945). A draft version of this report was reviewed by external peer reviewers; their comments and author responses are located in the Appendix.

KEY QUESTIONS AND ELIGIBILITY CRITERIA

The following key questions (KQ) were the focus of this review:

KQ1: What are the effects of automating the delivery of oral, enteral, or parenteral nutrition supports to hospitalized patients on key process, performance, and patient outcomes?

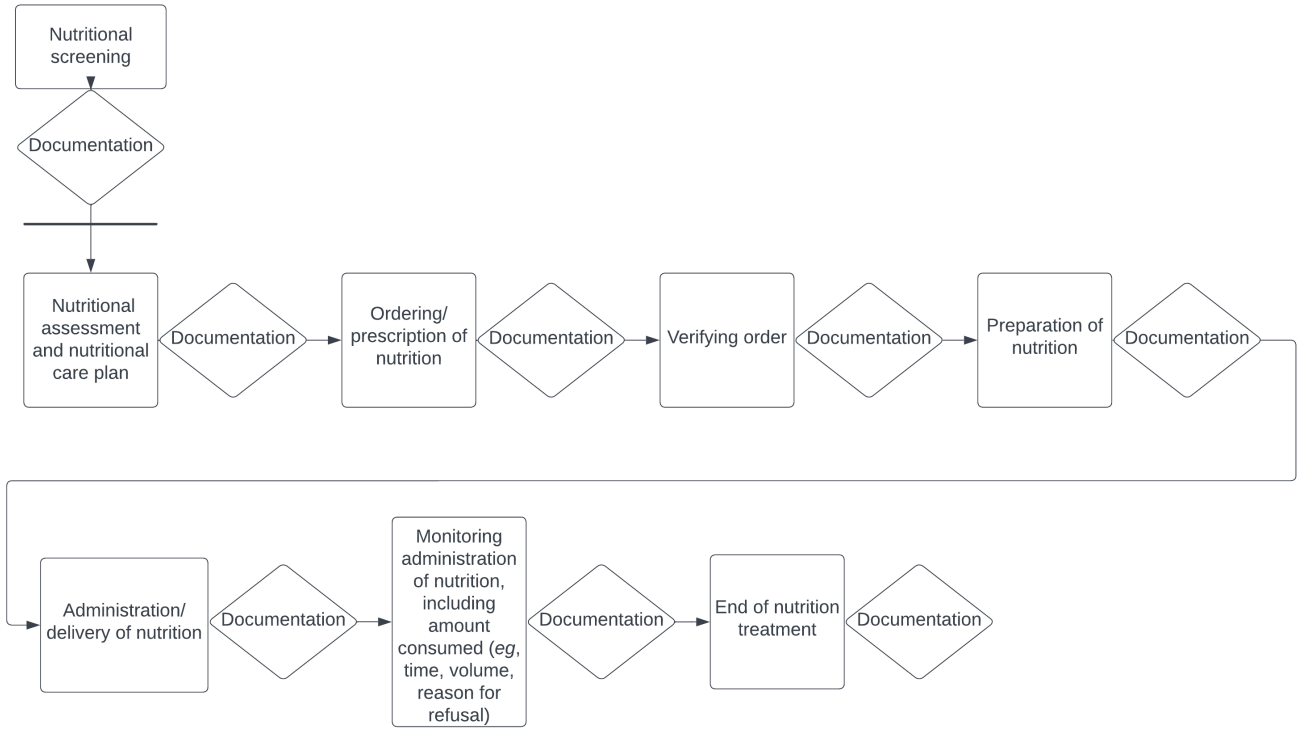
KQ2: How is automating the delivery of oral, enteral, or parenteral nutrition supports to hospitalized patients experienced by the staff involved in implementing and delivering this innovation?

For this report, nutritional supports can be delivered through any route: oral (by mouth), enteral (through an opening into the digestive system), or parenteral (through a vein). We define automation of nutrition delivery as a process or application of a technology to deliver hospital-based nutrition to patients that minimizes human intervention (*ie*, "humans" provide the thinking on the ordering side [inputs], and the delivery side [outputs] is automated to minimize touch points). Figure 1 provides a conceptual overview of the potential ways that the nutrition delivery process could be automated, including both automation of a delivery chain step and the potential for automation to trigger documentation that a step has been completed (*ie*, trigger for human to document step completion). We included studies that assessed automation at any point in the delivery chain, from nutritional assessment and ordering to bedside administration and eventual termination of nutrition supports.

To be included in this review, relevant studies needed to include at least 1 of the following aspects of automation:

- ***Trigger of documentation*** of any step starting at nutritional assessment through termination of supplementation;
- ***Ordering*** nutrition supports; or
- ***Delivery*** of nutrition supports.

Figure 1. Process Map of Hospital-Based Nutrition Delivery



Notes. This process map represents a general process of nutrition delivery in the hospital setting; it may not fully represent the process in every health care setting.

Due to the scope of the KQs in this review, we used different eligibility criteria for each KQ. As KQ1 was focused on effectiveness, we developed eligibility criteria using the PICOTS format (Table 1). The focus of KQ2 was on understanding qualitative experiences with automated nutrition delivery; therefore, we used the SPIDER criteria[30] to inform eligibility criteria (Table 2).

Table 1. KQ1 PICOTS Eligibility Criteria: Effectiveness of Automated Nutrition Delivery

Study Characteristic	Inclusion Criteria	Exclusion Criteria
Population	Hospitalized patients including long-term care, skilled nursing facility residents, and end-of-life patients who are at risk of malnutrition (*ie*, who have difficulty eating or absorbing nutrients through gastrointestinal tract).	• Simulated patients • People with eating disorders
Intervention	Automated nutrition delivery of oral, enteral, or parenteral nutrition supports that includes automated notifications to the hospital care team (*eg*, nurses and nursing assistants, physicians, pharmacists, food service, registered dietitians) that nutrition supports have been ordered or prescribed and requires responses that the care team has administered nutrition supports and/or how much the patient actually received (*eg*, electronic health record alerts, barcode scanning).	• Orders only (NPO) (*eg*, diet orders) • Standard orders without any specialization (*ie*, admissions orders) • Alert alone, without any other level of alerts or automation (*eg*, clearing of alerts, further documentation) • Automation of nutraceutical supplementations • Reminders only • Patient self-ordering of meals

Study Characteristic	Inclusion Criteria	Exclusion Criteria
Comparators	Any comparator (*eg*, usual care, active comparator, historical controls)	No comparator
Outcome	• *Process outcomes (ie,* supports delivered, supplement delivery errors) • *Performance outcomes (ie,* time required for supplement administration, provider satisfaction) • *Patient outcomes (ie, c*alories consumed, macronutrients consumed; body mass index and body weight; length of hospital stay; readmission rate; patient satisfaction) • *Patient-level harms* (*eg*, all-cause mortality, pressure injury, falls, organ damage, aspiration, refeeding syndrome)	Any outcomes not listed
Time[a]	Published after 2000	Published before 2000
Setting	• Hospital inpatient setting, including inpatient end of life care settings • Skilled nursing facilities or long-term care settings	• Specialty-specific settings for management of chronic medical conditions (*eg*, residential obesity care, residential eating disorder care) • Outpatient setting
Study design	• Randomized trials • Nonrandomized trials • Controlled before-after studies • Interrupted time-series studies or repeated measures studies • Prospective and retrospective observational studies (*ie*, cohort studies, case control studies) • Cross-sectional • Pre-post studies	• Descriptive studies with no outcomes data • Qualitative studies • Case reports and case studies with no outcome information • Studies that included only outcomes data from 1 point in time (post only, uncontrolled clinical study) • Modeling studies that used simulated data • Not a clinical study (*eg*, editorial, nonsystematic review, letter to the editor)
Countries	OECD[b]	Non-OECD
Publication types	Full publication in a peer-reviewed journal	Letters, editorials, reviews, dissertations, meeting abstracts, protocols without results

Notes. [a] Institute for Safe Medicine Practices (ICMP) established a guideline for standard order sets in 2010 and the Centers for Medicare and Medicaid Services (CMS) published its Conditions of Participation with its first section on standing orders in 2013.

[b] Organization for Economic Cooperation and Development (OECD) in 2022 includes Australia, Austria, Belgium, Canada, Chile, Colombia, Costa Rica, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Israel, Italy, Japan, Korea, Latvia, Lithuania, Luxembourg, Mexico, Netherlands, New Zealand, Norway, Poland, Portugal, Slovak Republic, Slovenia, Spain, Sweden, Switzerland, Turkey, United Kingdom, and United States.

Abbreviations. PICOTS=population, intervention, comparator, outcomes, timing, setting/study design.

Table 2. KQ2 SPIDER Criteria: Experiences with Automated Nutrition Delivery

Study Characteristic	Inclusion Criteria	Exclusion Criteria
Sample	Hospital staff involved in automating the delivery of oral, enteral, or parenteral nutrition supports to patients (*eg*, nurses and nursing assistants, pharmacists, food service, registered dietitians)	• Other members of staff not involved in the phenomena of interest • Patients • Patient informal caregivers
Phenomenon of interest	Experiences of staff using automated nutrition delivery of oral, enteral, or parenteral nutrition supports that include automated notifications to the hospital care team (*eg*, nurses and nursing assistants, physicians, pharmacists, food service, registered dietitians) that nutrition supports have been ordered/prescribed and requires responses that the care team has administered nutrition supports and/or how much the patient actually received (*eg*, electronic health record alerts, barcode scanning)	• Orders only (NPO) (*eg*, diet orders) • Standard orders without any specialization (*ie*, admissions orders) • Alert alone, without any other level of alerts or automation (*eg*, clearing of alerts, further documentation) • Automation of nutraceutical supplementations • Reminders only • Patient self-ordering of meals
Design	• Studies using qualitative methods for data collection and analysis	Quantitative only designs
Evaluation	*Primary purpose* was to explore the experiences and attitudes of hospital staff (*eg*, nursing, pharmacy, food service, dietetics) who interact with some aspect of implementing and delivering the automated delivery of nutrition	Evaluations of patients' or their informal caregivers' experiences with the automated delivery of nutrition
Research type	• Qualitative studies (*eg*, qualitative interviews, focus groups, observations, surveys with open-ended textual data, organizational case studies) • Ethnographies • Mixed methods studies that report qualitative data	• Quantitative studies with no qualitative component • Single case study or case reports of a single patient (*ie*, case study of 1 patient)
Countries	OECD[a]	Non-OECD
Time[b]	Published after 2000	Published before 2000

Notes. [a] Organization for Economic Cooperation and Development (OECD) in 2022 includes Australia, Austria, Belgium, Canada, Chile, Colombia, Costa Rica, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Israel, Italy, Japan, Korea, Latvia, Lithuania, Luxembourg, Mexico, Netherlands, New Zealand, Norway, Poland, Portugal, Slovak Republic, Slovenia, Spain, Sweden, Switzerland, Turkey, United Kingdom, and United States.

[b] Institute for Safe Medicine Practices (ICMP) established a guideline for standard order sets in 2010 and the Centers for Medicare and Medicaid Services (CMS) published its Conditions of Participation with its first section on standing orders in 2013.

Abbreviations. NPO=*nil per os* (*ie,* nothing by mouth).

SEARCHING AND SCREENING

To identify articles relevant to the key questions, an expert medical librarian conducted a primary search of MEDLINE (via Ovid), Embase (via Elsevier), and CINAHL from inception to January 16, 2022. We searched databases using a combination of database-specific controlled vocabulary terms and keywords in the titles and abstracts related to nutrition delivery. An experienced medical librarian devised and conducted the search with input on keywords from the other authors. The search strategies were peer reviewed by another librarian using a modified PRESS checklist.[31] See Appendix for complete search strategies. Titles, abstracts, and full-text articles were reviewed by 1 investigator and checked by another. All disagreements were resolved by consensus or discussion with a third reviewer.

As we did not identify any relevant qualitative studies for KQ2, the methods outlined below focus only on those used for KQ1.

DATA ABSTRACTION AND RISK OF BIAS ASSESSMENT

We abstracted data from published reports into a customized DistillerSR database. Data were abstracted by 1 reviewer and over-read by a second reviewer. We resolved disagreements by consensus or by obtaining a third reviewer's opinion. Data elements included descriptors to assess applicability, quality elements, intervention details, and outcomes, including adverse events.

Key characteristics abstracted included participant descriptors (*eg*, age, sex, race), study design, intervention characteristics (*eg*, nutrition delivery type, automation type), comparator, and outcomes. We treated multiple reports from a single study as a single data point, prioritizing results based on the most complete and appropriately analyzed data.

We used an adapted Cochrane ROBINS-I tool to assess risk of bias (ROB) for nonrandomized studies[32] that compare health effects of 2 or more interventions. The ROBINS-I includes domains for (1) confounding; (2) participant selection; (3) intervention classification; (4) deviations from intended interventions; (5) missing data; (6) outcome measurement; and (7) selective outcome reporting. Overall, ROB judgments included low ROB, serious ROB, critical ROB, and no information. For randomized trials, we adapted the Cochrane (RoB2) tool.[33] This tool includes the following domains: (1) bias arising from the randomization process; (2) bias due to deviations from intended interventions; (3) bias due to missing outcome data; (4) bias in measurement of the outcome; (5) bias in selection of the reported result and has overall ROB as low, some concerns, or high ROB. Lastly, we used NIH Cross-sectional Tool Risk of Bias for cross-sectional designs,[34] which includes 14 items that assess the risk of potential selection bias, information bias, measurement bias, or confounding. Studies were assigned an overall rating of good, fair, or poor ROB. All ROB assessment was completed independently by 2 investigators. Disagreements were resolved by consensus or by consulting a third investigator. (See Appendix for risk of bias ratings.)

SYNTHESIS

We summarized the primary literature using relevant data abstracted from the eligible studies and developed summary tables to describe key study characteristics of included studies (*eg*, study design, intervention details). We then determined the feasibility of completing a quantitative synthesis (*ie*, meta-analysis) to estimate summary effects. Feasibility of meta-analysis depended on the conceptual homogeneity of the studies based on study design (*eg*, randomized trials versus non-randomized EPOC studies), intervention (*ie*, type of automation), outcome features (*eg*, outcomes measuring the same

underlying concept at a similar timepoint), and completeness of results reporting. Further, we aggregated outcomes when there were at least 3 studies with the same outcome, based on the rationale that 2 studies do not provide adequate evidence for summary effects.

When quantitative synthesis was possible, we used random-effects meta-analysis models to pool available outcome data. Continuous outcomes were synthesized as mean differences when all studies used the same outcome measure and as standardized mean differences (Hedges' *g*) when different measures of the same construct were reported. Dichotomous outcomes were pooled using odds ratios. When studies with dichotomous outcomes reported zero outcome events, we utilized hypergeometric-normal models to avoid the need for continuity corrections (a continuity correction of 0.5 was added to all counts of studies with zero cells only when generating study-level odds ratios in forest plots). For analyses with fewer than 20 studies, we used the Knapp-Hartung approach to adjust standard errors of the estimated coefficients. We evaluated statistical heterogeneity using visual inspection of forest plots and 95% prediction intervals. Meta-analyses were conducted using the *metafor* package for R (R Foundation for Statistical Computing, Vienna, Austria).[35]

When a quantitative synthesis was not feasible, we narratively analyzed data. We emphasized evidence from higher quality studies with more precise estimates of effect. The narrative synthesis focused on documenting and identifying patterns in efficacy and safety of interventions across conditions and outcome categories. We interrogated potential reasons for inconsistency in treatment effects across studies by comparing differences in study population, intervention, comparator, and outcome definitions.

Strength of Evidence

We assessed the certainty of evidence (COE) for KQ1 using the Grading of Recommendations Assessment, Development and Evaluation (GRADE) working group process.[36] We limited GRADE ratings to those outcomes identified by the VHA stakeholders and technical expert panel as critical to decision-making (*ie*, provider satisfaction, nutrition supports delivered, errors). In brief, the GRADE approach requires assessment of 4 domains:

- Risk of bias (*eg,* Are there major limitations in included study designs for this outcome?)
- Consistency of effects (*eg*, Do point estimates vary widely across studies on this outcome?)
- Directness (*eg,* Are we confident the evidence directly compares interventions of most interest to key stakeholders? Are these interventions assessed in populations of interest to key stakeholders?)
- Precision (*eg,* For this outcome, are there relatively few patients? Are the 95% confidence intervals wide?)

Additional domains used were coherence, dose-response association, impact of plausible residual confounders, strength of association (magnitude of effect), and publication bias, as appropriate. These domains were considered qualitatively; we assigned a summary COE rating after discussion by 2 investigators (AMG, JMG). In keeping with GRADE guidelines, we also provided separate COE ratings for randomized studies and observational studies.

PRIMARY QUALITATIVE INQUIRY METHODS

A key need for VA operational partners was better understanding the experiences and perceptions of staff who had implemented some type of automation of nutrition delivery. As we anticipated that there may be a low yield for KQ2 (qualitative evidence synthesis), we designed and conducted a primary qualitative study to explore staff perspectives on, and experiences with, automated nutrition delivery innovations within the VHA.

The Durham VA institutional review board (IRB) reviewed and designated this study as quality improvement. A trained qualitative interviewer (AS) conducted semi-structured individual interviews with staff involved in the implementation. As mandated by the VHA, no potential key informants were approached about this study until we had obtained approvals from national VHA union representatives.

Research Question

The following research question was the focus of this primary qualitative inquiry: *How is automating the delivery of oral, enteral, or parenteral nutrition supports to hospitalized patients experienced by the staff involved in implementing and delivering it?*

Key Informant Participants

Eligible qualitative interview key informant participants included VHA-employed staff and leadership who had interacted with some form of automation of nutrition supports at a VHA hospital. We intentionally sought to include a diverse set of key informants as defined by their roles within the VHA (*eg*, food service delivery, nursing, pharmacy service). We recruited key informants via email after being identified by VHA operational partners as those who have direct experience with the innovation. We also used snowball recruitment: at the conclusion of each qualitative interview, we asked the key informant to help identify other potential VHA staff with relevant expertise in automating the delivery of nutritional supports in the VHA. Key informants were not compensated for their time.

Positionality

Our qualitative team represents diverse backgrounds in terms of age, educational attainment, and lived experience with VHA quality improvement projects. We acknowledge that our positionality can influence this project. As such we adhered to qualitative methodological standards that promote trustworthiness and credibility. These methods included practicing reflexivity, maintaining an audit trail of analytic decisions, employing standardizing procedures such as an intercoder reliability process, and incorporating member checking.

Qualitative Data Collection

We designed a semi-structured qualitative interview guide (Appendix) to elicit information about how automating the delivery of oral, enteral, or parenteral nutrition supports to hospitalized patients was experienced by the staff involved in implementing and delivering this innovation. For example, we asked about the key informant's role in automating nutrition delivery, how the innovation fit into their workflow, how it impacted resources, and what barriers and facilitators they experienced when implementing the intervention. Interviews were conducted by a trained qualitative interviewer (AS) using MS Teams videoconferencing software; they were audio recorded and auto-transcribed, and they lasted an average of 27.8 minutes (range: 12.9–47.13).

Qualitative Analysis

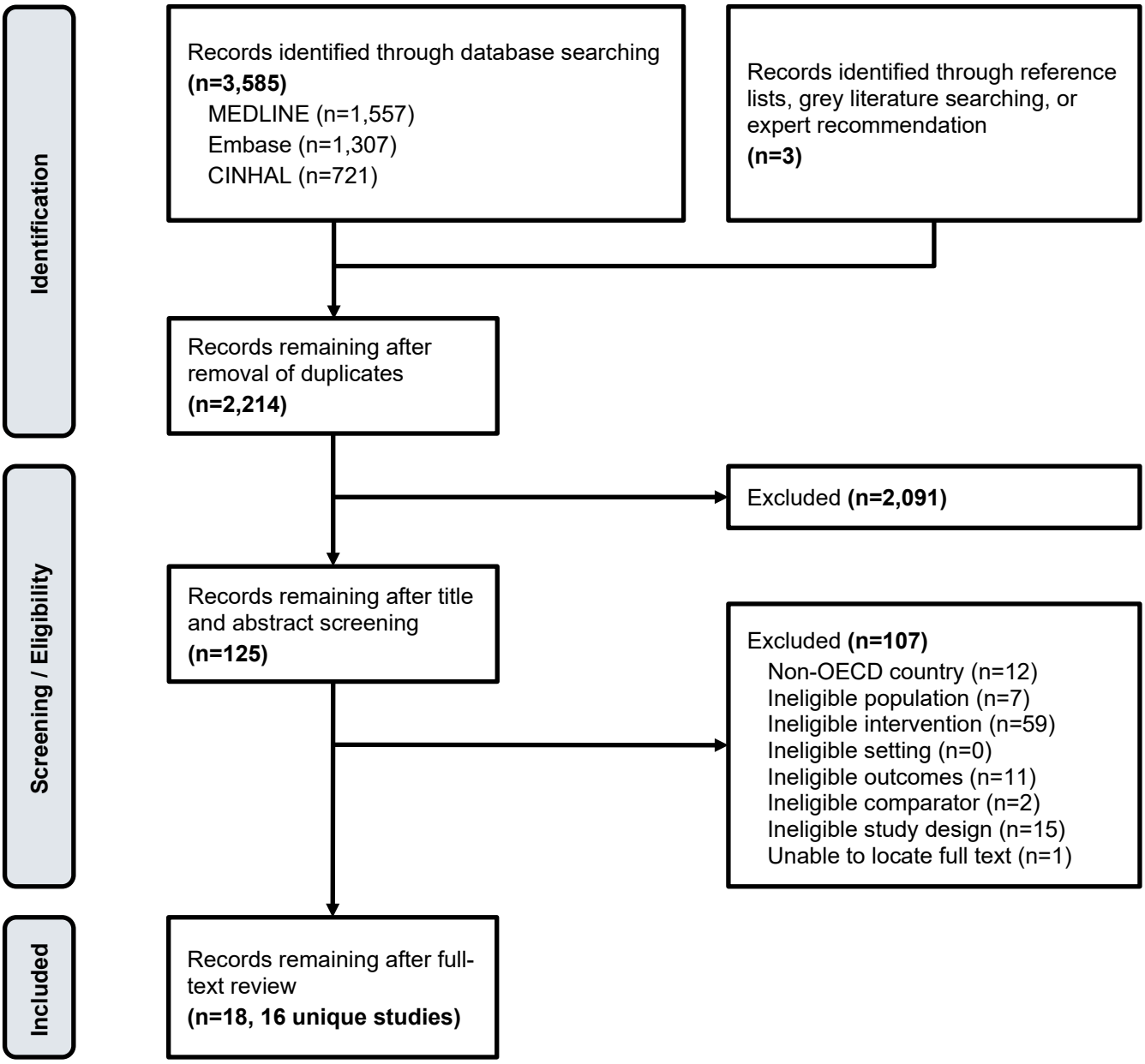
We analyzed interview data using rapid qualitative analysis methods common in health services quality improvement research.[37] Interview transcripts and structured interviewer notes were reviewed by the qualitative team (AS, JDS) and edited for clarity. We then summarized the notes into a matrix guided by the structure of the interview guide. Further analyses consisted of iterative dyad-level memo development and matrix analyses[38] to elucidate common and contrasting experiences and identify themes. Each team member reviewed a subset of the other's work and resolved coding disagreements through regular coder discussion and consensus.

RESULTS

LITERATURE FLOW DIAGRAM

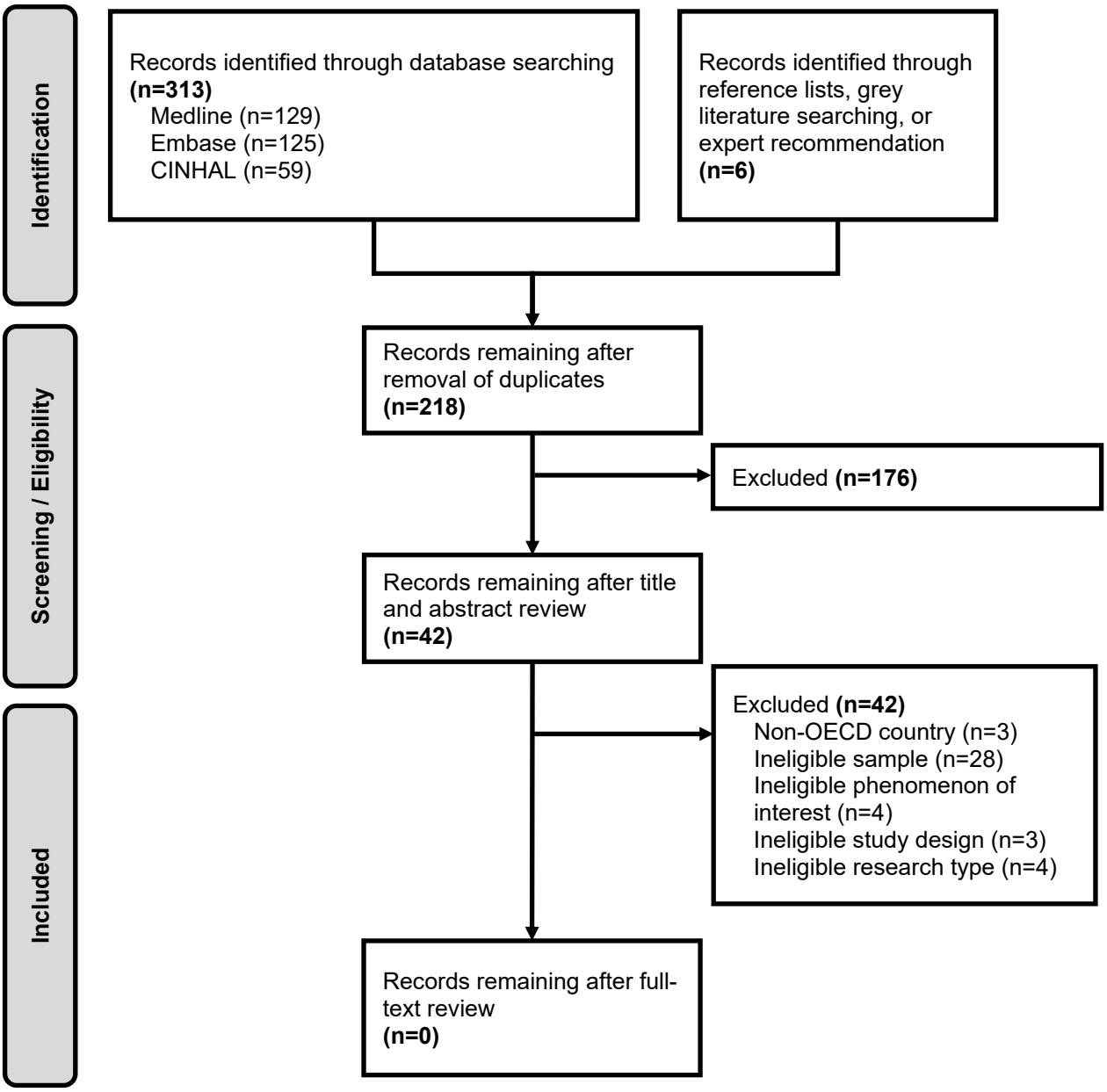
Figures 2 and 3 summarize the results of the study selection process for KQ1 and KQ2, respectively. A full list of excluded studies is provided in the Appendix.

Figure 2. Literature Flowchart for KQ1: Effectiveness of Automated Nutrition Delivery



Abbreviations. ECD=Organization for Economic Cooperation and Development.

Figure 3. Literature Flowchart for KQ2: Experiences with Automated Nutrition Delivery



Abbreviations. OECD=Organization for Economic Cooperation and Development.

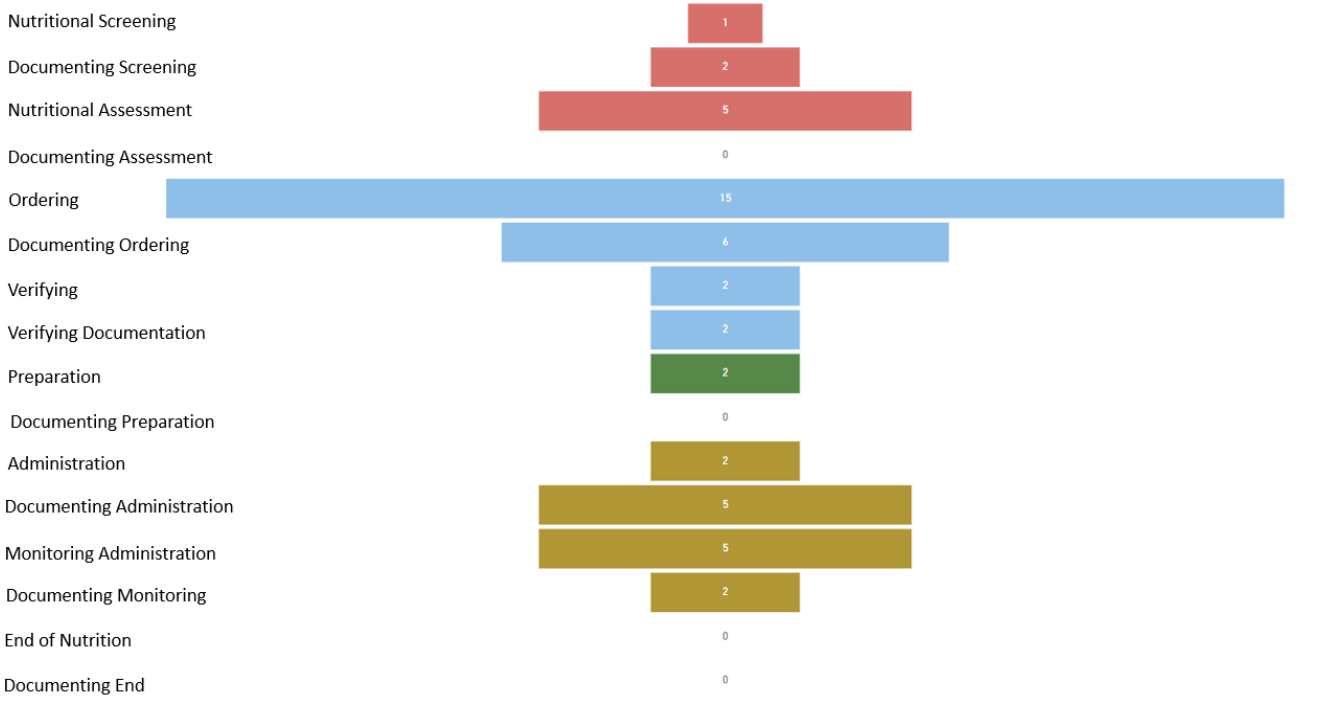
OVERVIEW OF INCLUDED STUDIES

KQ1

For the KQ1 search (effectiveness of automated nutrition delivery), we identified 3,585 studies through searches of MEDLINE (via Ovid), EMBASE, and CINAHL (via EBSCO) (Figure 2). An additional 3 articles were identified through manually searching and reviewing bibliographies of relevant review articles for a total of 3,588 articles. After removing duplicates, 2,214 articles remained for title and abstract screening. Of these abstracts, 125 articles flowed to full-text review. We then retained 18 studies for data abstraction, of which, 16 were identified as unique studies. They consisted of 1 RCT, 1 controlled before-after study, 11 uncontrolled before-after studies, and 3 cross-sectional studies.

Included KQ1 studies were conducted across North America and Europe (USA, Poland, Spain, and Greece). We identified no studies conducted in the VA; most studies were conducted with pediatric populations (Table 3). The majority of studies included some form of ordering automation (*ie*, CPOE; $N = 12$), many of which were combined with additional features such as decision support tools or automations in compounding nutrition supports (Figure 4). Only 5 studies involved interventions that automated some tasks associated with delivery of ordered products, including documenting that nutrition products had been delivered, and administered, to the patient.

Figure 4. Distribution of Automation Features in Interventions Across the Nutrition Delivery Process[a]



Notes. [a] Screening and nutritional assessment are grouped with red bars, ordering and verifying bars are in blue, preparation bar is in green, and administration and monitoring bars are grouped together with gold bars. Interventions could encompass multiple aspects of the delivery process.

One RCT study was rated as having some concern for risk of bias due to deviations form intended interventions.[39] Of the observational studies, 5 were rated as moderate ROB, 6 as serious, 1 as critical, and 1 as fair ROB. Sources of bias among the observation studies included bias due to confounding,

bias due to selection of participants, deviations of intended interventions, missing outcome data, and selection of reported results. Of the 3 cross-sectional studies, 2 were rated as poor and 1 as fair ROB. Common sources of bias in the cross-sectional studies included inadequate accounting for confounding variables, selection bias, and sample size justification. See Appendix for the ROB figures.

KQ2

For the KQ2 search (experiences with automated nutrition delivery), we identified 313 studies through searches of MEDLINE (via Ovid), EMBASE, and CINAHL (via EBSCO) (Figure 3). An additional 6 articles were identified through hand searching and reviewing bibliographies of relevant review articles for a total of 319 articles. After removing duplicates, 218 articles remained. After applying inclusion and exclusion criteria to titles and abstracts, 42 articles were screened at the full-text review stage. Of these, none were retained for data abstraction.

Table 3. Profile of Included Studies

Study Characteristic	Characteristic Category (Number of Relevant Studies)
Total Studies	• 16 studies (18 references)
Key Question	• KQ1 (*N* = 16) • KQ2 (*N* = 0)
Study Desings	• Randomized controlled trial (*N* = 1) • Controlled before-after (*N* = 1) • Uncontrolled before-after (*N* = 11) • Cross-sectional (*N* = 3)
Study Year Range	• 2005 to 2021
Population Focus	• Adults only (*N* = 5) • Children only (*N* = 10 • Not reported (*N* = *1)*
Enrollment Setting	• NICU (*N* = 7) • PICU (*N* = 1) • Pediatric cancer unit (*N* = 1) • Children's hospital (*N* = 2) • Multiple hospital units (*N* = 3) • Single hospital (*N* = 1) • Multiple hospitals (*N* = 1)
Study Location	• USA (*N* = 11) • Europe (*N* = 5)
Intervention Categories	• CPOE (*N* = 6) • CPOE + calculator (*N* = 3) • CPOE+ decision support (*N* = 1) • CPOE + compounding (*N* = 1) • CPOE +decision support+ compounding (*N* = 1) • MAR (*N* = 2) • Barcode scanner (*N* = 1) EMR alerts (*N* = 1)

Study Characteristic	Characteristic Category (Number of Relevant Studies)
Process Outcomes	• Nutrition supports delivered - not documented (*N* = 4) Nutrition supports delivered and documented (*N* = 2) Delivery errors (*N* = 2) • Ordering errors (*N* = 4)
Performance Outcomes	• Provider satisfaction (*N* = 2) • Time (*N* = 4)
Patient Outcomes	• Time to regain birth weight (*N* = 4) • Calories or nutrients consumed (*N* = 5) • Length of hospital stay (*N* = 3) • Hospital readmission (*N* = 2) • Temporary harms (*N* = 3) • Serious harms (*N* = 1) • Deaths (*N* = 2)
ROBINS I **Risk of Bias**	• Low (*N* = 0) • Moderate (*N* = 5) • Serious (*N* = 6) • Critical (*N* = 1)
NIH Cross-Sectional Tool **Risk of Bias**	• Good (*N* = 0) • Fair (*N* = 1) • Poor (*N* = 2)
ROB 2 **Risk of Bias**	• Low (*N* = 0) • Some concerns (*N* = 1) • High (*N* = 0)

Abbreviations. CPOE=computerized provider order entry; MAR=medication administration record; NICU=neonatal intensive care unit; PICU=pediatric intensive care unit.

KEY QUESTION 1: EFFECTIVENESS OF AUTOMATED NUTRITION DELIVERY

Process Outcomes

In total, 11 studies reported on process outcomes associated with the automation of delivering nutrition supports.[40-50] These studies reported on the following outcomes: nutrition supports delivered (N = 5)[40-44]; ordering errors (N = 4)[47-50]; and delivery errors (N = 2).[45,46] Consistent with the process map in Figure 1, we synthesized findings by steps in the delivery process, first summarizing interventions that did not include documentation and then summarizing interventions that included documentation.

Delivery of Nutrition Supports—Not Documented

Two uncontrolled, single-center before-after studies (1 serious ROB, 1 moderate ROB) examined the delivery of nutrition supports that did not include an automated documentation of receipt or amount provided or consumed.[40,41,43] The automated delivery systems for nutrition supports described in these 3 studies included an electronic medical record (EMR) alert for vitamin D testing and supplementation,[40] CPOE with a clinical decision support tool and feeding order set for initiating enteral nutrition upon admission to the pediatric intensive care unit,[41] and CPOE without a clinical decision support tool for parenteral nutrition.[43] Two of the studies were conducted in the United States,[40,41] and 1 was conducted in Spain.[43]

Automating the delivery of nutrition supports resulted in increased delivery and/or earlier initiation of nutrition supplementation in 2 studies.[40,41] The first study implemented an EMR best practice advisory (BPA) alert for testing and supplementation of vitamin D in children with newly diagnosed cancer and was conducted in a large tertiary academic hospital.[40] Findings from this study showed 97% (N = 32) of patients had vitamin D testing and 100% (33) received appropriate vitamin D supplementation delivered after automation was initiated compared to the historic control in which 4 of 26 (15%) patients had vitamin D testing and 2 of 26 (8%) received appropriate vitamin D supplementation. This study also used a CDS tool and educational training to improve compliance; however, the decision support tree was provided as a hard copy and not incorporated as part of the automated system.[40] In the second study, a CPOE with an automated CDS tool and feeding order set was implemented in a pediatric intensive care unit (PICU) to examine changes in initiating enteral nutrition within the first 48 hours of admission.[41] After implementation of the automated CDS tools and feeding order set, 81% patients started enteral nutrition within the first 48 hours of admission compared to 63% in the historic control ($p < 0.01$).[41]

The last study found a decrease in nutrition supplementation orders after implementation of a CPOE system without a CDS in a hospital in Spain.[43] In the year preceding implementation of the automated system, parenteral nutrition was prescribed 3,530 times across 12 clinical management units. Following implementation of the automated delivery system, parenteral nutrition was prescribed 2,622 times across the same units in 12 months.

Delivery of Nutrition Supports—Documented

Two uncontrolled, single-center, before-after quality improvement studies examined the automated delivery combined with automated documentation of nutrition supports (Table 4).[42,44] The automated delivery and documentation system for nutrition supports included the addition of oral nutrition supplementation (ONS) to the medication order sets and documentation of delivery and consumption

in the medication administration record (MAR)[42] and linkage of the ONS order to the MAR for documentation of consumption and delivery during the administered of medication to patients.[44] Both studies were conducted in the United States, and funding for the studies was from nonprofit and for-profit awards. Both studies reported positive impacts of automating delivery and documentation of administration on and consumption of oral nutrition supplements resulted in increased administration/delivery and consumption of nutrition supplementation.

The nutritional automation delivery and documentation systems varied across the 2 studies. The first study utilized a Plan-Do-Study-Act 4-cycle iterative design to examine the change in documentation of administration and consumption of ONS following the implementation of nutritional automation delivery and documentation systems.[42] The automated system included adding ONS to the medication order sets and an electronic nutrition administration record tab in the MAR that prompted documentation of administration and provided a direct link to the intake flowsheet. The study was conducted in patients on medical and oncology units in a medium-sized academic health science center hospital. Following the 4 cycles, consumption of ONS documented in the flowsheet increased from 4,675 of 85,930 mL (5%) in November and December 2014 to 11,812 of 56,955 mL (21%) in November and December 2015; the number of unopened and returned ONS was reduced from 76% to 54%; and 100% of ONS ordered in the MAR was documented as given or not given with 41% given and 59% not given. The second quality improvement study investigated the change in adult patients at risk for malnutrition receiving ONS after the implementation of automating the ONS order to link to the MAR to allow nurses to document the delivery, dose, and compliance during medication pass.[44] In adults aged 18 and older, oral nutrition supplement delivery increased from 6.1% in the second half of 2011 to 8.1% in the second half of 2013 following the implementation ($p < 0.01$).[44]

Table 4. Impact of Automated Nutrition Innovation on Supports Delivered

Nutrition Supports Delivered, Not Documented

Study Design	Innovation Comparator	Outcome Measure Definition	Results	ROB
Ziemba, 2019[41] **Uncontrolled before-after**	Decision support + CPOE Pre-implementation of intervention	Number with order sets implemented within 48 hours of admission	*Decision support + CPOE intervention* *N* = 221 (81%) Comparator *N* = 236 (63%) $p < 0.01$	Serious
Shliakhtsitsava, 2021[40] **Uncontrolled before-after**	EMR Alerts Historical control	Patients with vitamin D testing and receiving appropriate supplementation	*EMR alerts intervention* 97% *Comparator* 8%	Moderate
De Rueda Félix, 2015[43] **Uncontrolled before-after**	CPOE only Pre-implementation of intervention	TPN prescribed in the 12 months before-after implementation of CPOE	*CPOE intervention* *N* = 2622 *Pre-implementation comparator* *N* = 3530	Serious

Nutrition Supports Delivered and Documented

Study Design	Innovation Comparator	Outcome Measure Definition	Results	ROB
Citty, 2017[42] **Uncontrolled before-after**	MAR Pre-implementation of intervention	Percent documented as administered (*ie*, provided to the patient's bedside) in the ENAR (no baseline data for this outcome because the system did not exist)	*MAR intervention* 41%	Moderate
Citty, 2017[42] **Uncontrolled before-after**	MAR Pre-implementation of intervention	Proportion of ml of delivered ONS documented as consumed in the intake flowsheet (average over 4 24-hour periods)	*MAR intervention* 1,812 ml/56,955 ml (21%) *Pre-implementation comparator* 4,675 ml/85920 ml (5%)	Moderate
Citty, 2017[42] **Uncontrolled before-after**	MAR Pre-implementation of intervention	Proportion of ml of ONS documented as administered (given, not given) with reasons (no baseline data for this outcome because the system did not exist	*MAR intervention* 100% (documented) 41% (documented as given)	Moderate
Meehan, 2016[44] **Uncontrolled before-after**	MAR Pre-implementation of intervention	Patients receiving ONS	*MAR intervention* 794/9761 (8.1%) *Pre-implementation comparator* 613/10106 6.1% $p < 0.01$	Serious

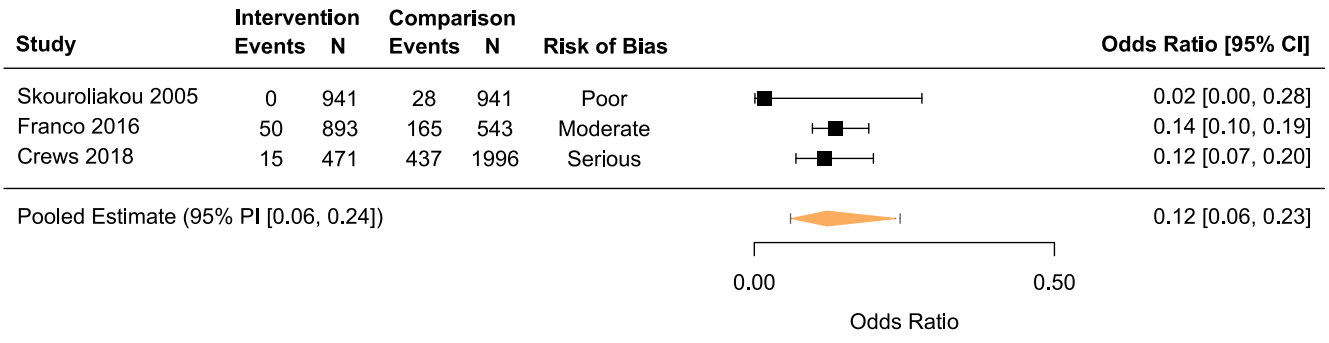
Abbreviations. CPOE=computerized provider order entry; EMR=electronic medical record; MAR=medication administration record; ONS=oral nutrition supplement; TPN=total parenteral nutrition.

Ordering Errors

One cross-sectional study (poor ROB)[47] and 3 uncontrolled, single-center, before-after studies (2 moderate ROB, 1 serious ROB)[48-50] investigated ordering errors associated with automated nutrition supplementation. The 3 uncontrolled before-after studies used CPOE, and 1 of those studies[49] utilized an automated parenteral nutrition calculator and ordering system. The cross-sectional study used a form of CPOE, a total parenteral nutrition (TPN) Formulated Automated Assistant, to aid in the ordering of TPN.[47] Outcomes assessed varied across the studies. Two studies measured TPN ordering error rates,[49,50] incidence of adjustments by pharmacist,[48] and manual versus computer TPN formulation calculation errors.[47] Three studies were conducted in the United States at single-site children's hospitals,[48-50] and 1 study was conducted in Greece at a maternity hospital.[47] All individual studies demonstrated a reduction in ordering errors.

We were able to pool results across 3 studies (Figure 5).[47,48,50] One study reported errors across 3 categories of birth weight; we were unable to combine these into 1 effect estimate.[49] Consistent with the individual study estimates, pooled results indicated the implementation of CPOE significantly reduced ordering errors (OR = 0.12; 95% CI [0.06, 0.23]; 95% prediction interval [PI] [0.06, 0.24]).

Figure 5. Effects of Implementing Computerized Provider Order Entry on Nutrition Supplementation Ordering Errors



Abbreviations. PI=95% prediction interval.

An additional single-center, before-after study conducted at a children's hospital with a level 1 pediatric trauma center[49] assessed the impact of a CPOE and computerized neonatal parenteral nutrition (PN) calculator on order errors. Infants were divided into 3 birth weight groups, <1000 g, 1001–1500 g, and >1500 g. After incorporation of the PN calculator and CPOE system, fewer errors were detected in all 3 birthweight groups. The incidence of ordering errors was reduced from 4.6 per 100 in 2007 to 0.1 per 100 following implementation of the parenteral nutrition calculator and CPOE (no significance tests reported).

Delivery Errors

Two cross-sectional studies looked at delivery errors associated with automated nutrition supplementation delivery (Table 5).[45,46] One study measured delivery errors prevented in human and fortified or formula milk when barcode scanning was used,[45] and 1 study measured errors in parenteral nutrition prescribing, transcribing, compounding, and administration after implementation of automated ordering and compounding.[46] Both studies were conducted in the United States at similar size single-site children's hospitals.

The most recent study, published in 2021, analyzed the impact of using a barcode scanner for human milk, fortifier, and formulas on near misses or errors prevented.[45] Near misses were defined as scans that identified the wrong provider order or record lot number or expired item at the time of feeding preparation and errors were defined as feeding an infant the wrong order, lot number, or expired milk. Over 7 years, use of barcode scanning resulted in identification of 1,226 near misses of delivery of the wrong provider order or record lot number of 1,231 near misses and errors. Four of the five errors of delivering the wrong milk were due to the human milk not being scanned at the bedside, and 1 error was due to not scanning the milk prior to discharge.[45] Additionally, 2,103 near misses of using expired human milk were identified. As a result of barcode scanning, no errors for delivering expired milk to an infant were made. Over 2 and a half years, barcode scanning resulted in identification of 480 near misses of delivery of the wrong fortifier or formula, and no infant patient received the wrong fortifier or formula.

The older cross-sectional single-site study examined the frequency of parenteral nutrition administration, transcription, and preparation errors 7 years following the use of a CPOE program with clinical decision support and automated compounding device technologies.[46] A retrospective look at 52,679 parenteral nutrition orders over a 7-year period found 230 of 84,503 medication errors. Of the 230 errors, 219 (95%) were administration errors. The administration errors included rate changes (34%) or lipid adjustments (23%) after parenteral nutrition initiation and medication incompatibilities (13%). There were no parenteral nutrition transcription errors identified. Using the NCC-MERP harm categories, the majority (90.9%) of the errors were in categories A–D and not likely to cause harm, while 21 of 230 errors (9.1%) were in categories E–F and may have caused temporary patient harm. No error led to permanent harm, required life sustaining treatment, or resulted in death.

Table 5. Impact of Automated Nutrition Innovation on Delivery Errors

Study Design	Innovation Comparator	Outcome Measure Definition	Results	ROB
Steele, 2021[45] **Cross-sectional**	Barcode scanner No comparator	Overall errors prevented (wrong infant's milk)	*Barcode scanner intervention* 1226/1231 (99%)	Fair
Steele, 2021[45] **Cross-sectional**	Barcode scanner No comparator	Overall errors prevented (expired human milk)	*Barcode scanner intervention* *N* = 2103 (100%)	Fair
Steele, 2021[45] **Cross-sectional**	Barcode scanner No comparator	Overall errors prevented (fortifier or formula)	*Barcode scanner intervention* *N* = 480 (100%)	Fair
MacKay, 2016[46] **Cross-sectional**	CPOE + compounding + decision support Historical control of national data	Medication errors over the last 7 years	*CPOE + compounding + decision support* *230/84503 (0.27%)* *Historical control* 74/4730 (1.6%)	Poor

Abbreviations. CPOE=computerized provider order entry.

Certainty of Evidence for Prioritized Process Outcomes

We found very low certainty of the evidence for the prioritized process outcomes (*ie,* supplements delivered, delivery errors, ordering errors). The COE was downgraded for serious risk of bias, indirectness, and very serious imprecision (Table 6).

Table 6. GRADE Ratings for Prioritized Process Outcomes

Outcome	Number of Studies	Findings	Certainty of Evidence (Rationale)
Nutrition supplements delivered (not documented)	4 observational studies (4,348 patients)	Order sets implemented in the AND group: 81% versus 63% in the comparator group Patients receiving appropriate supplementation: 97% in the AND group compared to 8% in the comparator group Supplements returned: 76% in the intervention arm and 54% in the comparator group Total reduction in supports prescribed: 908 after implementation of the AND system	**Very low certainty** (downgraded for serious risk of bias, serious indirectness, and very serious imprecision)
Nutrition supports delivered and documented	2 observational studies (19,978 patients)	Documented as consumed was 21% versus 5% in the comparator group Patients receiving nutrition was 8.1% versus 6.1% in the comparator group	**Very low certainty** (downgraded for serious risk of bias, serious indirectness, and very serious imprecision)
Delivery errors	2 observational studies (886,203 patients)	Range of errors prevented 99% to 100% Range of errors since AND implementation 0% to 0.27%	**Very low certainty** (downgraded for serious risk of bias, very serious indirectness, and extremely serious imprecision)
Ordering errors	4 observational studies (3,663 patients)	Calculation errors were 0 in the AND group and 28 in the comparator group Orders needing pharmacist adjustment was 5.6% in the AND group and 30.4% in the comparator group Overall ordering errors were reduced to 0.1 per 100 in the AND group and 4.6 per 100 in the comparator group Orders needing clarification or reentry was 3.2% in the AND group and 21.9% in the comparator group	**Very low certainty** (downgraded for serious risk of bias, and very serious indirectness)

Abbreviations. AND=automated nutrition delivery.

Performance Outcomes

Only 6 studies reported on performance outcomes associated with the automation of delivering nutrition supports.[40-42,44,50,51] These studies reported on some aspect of hospital staff satisfaction with the intervention (N = 2)[42,52] or the time savings from automation (N = 4).[41,44,47,50]

Staff Satisfaction

Two moderate ROB uncontrolled, single-center before-after studies[40,51] examined staff satisfaction with tools developed to address vitamin D supplementation in children newly diagnosed with malignancy and malnutrition in hospitalized patients, respectively (Table 7). Both studies were conducted in the United States at tertiary care academic health centers and integrated with pre-existing electronic health records (EHRs).

In the first study,[40] a multidisciplinary team at a children's hospital developed an institutional guideline for vitamin D testing, supplementation, and follow-up testing in children with newly diagnosed cancers after previously noting low rates of testing and supplementation for vitamin D deficiency in their patient population. This institutional guideline was included in a clinical decision-making tree and incorporated into pre-existing oncology order sets within the hospital's EHR, along with an accompanying BPA for patients lacking recent vitamin D testing or a lack of supplementation in patients in whom testing had been performed and for whom it was indicated. Overall, 16 of 24 eligible clinicians filled out a survey with Likert scales related to use of the clinical decision-making tree and BPA after the implementation of the tools. Responses to these surveys were dichotomized for provider satisfaction, with responses of "moderately high" to "high" utility considered positive. Of the 16 respondents, 67% found the decision-making tree to have moderately high to high utility, and 86% found the BPA/automated triggers to have moderately high to high utility. As this survey was conducted post-implementation, no additional statistical analyses were performed on these data (Table 7).

In the second study,[51] a multidisciplinary team created an electronic nutrition administration record (ENAR) to consolidate and standardize information about enteral nutrition orders and administration from previously disparate sections of the pre-existing CPOE system and EHR and to reduce redundant documentation. This ENAR section was developed within the MAR, given similar nursing documentation processes for both nutrition supplementation and medications, and it was linked to the "intake and output" flow sheet for ease of review by clinicians. Pre- and post-implementation surveys were performed for nursing and assistant nursing staff related to documentation workflows, with additional post-implementation items including items regarding the tool's effects on overall practice, documentation accuracy, and awareness of nutritional status. Overall, attitudes were significantly more favorable when comparing enteral nutrition practices after MAR implementation to pre-implementation context. For example, nursing staff reported significant changes in their confidence and knowledge of which patients had an order for ONS. Similarly, hospital staff found it very easy to know when and how much ONS was last given versus pre-implementation, very easy to document the type of ONS consumed, and very easy to document the volume of ONS consumed. While nurses and nursing assistants reported slightly higher rates of ease in locating the ONS to give to patients post-implementation, the difference was not statistically significant. In questions that were asked only in the post-implementation survey, 66% of survey respondents agreed or strongly agreed that documenting within the ENAR had a positive effect on their practice (Table 7).

Table 7. Impact of Automated Nutrition Innovation on Hospital Staff Satisfaction

Study Design	Innovation Comparator	Outcome Measure Definition	Results	ROB
Shliakhtsitsava, 2021[40] **Uncontrolled before-after**	EMR alerts Pre-implementation of innovation	"Moderately high" to "High" perceived utility of automated triggers for the AND innovation	*EMR alert intervention* *N* = 16 (86%) *Pre-implementation comparator* NR	Moderate
Citty, 2017[42] **Uncontrolled before-after** **Companion paper: Kamel, 2021[51]**	MAR Pre-implementation of intervention	Percent of RN and nursing assistants endorsing “very easy” in knowing that their patient had an ONS order	*MAR intervention* *N* = 99 (83%) *Pre-implementation comparator N* = 128 (56%) *p* = 0.01	Moderate
Citty, 2017[42] **Uncontrolled before-after** **Companion paper: Kamel, 2021[51]**	MAR Pre-implementation of intervention	Perceived ease of ONS administration and documentation: RN and nursing assistants endorsing "very easy" documenting the ONS product consumed	*MAR intervention* *N* = 89 (74%) *Pre-implementation comparator N* = 102 (45%) *p* = 0.01	Moderate
Citty, 2017[42] **Uncontrolled before-after** **Companion paper: Kamel, 2021[51]**	MAR Pre-implementation of intervention	Perceived ease of ONS administration and documentation: RN and nursing assistants endorsing "very easy" knowing when and how much ONS product was last given to their patient	*MAR intervention* *N* = 58 (48%) Comparator: *N* = 38 (17%) *p* = 0.01	Moderate
Citty, 2017[42] **Uncontrolled before-after** **Companion paper: Kamel, 2021[51]**	MAR Pre-implementation of intervention	Perceived ease of ONS administration and documentation: RN and nursing assistants endorsing "very easy” to find the ONS sent from dietary to nursing staff to give to patient	*MAR intervention* *N* = 72 (60%) Comparator: *N* = 111 (49%) *p* = 0.12	Moderate
Citty, 2017[42] **Uncontrolled before-after** **Companion paper: Kamel, 2021[51]**	MAR Pre-implementation of intervention	Perceived ease of ONS administration and documentation: RN and nursing assistants endorsing "very easy" documenting volume of ONS consumed	*MAR intervention* *N* = 73 (63%) Comparator: 110 (49%) *p* = 0.01	Moderate

Study Design	Innovation Comparator	Outcome Measure Definition	Results	ROB
Citty, 2017[42] **Uncontrolled before-after** **Companion paper: Kamel, 2021[51]**	MAR Pre-implementation of intervention	Perceived improvement of ONS administration and documentation: All staff (RN, RD, MD) endorsing "is much improved" in placing and finding ONS orders	*MAR intervention* 67%	Moderate
Citty, 2017[42] **Uncontrolled before-after** **Companion paper: Kamel, 2021[51]**	MAR Pre-implementation of intervention	Perceived improvement of ONS administration and documentation: All staff (RN, RD, MD) endorsing "is much improved" in administration of ONS	*MAR intervention* 60%	Moderate
Citty, 2017[42] **Uncontrolled before-after** **Companion paper: Kamel, 2021[51]**	MAR Pre-implementation of intervention	Perceived improvement of ONS administration and documentation: All staff (RN, RD, MD) endorsing "is much improved" in documentation accuracy of ONS	*MAR intervention* 40%	Moderate
Citty, 2017[42] **Uncontrolled before-after** **Companion paper: Kamel, 2021[51]**	MAR Pre-implementation of intervention	Perceived impact of MAR for ONS administration and documentation: All staff (RN, RD, MD) endorsing "strongly agree/agree" that MAR for ONS has a "positive effect on my own practice"	*MAR intervention* *N* = 94 (66%)	Moderate

Abbreviations. CPOE=computerized provider order entry; EMR=electronic medical record; MAR=medication administration record; ONS=oral nutrition supplement; TPN=total parenteral nutrition.

Certainty of Evidence for Prioritized Performance Outcomes

We rated the COE for the 2 observational studies reporting an increase in hospital staff satisfaction as very low due to serious risk of bias and very serious imprecision (Table 8).

Table 8. GRADE Ratings for Prioritized Performance Outcomes

Outcome	Number of Studies	Findings	Certainty of Evidence (Rationale)
Staff satisfaction	2 observational studies (170 patients)	Providers highly rating the utility of AND: 86% Providers highly rating ease of AND ranged from 48% to 63% versus 17% to 49% in the comparator group	**Very low certainty** (downgraded for serious risk of bias, and very serious imprecision)

Hospital Staff Time

One cross-sectional study (poor ROB)[47] and 3 uncontrolled, single-center, before-after studies (2 serious ROB; 1 moderate ROB)[41,44,50] analyzed aspects of the staff time associated with nutrition supplementation. These included 2 studies measuring time for clinician ordering supplementation,[47,50] 2 examining pharmacist time for calculating and clarifying orders,[47,50] 1 studying time for TPN preparation,[47] and 2 documenting time from screening or admission to initiation of nutrition interventions.[41,44] The cross-sectional study was performed in Europe at an obstetrics and maternity hospital with neonatal care, and the 3 before-after studies were performed in the United States. Two of these latter 3 studies were initiated at children's hospitals, while the third was at a level 1 trauma center and magnet hospital with adult care wards. Table 9 provides an overview of the impact of automation innovations on time metrics.

Time Required as Part of Ordering and Processing Nutrition Supplementation

The older European poor ROB cross-sectional study examining clinician, pharmacist, and technologist time[47] compared time expenditures for 96 patient orders using a CDS system named the "TPN Formulation Automated Assistant" versus their pre-existing method of manual calculations. In all 96 cases, orders were performed using both methods, with a third party measuring the time required. In all 3 comparisons, use of the computerized tool significantly reduced time expenditures. Physician ordering time was reduced from 7.1 minutes (SD 2.5 min) to 1.1 minutes (SD 0.3), pharmacist calculation time was reduced from 4.2 (SD 2.1) minutes to 1.9 (SD 0.3) minutes, and overall time for TPN preparation from 15.4 (SD 4.4) minutes to 5.2 (SD 0.8) minutes (Table 9).

A US-based before-after study[50] rated as serious ROB analyzed clinician order writing time and pharmacist time to clarify and process those TPN orders as part of a transition from paper TPN orders to electronic ordering through the local EHR. This intervention was paired with the creation of standardized TPN solutions. For the clinician-ordering outcome, the project lead physician randomly audited orders throughout the project on a quarterly basis, while the project lead pharmacist performed similar quarterly audits for the pharmacist processing time outcome. The number of audits performed was not shared in the paper, nor were any statistical analyses performed. In what is reported, clinician order writing time dropped from 3.5 minutes using paper orders to less than 1 minute using the computerized orders by the end of the project, while pharmacist processing time decreased from 10 minutes per paper order to 5 minutes per computerized order by the project's conclusion.

Time to Initiation of Nutrition Supplementation

The other 2 before-after studies[41,44] looked at time to initiation of nutrition supports and time to achieving goal nutrition supplementation in patients hospitalized in a pediatric intensive care unit (PICU) and general medical wards, respectively (Table 9). The PICU study[41] focused on children < 1 year of age with a diagnosis of respiratory distress or insufficiency, creating an enteral nutrition order set and BPA with age-appropriate supports and titration orders for bedside nurses. The BPA was designed to send an alert 18 hours after admission to the PICU for the eligible patients in whom no enteral feeding had been ordered. The authors compared 272 children admitted post-intervention to a historical cohort in the almost 3 years pre-implementation, finding that a higher proportion of children had nutrition initiated within 48 hours of admission post-implementation (221 [81%] post-implementation vs 236 [63%] pre-implementation, $p < .01$) and that this nutrition was begun 0.4 days sooner (1.3 days post-implementation vs 1.7 days pre-implementation, $p < .01$).

The study in adult patients on general medical wards[44] utilized nursing screening with the Malnutrition Screening Tool.[53] After identifying patients at risk with the screening tool, the intervention empowered nurses to directly order an intervention with ONS through the EHR, rather than the previous workflow of nurses referring for dietician assessment and recommendations forwarded for physician approval. In the post-implementation workflow, the nursing order was integrated into the MAR and simultaneously notified the dietician to evaluate the patient and validate the order. Chart audits were done for 30 random patients retrospectively to create the comparison cohort, with the time required to initiate ONS reduced from 2.3 days pre-implementation to < 1 day.

Table 9. Impact of Automated Nutrition Innovation on Hospital Staff Time

Study Design	Innovation Comparator	Outcome Measure Definition	Results	ROB
Skouroliakou, 2005[47] **Cross-sectional**	CPOE + compounder Pre-implementation of intervention	Mean time physician spent on TPN prescription	*Calculator + compounder intervention* Mean 1.1 minutes (SD 0.3) *Pre-implementation comparator* Mean 7.1 minutes (SD 2.5) $p < .05$	Poor
Skouroliakou, 2005[47] **Cross-sectional**	CPOE + compounder Pre-implementation of intervention	Mean time pharmacist spent on necessary calculations	*Calculator + compounder intervention* Mean 1.9 minutes (SD 0.3) *Pre-implementation comparator* Mean 4.2 minutes (SD 2.10) $p < .05$	Poor
Skouroliakou, 2005[47] **Cross-sectional**	CPOE + compounder Pre-implementation of intervention	Mean time spent on the preparation of a TPN solution	*Calculator + compounder intervention* Mean 5.2 minutes (SD 0.8) *Pre-implementation comparator* Mean 15.4 minutes (SD 4.4) $p < .05$	Poor
Crews, 2018[50] **Uncontrolled before-after**	CPOE only Pre-implementation of intervention	Order writing time for clinicians	*CPOE only intervention* Mean 1 minute *Pre-implementation comparator* Mean 3.5	Serious
Crews, 2018[50] **Uncontrolled before-after**	CPOE only Pre-implementation of intervention	Time for pharmacist error clarification, correction, and processing for custom TPN	*CPOE only intervention* Mean 5 minutes *Pre-implementation comparator* Mean 10 minute	Serious
Meehan, 2016[44] **Uncontrolled before-after**	MAR Pre-implementation of intervention	Time from nutrition screening to initiation of nutrition intervention	*MAR intervention* Mean < 24 hours *Pre-implementation comparator* Mean 2.3 days	Serious

Study Design	Innovation Comparator	Outcome Measure Definition	Results	ROB
Ziemba, 2019[41] **Uncontrolled before-after**	Decision support + CPOE Pre-implementation of intervention	Time to initiation of enteral nutrition from time of admission to the PICU	*Decision support + CPOE intervention* Median 1.3 days *Pre-implementation comparator* Median 1.7 days $p < .01$	Moderate

Abbreviations. CPOE=computerized provider order entry; MAR=medication administration record; ONS=oral nutrition supplementation.

Patient-Level Outcomes

In total, 10 studies[39,41,44,46,48,49,54-57] reported on the prioritized patient-level outcomes associated with the automation of delivering nutritional supports. These studies reported on the following outcomes: time to regain birthweight ($N = 4$),[54-56,58] calories or nutrients consumed ($N = 5$),[41,48,49,55,56] length of hospital stay ($N = 3$),[41,44,57] hospital readmissions ($N = 2$),[44,57] and patient harms ($N = 4$).[44,46,55] Only time to regain birthweight was able to be meta-analyzed. All other outcomes are narratively synthesized.[41]

Time to Regain Birthweight

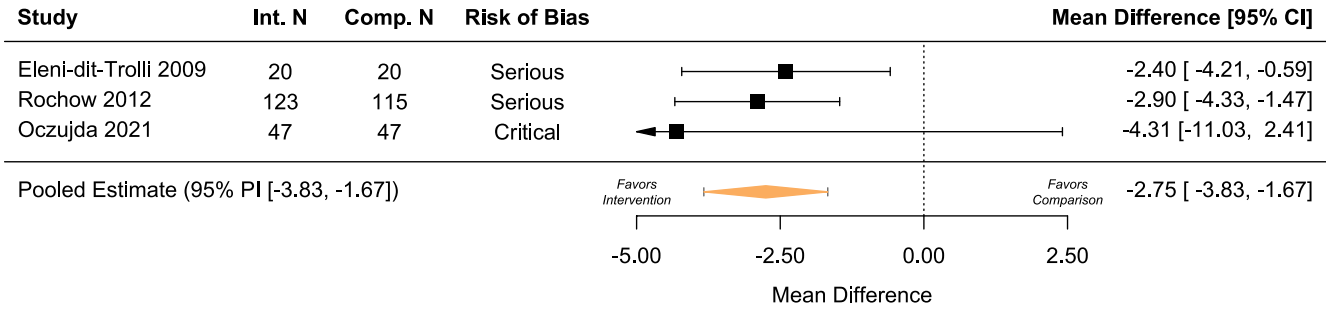
One US-based randomized controlled trial[39] and 3 European-based uncontrolled, single-center, before-after studies[54-56] examined the time it took preterm infants to regain their birthweight. Two of these studies[39,54] explored CPOE with embedded calculators and the other 2[55,56] explored CPOE alone. No studies were rated as low risk of bias.

In the RCT rated as some risk of bias, 42 preterm infants who were less than 3 days old and weighing 1500 grams or less were randomized to receive either the Parenteral Protein Calculator (PPC) ($N = 19$) or standard of care ($N = 23$). The PPC tool was developed over 4 months by an interprofessional team of clinical informatics, neonatologists, pharmacists, and others at Vanderbilt University Medical Center. The PPC was a CPOE-integrated computerized decision support system that automated the calculations of parenteral protein values based off information in the structured CPOE and subtracting for enteral protein. The CPOE tool populated the parenteral protein value into the protein field at the time of PN ordering. In the usual care control group, providers calculated the parenteral protein dose with protocols available online and quick-access notes placed in provider work areas. The PPC group regained birthweight faster than the control group, but the trend was not statistically significant (9.6 vs 8 days; OR = 0.38; 95% CI [0.14, 1.41]).

The 3 other studies were all uncontrolled before-after studies (2 serious ROB[54,55]; 1 critical ROB[56]) that compared retrospective cohorts of preterm infants before and after implementation of CPOE for preterm infant feeding orders. One study[54] assessed the impact of CPOE with a calculator and the other 2 studies[55,56] assessed the impact of a CPOE without an integrated calculator. In total, these studies included 372 preterm infants (study sample size range: 40 to 238). Individually, these 3 studies showed a trend toward faster weight regain in the group of infants admitted to the neonatal units after implementation of the CPOE nutritional system redesign. These studies were deemed to have sufficient conceptual homogeneity to perform quantitative synthesis. Based on meta-analysis of all patients

(Figure 6), there was a significant mean difference in days to regain birthweight favoring the CPOE-exposed cohort of infants (MD = -2.75 days; 95% CI [-3.83, -1.67]; 95% PI [-3.83, -1.67]).

Figure 6. Mean Difference in Time to Regain Birthweight Among Infants in Hospital Settings After Implementation of Computerized Provider Order Entry Systems



Abbreviations. PI=95% prediction interval.

Nutrition Supports Consumed

A total of 5 uncontrolled before-after studies[41,48,49,55,56] assessed the impact of automation of nutrition delivery on some metric of calories or macronutrients consumed. Three were US based[41,48,49] and 2[55,56] were based in Europe. All were assessing implementation of CPOE, with or without additional elements: CPOE only (N = 3),[48,55,56] CPOE plus an embedded calculator (N = 1),[49] and CPOE with an integrated decision support tool (N = 1).[41] Three of the studies were rated as moderate risk of bias[41,48,49] and all were conducted in pediatric populations. Populations, interventions, and outcomes were too diverse to conduct meta-analysis.

The 3 studies that assessed the implementation of CPOE only were all conducted in preterm infants. Two[55,56] focused on some metric of preterm infant energy intake (*eg*, total energy intake, intake per day, first day of life energy intake); all studies demonstrated a signal for increased energy intake post-implementation of a CPOE (Table 10). The other CPOE-only study[48] focused on the proportion of preterm infants that achieved goal PN across 3 macronutrients; this study also showed improved goal nutrition outcomes after CPOE implementation. Days to nutrition goal attainment did not differ before (10.8 days) and after (10 days) CPOE implementation.

Two studies assessed CPOE plus some additional components; results were mixed. The first study[41] assessed CPOE with an embedded decision support tool among critically ill children in a pediatric intensive care unit. After CPOE implementation, significantly more pediatric patients achieved goal enteral nutrition within the first 48 hours after hospital admission. The last study was conducted among infants requiring parenteral nutrition in the first three weeks of life and found no difference in total calories consumed before and after implementation of a CPOE with an integrated calculator among 3 different birthweight categories of infants.[49]

Table 10. Impact of Automated Nutrition Innovation on Nutrition Supports Consumed

Study Design	Intervention Comparator	Outcome Measure Definition	Results	ROB
Franco, 2016[48] **Uncontrolled before-after**	CPOE only Pre-implementation of intervention	Proportion of neonatal patients who achieve goal nutrition on 3 key macronutrients concurrently (*ie*, amino acids, lipids, glucose infusion rate)	*CPOE only intervention* *N* = 12 (25.5%) *Pre-implementation comparator* *N* = 2 (4.5%) *p* = .05	Moderate
Eleni-dit-Trolli, 2009[55] **Uncontrolled before-after**	CPOE only Pre-implementation of intervention	Cumulative total energy intake (kcal/kg) among preterm infants	*CPOE only intervention* Mean: 3308 SD:165 *Pre-implementation comparator* *N* = 20 Mean: 2971 SD:344 Mean difference: 337 *p* = .001	Serious
Eleni-dit-Trolli, 2009[55] **Uncontrolled before-after**	CPOE only Pre-implementation of intervention	Mean total energy intake per day (g/kg)	*CPOE only intervention* Mean: 118 SD: 6 *Pre-implementation comparator* *N* = 20 Mean:106 SD: 12 Mean difference: 12 *p* not reported	Serious
Oczujda, 2021[56] **Uncontrolled before-after**	CPOE only Pre-implementation of intervention	First DOL energy, kcal/kg/d	*CPOE only intervention* *N* = 47 Mean: 62.9 SD: 18.1 *Pre-implementation comparator* *N* = 47 Mean: 32.2 SD: 8.03 *p* < .0001	Serious

Study Design	Intervention Comparator	Outcome Measure Definition	Results	ROB
Oczujda, 2021[56] **Uncontrolled before-after**	CPOE only Pre-implementation of intervention	14th DOL energy, kcal/kg/d	*CPOE only intervention* *N* = 47 Mean: 102.1 SD: 30.9 *Pre-implementation comparator* *N* = 47 Mean: 68.4 SD: 21.6 *p* < .001	Serious
Ziemba, 2019[41] **Uncontrolled before-after**	Decision support + CPOE Pre-implementation of intervention	Percentage of children who reached goal EN in the first 48 hours of admission	*Decision support + CPOE intervention* *N* = 272 *(*38%) *Pre-implementation* comparator *N* = 337 (18%) *p* < .01	Serious
Huston 2013[49] **Uncontrolled before-after**	CPOE + calculator Pre-implementation of intervention	Caloric intake, kcal/kg/d among babies weighing ≤1000 g)	*CPOE + calculator intervention* *N* = 26 Mean 88, SD: 9 *Pre-implementation comparator* *N* = 22 Mean: 87, SD: 10	Moderate
Huston 2013[49] **Uncontrolled before-after**	CPOE + calculator Pre-implementation of intervention	Caloric intake, kcal/kg/d among babies weighing (> 1500 g)	*CPOE + calculator intervention* *N* = 16 Mean: 94, SD: 8 *Pre-implementation comparator* *N* = 27 Mean: 93, SD:11	Moderate
Huston 2013[49] **Uncontrolled before-after**	CPOE + calculator Pre-implementation of intervention	Caloric intake, kcal/kg/d among babies weighing 1001–1500 g	*CPOE + calculator intervention* *N* = 45 Mean 92, SD: 5 *Pre-implementation comparator* *N* = 28 Mean: 92, SD: 6	Moderate

Abbreviations. CPOE=computerized provider order entry.

Length of Hospital Stay and Hospital Readmission

One serious ROB controlled before-after study[57] and 2 uncontrolled before-after studies (1 moderate ROB, 1 serious ROB)[41,44] assessed the impact of automation of nutrition delivery on patient length of hospital stay. All 3 studies were conducted in the United States and assessed some form of a CPOE.[41] Sriram (2017) assessed the impact of adding CPOE to a MAR for adults at risk for malnutrition.[57] Ziemba (2019) compared the PICU implementing of a CPOE with an embedded decision support tool for infants in respiratory distress.[41] The last study by Meehan (2016) assessed the impact before and after implementation of a MAR with a CPOE among adults at risk for malnutrition on length of hospital stay (Table 11).[44]

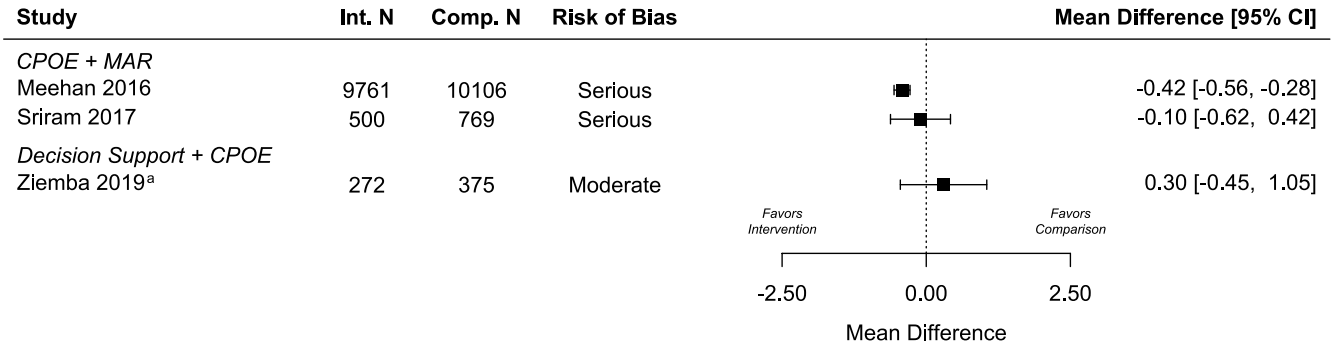
Table 11. Impact of Automated Nutrition Innovation on Length of Hospital Stay

Study Design	Intervention Comparator	Outcome Measure Definition	Results	ROB
Sriram, 2017[57] **Controlled before-after**	CPOE + MAR MAR no CPOE	Hospital length of stay (defined by subtracting admission day from discharge day).	*CPOE + MAR intervention* *N* = 500 Mean: 5.3 days, SD: 4.5 *MAR no CPOE Comparator* *N* = 769 Mean: 5.4 days, SD: 4.8 Relative risk reduction: 11.7% with CPOE vs 10.0% without CPOE *p* = .011	Serious
Ziemba, 2019[41] **Uncontrolled before-after**	Decision support + CPOE Pre-implementation of intervention	Length of stay (LOS) from admission to hospital discharge days	*Decision support + CPOE intervention* *N* = 272 Median: 8.7, SD: NR *Pre-implementation comparator* *N* = 375 Median: 8.4, SD: NR	Serious
Meehan, 2016[44] **Uncontrolled before-after**	MAR Pre-implementation of intervention	Length of patient hospital stay (in days)	*MAR only intervention* Mean: 4.47 days SE: 0.05 *Pre-implementation comparator* Mean: 4.87 days, SE: 0.05 Mean difference: 0.40 days *p* < .01	Serious

Abbreviations. CPOE=computerized provider order entry; MAR=medication administration record.

Both of the CPOE embedded within a MAR demonstrated a signal in reducing hospital stays while the CPOE with decision support did not. (See Figure 7 for visualization of point estimates.) The 2 MAR studies also assessed the impact of this innovation on 30-day hospital readmissions and found a significant reduction compared to pre-implementation rates (Table 12).

Figure 7. Mean Difference in Days in Hospital in Patients Exposed to Hospital Settings after Implementation of Computerized Provider Order Entry Systems



Notes. [a] Missing group-level standard deviations were imputed as means of group-level standard deviations reported by Meehan 2016 and Sriram 2017.

Abbreviations. PI=95% prediction interval.

Table 12. Impact of Automated Nutrition Innovation on Hospital Readmissions

Study Design	Intervention Comparator	Outcome Measure Definition	Results	ROB
Sriram, 2017[57] **Controlled before-after**	CPOE + MAR MAR no CPOE	Unplanned, all-cause 30-day hospital readmission to any of 12 hospitals in the AHC system	*CPOE + MAR intervention* *N* = 500 (15.6%) *MAR no CPOE comparator* *N* = 769 (16.4%) Relative risk reduction: 22% with COPE vs 18% without CPOE *p* = .01	Serious
Meehan, 2016[44] **Uncontrolled before-after**	MAR Pre-implementation of intervention	Rate of readmission to the hospital within 30 days for those that are nutrition sensitive (percent probability)	*MAR only intervention* *N* = 9761 (19.7% post-implementation) *Pre-implementation comparator* *N* = 10106 (16.3%) *p* < .01	Serious

Abbreviations. CPOE=computerized provider order entry; MAR=medication administration record.

Patient-Level Harms

Three studies assessed some form of patient-level harms; all studies assessed some form of CPOE implementation.[41,46,55] Two US-based studies assessed all-cause mortality and both were conducted among pediatric populations. One poor ROB cross-sectional study[46] assessed CPOE with automated compounding and decision support at a large children's hospital and the other was a serious ROB uncontrolled before-after study that assessed CPOE with a decision support aid in the PICU of a large urban hospital. Both reported no death in the cohorts before and after implementation of the CPOE systems (Table 13). The cross-sectional study by MacKay (2016) also reported harms as categorized by the National Coordinating Council for Medication Error Reporting and Prevention (NCC MERP);

21 errors were identified after CPOE implementation and classified as temporary harms. The last study was a serious ROB uncontrolled before-after study of a CPOE only innovation conducted among preterm infants in France.[55] This study reported that the number of infants with other harms (*eg*, nosocomial infections, intraventricular hemorrhage) did not differ before and after CPOE implementation.

Table 13. Impact of Automated Nutrition Innovation on Patient-Level Harms

Temporary Patient Harms

Study Design	Intervention Comparator	Outcome Measure Definition	Results	ROB
MacKay, 2016[46] **Cross-sectional**	CPOE + compounding + decision support	NCC-MERP harm categories E–F (temporary harm category) over the last 7 years	*CPOE + compounding + decision support intervention* *N* = 21 (9.1%)	Poor
Eleni-dit-Trolli, 2009[55] **Uncontrolled before-after**	CPOE only Pre-implementation of intervention	Negative patient health outcomes	NR; author states that numbers similar between groups	Serious

Deaths

Study Design	Intervention Comparator	Outcome Measure Definition	Results	ROB
MacKay, 2016[46] **Cross-sectional**	CPOE + compounding + decision support	All-cause mortality	No deaths after implementation	Poor
Ziemba, 2019[41] **Uncontrolled before-after**	Decision support + CPOE Pre-implementation of intervention	All-cause mortality	0% *N* = 272 Comparator 0% *N* = 375	Serious

Abbreviations. CPOE=computerized provider order entry; NCC MERP=National Coordinating Council for Medication Error Reporting and Prevention.

KEY QUESTION 2: EXPERIENCES WITH AUTOMATED NUTRITION DELIVERY

No studies were identified that addressed KQ2.

QUALITATIVE STUDY: VHA STAFF EXPERIENCES AND PERCEPTIONS OF AUTOMATED NUTRITION DELIVERY

Key Informants

We interviewed 12 VHA employees across 4 VA Health Care Systems who had interacted with or participated in implementation attempts of an automated nutrition delivery system. Past and present relevant roles of these participants included staff from pharmacy, nutrition, informatics, research, nursing, and clinical providers. We also had representation from leadership in these areas: pharmacy, nutrition, food service, informatics, and nursing. Our sample spanned a cross-section of staff involved with AND whose roles were largely interdisciplinary in nature. Several key informants had multiple job roles and capacities in implementing AND within the VA health care system, leading to more than 12 job titles. (See Appendix for more information of key informant roles.)

Results of the Qualitative Analysis

Making the Case: Why Automate Nutrition Supports?

All participants described significant gaps in documentation, care delivery, and patient safety metrics in the absence of automation of nutrition supports. The theme of a lack of information and communication flowed through all interviews when describing nutrition delivery without having an automation innovation in place. Prior to the implementation of nutrition support automation innovations, key informants often described inconsistent, incomplete documentation of delivery and administration of nutrition orders. Nutritionists and other providers reported that there was no systematic way of knowing if a nutrition intervention was received by the intended patient, whether there was documentation regarding barriers to administration (*eg*, patient intolerance), or the outcomes of that nutrition intervention. Without automation, paper nutrition charts were the standard; these were not easily accessible to staff on the hospital floors.

The lack of integration of delivery of nutrition support added burden to the staff workload. Informants described seeing nutrition products "piling up" at the nursing desks or being pushed to inappropriate storage locations. Staff morale was also impacted by a lack of information about the nutritional regimes needed by specific patients under their care. Further, some informants described information gaps in nutrition supplementation orders as a potential source of conflict between those who order nutrition products (nutrition service line) and those responsible for administering nutrition products (nursing service line). One nutritionist informant shared:

> "It was very frustrating to me to not be able to get the protein supports I had ordered to my patients. I would order it in the electronic record and I was never sure if the intervention was completed by the nursing staff. There was no sign in the medical record. And I could see evidence that it wasn't, because when I went onto the wards, the [nutrition supplement] products were piling up. I started to wonder why I'm even here if I can't make this happen. I started showing up on the unit so I could see what was happening. It just wasn't possible to change anything on that level. The nurses were frustrated too. There are no reminders and no clear indication what to do with the stock that's piling up on their desks. We began collaborating on ideas to solve the problem. I needed to better understand their workflow issues. They suggested BCMA [barcode medication administration]."

Staff also expressed that the lack of automation also impacted patient care and patient safety. Without any automation of the delivery of nutrition interventions, the "6 rights protocol" of right person, product, dose, timing, route, and documentation could not be verified nor documented. There were no safety checks, no accountability processes, and no reliable way to investigate potential nutrition-related safety events (*ie*, undocumented error of omission). Nearly all staff informants mentioned increasing patient safety as a key driver in the need for automation among hospitalized patients in the VHA.

Implementation Facilitators and Barriers: What Helps or Hinders the Implementation of Automation of Nutrition Delivery?

The implementation of AND varied by site. Yet most sites articulated common facilitators and barriers to implementing the innovation.

Facilitators of Implementation

Main implementation facilitators were an intentional planning period, multidisciplinary implementation team, a culture of innovation, building off existing VHA structures, and the importance of a local champion for the automation of nutrition support delivery. Development of a multidisciplinary planning team was described as a key factor in the successful implementation. In a VHA that implemented a BCMA, informants described a multidisciplinary workgroup that was convened to plan, implement, and maintain the innovation at their site. Workgroup members included nutrition, food service, pharmacy, information technology, and nursing. Participants on the implementation team reflected on the process as being "rewarding to collaborate with a team committed to patient health and innovation." Informants identified several key drivers of a rewarding team effort to implementation automation of nutrition support delivery: collaborative group spirit, collegial nature of the group, creative problem solving (*eg*, supply chain issues, addressing storage limitations, coordinating workflows). They noted the importance of the culture of innovation at their health care site, particularly the strong visible support of leadership (*eg*, verbal encouragement, time to participant in workgroups during regular tour of duty). Several informants mentioned the key role of having a local champion to support and spearhead progress. Finally, participants mentioned that implementation of the automation innovation would not have been possible without leveraging existing systems familiar to staff.

Barriers to Implementation

Implementation barriers centered on the involvement of staff in the pharmacy service line who had not traditionally been involved in the delivery of nutrition products and services. Key informants described these implementation barriers related to the role of the pharmacy service when implementing the automation of nutrition supports at their site: perceived increase in scope of job role, discomfort with duties outside of expertise, and perceptions of increased work time. Some pharmacy informants described discomfort in working with nutrition supplement products that were beyond their training or perceived scope of practice. Specifically, pharmacists were wary of verifying orders for nutrition products, as they felt they did not have the appropriate expertise. Other key informants stated some pharmacy staff members at their site feared a "slippery slope" of an expansion in the scope for the pharmacy service. As 1 participant noted, "well if we include nutrition supports, what's stopping them from having us include bandages and gauze?"

Other potential barriers to implementation that were not centered on the pharmacy service included the potential for unclear responsibilities around the product procurement, product quality vetting, and

storage of nutrition supports. There was additional resistance to investing the time and energy into new systems and protocols that would be eventually replaced by the upcoming modernization of the VHA electronic health record system. Yet most informants reported that the actual impact of automating nutrition delivery at their sites was minimal, after the initial investment in setting up systems to implement the innovation.

Outcomes: What Happens After Implementing the Automation of Nutrition Delivery?

Patient Care Quality

Key informants repeatedly emphasized how important the automation of delivering nutrition supports was in assuring high quality patient care for hospitalized Veterans. Automation also allowed more consistency in care between the VHA and partner academic institutions, between inpatient and outpatient care, and in hospital discharge planning. One participant said, "Now I know what the patient got and [at] what frequency, so I can continue that for them at [hospital] discharge."

Patient Safety

Key informants felt automation was important for patient safety in many ways. These included automatic checks for allergies in the system, tracking medication interactions, and reducing administration errors, which all led to decreases in potential harms. Patient safety was also addressed through the enhanced documentation in automated systems, which increased transparency and communication across providers involved in a patient's care and provided a source of information to document safety incidents to allow for the identification of patterns for future quality improvement efforts. For those informants having experience with BCMA, barcode administration allowed staff to input safety messages on orders or check for interactions with medications, track product expirations, and provide a way to reliably check for non-delivery of nutrition interventions (*ie*, errors of omission).

Staff Workload and Workflow

In general, informants reported that most of their pre-implementation concerns about the negative impacts of automating nutrition support delivery on their workflow and workload did not come to fruition. No informant described that automation made their jobs more difficult or burdensome post-implementation. Specifically, automating the delivery of nutrition support created efficiencies in workload after the initial implementation trial period. Clinical informants stated that standardized quick orders made ordering nutrition supports easier and faster. Food service staff noted the benefits of receiving automatic notices of new orders and patient room changes. Meal costing and reordering of nutrition products on discharge also became easier due to the increased transparency among providers when orders were easily populated and visible in the electronic health record.

Yet automated systems were not seamless. Some informants reported increases in their workload due to the implementation of automated nutrition delivery systems. For staff, much of the increased workload around implementation was reported as being temporary, revolving around the development of the new systems, needs of initial staff training, and early troubleshooting of implementation challenges. Other changes to workflow revolved around increased coordination between departments and negotiation of interdepartmental roles and responsibilities. It was not always clear to those ordering nutrition products how the timing of their orders integrates into other departmental workflows. One informant shared that if an order was a "few minutes too late," it is possible that a patient could go without nutrition for as long as 12 hours. Additionally, some voiced concerns that the

"fit" of automating nutrition delivery into the pharmacy workflow may not be ideal. For example, gaps exist in medicine interaction and food allergen reconciliation.

Several participants noted an ongoing need for pharmacy and nutrition to have cross-training and collaborative opportunities to learn from each other. Last, a change in workload, primarily for leadership, was the increased safety and error reporting resulting from systems capable of error documentation. Yet informants acknowledged these errors were likely existing at higher rates pre-implementation of the automated nutrition systems but with lower ability to detect and document errors. Informants also identified potential changes to workloads due to procurement issues, such as delineating roles and responsibilities for nutrition product storage, or contingency planning for potential shortages. Table 14 details perceived impact of the automation innovation on workload and workflow before and after implementation across VHA job roles.

Table 14. Impact of Automating Delivery of Nutrition Supports on Perceived Workload and Workflow Before and After Implementation

Department/Role	Perceived Impact on Workload and Workflow Before Implementation of AND	Impact on Workload and Workflow After Implementation of AND
Inpatient pharmacists	• Concerns that workload would dramatically increase • Verifying nutrition orders is outside the scope of pharmacist training	• Nominal impact on workload (~5 orders a week, processed the same as medication) • Established protocols for verifying orders and limiting responsibility within pharmacists' scope of training • Errors hardly occurred so management of errors were nominal
Formulary managers BCMA coordinator	• Slippery slope of non-medication additions to BCMA • Takes more time to source, vet, and secure additional products	• Clear limits placed on the scope of items added to BCMA • Creation of a new position (Inventory Pharmacy Manager) to take on some duties
Nutritionists/dietitians	• Will increase feedback • Will reduce order entry time • Will reduce the need to physically visit patients to determine delivery and proper administration • Will increase morale: Allows the nutritionists to feel that their work matters/affects patient care	• Increases feedback on interventions • Reduces order entry time • Reduces the need to track down what is happening on the floors • Increases morale: Allows the nutritionists to feel that their work matters/ affects patient care
Nurses	• Concerned about increases in workload, although they wanted to be cued to administer nutrition through the electronic health record and document using BCMA and the electronic health record	• Improved accuracy and timing of delivery with cueing through systems already in use • Documentation was streamlined into system • Took no longer than administering a drug • Entire process improved and simplified workflow

Department/Role	Perceived Impact on Workload and Workflow Before Implementation of AND	Impact on Workload and Workflow After Implementation of AND
Food service	• Questions about changes in storage and delivery • Needed to learn and integrate new systems for receiving and creating orders	• No changes in storage and delivery • Learning new systems took significant effort, trial, and error, but was resolved quickly • Error reports became more frequent because of increased documentation, creating workload increase for leadership
Information technology	• Increase in items needed to code into the BCMA system • Needed to develop a system to communicate with food services about nutrition products that need to be delivered to units	• During development phase, spent 4 hours/week on developing the necessary infrastructure • Slight increase in workload with nutrition products to field barcode changes, additions, and issues

Abbreviations. BCMA=barcode medication administration.

In addition, although we were unable to interview staff in logistics and procurement roles involved in a post-implementation of automation of nutrition delivery, other staff reported the following concerns and impacts:

- Concerns about changes in responsibility for acquisitions, contracts, storage.
- Planning for contingencies like product shortages, recalls, and even small changes in product (*eg*, change of flavor), which would create larger problems when utilization is determined by barcode.
- Elevating nutrition products to the standards of pharmacy creates increased demand on logistics to vet products to ensure reliability and integrity of vendors and products.

Staff Satisfaction and Perceptions of Institutional Reputation

Several informants across different service lines spoke of the positive impact of automating nutrition delivery on their work satisfaction and overall morale as an employee. Nursing service informants reported that they have more system support to effectively implement nutrition interventions, which reduces their work stress. Dietitians reported having more feedback about intervention approaches, increased confidence that their expert recommendations are being implemented, and a more reliable way to evaluate the impact of interventions on patient health. Also, the potential conflict between service lines was alleviated post-implementation through improved verification and follow through on nutrition support orders. As one informant noted, nutritional support BCMA created "more transparency" for all providers involved in patient care and nutrition.

On the contrary, informants also noted the lack of consistency in the automation of nutrition supports across VHA institutions. Informants noted that this type of service is becoming standard at many of the VHA academic partner institutions, while it is still relatively rare in VHA hospitals. VHA staff informants were concerned that Veteran patient customers were comparing the care they receive at each institution; the way that nutrition supports are delivered (or not delivered) factors into these customer service perceptions. As one informant said:

> "I was also concerned about the different perceptions of care when nutrition is seamlessly automated in the BCMA system across the street, but not here. I didn't like that they could effectively get an intervention at the university hospital, but not get it when they transferred back to the VA."

DISCUSSION

A landmark 1999 Institute of Medicine (IOM) report estimated 44,000 to 98,000 Americans die annually from medical errors.[59] Automating the delivery of nutritional products for patients in the hospital setting may reduce medical errors while increasing successful nutritional support for at-risk populations. Yet it is unknown to what degree automation optimizes key clinical and patient outcomes. Also, it is unknown how hospital staff implementing and delivering nutrition supports experience such automation innovations.

Our systematic review identified 16 relevant studies that assessed the impact of various forms of automating the delivery of nutrition to hospitalized patients (KQ1). We identified no relevant studies for KQ2, exploring qualitative perceptions of hospital staff on nutritional delivery automation. For KQ1, most included studies were uncontrolled before-after studies ($N = 11$), with no studies rated as low ROB. Most studies were conducted with pediatric populations ($N = 11$), of which the majority involved infants in neonatal intensive care units. In the identified studies, the most common type of innovation was automating aspects of nutrition orders (*ie*, CPOE; $N = 12$), combined with additional features such as decision support tools or automations in compounding nutrition products. Only 5 studies involved interventions that automated some tasks associated with documenting that nutrition products had been delivered and given to patients at the bedside (Figure 4).

Across all three outcome categories, most studies reported improved outcomes associated with the automation innovation (*ie*, process outcomes, 90.9%; performance outcomes, 100%; patient outcomes, 85.7%). The only exception was patient harm; the three studies reporting this outcome showed no difference in temporary or serious harms before and after automation implementation (see Figure 8). Yet while the overall trend across results was consistent and positive, the COE for prioritized outcomes (*ie*, delivery errors, ordering errors, provider satisfaction) were all rated as very low. Certainty of evidence ratings were downgraded due to major limitations in the included studies' designs and high imprecision of estimates, or concerns about directness of the findings from included studies with populations of most interest to the VA (*ie*, majority infant populations in included studies vs all adults in VA hospital populations).

Figure 8. Outcome Trends by Automated Nutrition Delivery Intervention Type

Intervention Type[a] / Study	Process Outcomes			Performance Outcomes			Patient Outcomes				
	Supports Delivered	Ordering Errors	Delivery Errors	Provider Satisfactiaon	Staff Time	Time to Initiate Supplementation	Time to Regain Birthweight	Nutrients Consumed	Length of Hospital Stay	Hospital Readmissions	Patient Harms[b]
Computerized Provider Order Entry											
Crews, 2018[50]		■			■		■				
Eleni-dit-Trolli, 2009[55]								■			▭
Franco, 2016[48]		■						■			
de Rueda, 2015[43]	▭										
Oczujda, 2021[56]							■	■			
Sriram, 2017[57]									■	■	
Computerized Provider Order Entry + Calculator											
Alrifai, 2018[39]							■				
Huston, 2013[49]		■						▭			
Rochow, 2012[54]							■				
Computerized Provider Order Entry + Compounding											
Skouroliakou, 2005[47]		■			■						
Computerized Provider Order Entry + Decision Support											
Ziemba, 2019[41]	■					■		■	▭		▭
MacKay, 2016[46]			■								▭
Citty, 2017[42]	■			■							
Meehan, 2016[44]	■					■			■	■	
Barcode Scanner											
Steele, 2021[45]			■								
Electronic Medical Record Alerts											
Shliakhtsitsava, 2021[40]	■			■							

Notes. [a] Dark blue shading indicates the results favored the automation intervention, regardless of statistical significance. Orange shading indicates that an outcome was reported in the study but did not trend towards improvements in the automation intervention condition.

[b] All 3 studies reporting patient harms showed no difference in harms when comparing assessments before and after automation intervention implementation.

While we found no published qualitative studies to address KQ2, we conducted our own qualitative inquiry into staff perspectives on, and experiences with, automated nutrition delivery innovations within the VHA. We interviewed 12 VHA employees across 4 VA Health Care Systems who had interacted with, or participated in, attempts to implement an automated nutrition delivery system. Overall, staff expressed a robust rationale for using automated nutrition to both reduce staff workload and improve patient care and safety. While key informants had experience with a variety of automated nutrition delivery innovations, our findings support a core set of common implementation barriers and facilitators. Key VHA informants reported that the following factors made it easier to implement some type of automation of nutritional delivery in VHA hospitals: integration of an intentional planning period, use of a multidisciplinary implementation team, having a culture of innovation at their hospital, visible support of leadership (*eg*, time to participant in workgroups during regular tour of duty), effectiveness of building off existing VHA structures, and the essential role of a hospital staff member committed to implementing the change (*ie,* a local site champion).

Findings from our primary qualitative study highlighted both perceived and experienced workload barriers across different hospital staff roles (*eg*, nutrition, nursing, pharmacy, food service). The primary barriers to implementation centered on reservations within the pharmacy service line about adapting to perceived increases in workload and uncertainty with scope of duties outside of their professional expertise (*eg*, verifying nutritional orders without appropriate training) prior to implementation. In contrast, most VHA hospital staff informants, including the pharmacy service line, reported minimal impacts to their scope or workload after the start-up phase.

Taken together, the results of the systematic review show a generally consistent trend towards positive outcomes associated with the implementation of some form of automating nutritional support delivery to hospitalized patients. Findings from our qualitative study provide rich complementary contextual evidence of VHA staff with experience in implementing these types of automation innovations. Our findings are consistent with other recently published studies[60] evaluating automated nutrition delivery within hospitalized patients that also demonstrated improved patient outcomes and reductions in ordering or delivery errors. For example, a recent quality improvement (QI) project at the Phoenix VA Health Care System assessed the impact of adding enteral nutrition orders within the MAR, and using an existing medication barcode system for nutrition administration, documentation, and monitoring.[61] This uncontrolled before-after study reported improved documentation of enteral nutritional support received by patients. Additionally, of those nutritional supports ordered but not given to patients, nearly all had documented reasons within the MAR (*eg*, patient refusal, nutritional support unavailable), which provides hospital staff additional information to guide patient care. Lastly, our results are consistent with an older review of nutrition informatics applications which included decision support tools and CPOE applications focused on nutritional supports.[62] This review also found that nutrition-specific computerized applications can support improvement in patient outcomes and in clinician performance, specifically within the settings of delivery of nutrients, malnutrition rates, weight loss, blood glucose values, provider efficiency, and rates of error.

Findings from our systematic review and primary qualitative study, coupled with recently published studies, characterize several key considerations for automated nutrition delivery implementation. First, implementation of automated nutrition delivery within a hospital setting is a multi-disciplinary effort. Most of the studies of our review were based on reports from QI projects that described multi-disciplinary planning teams. These planning teams focused on mapping automated nutrition delivery impacts on diverse hospital service lines prior to implementation.[50,63,64] Second, most studies reported on the necessity of robust education and training across hospital service lines prior to implementing

automated nutrition delivery innovations. One study detailed an interdisciplinary workgroup to foster collaboration and ongoing education between pharmacy and nutrition staff.[64] Findings from our primary qualitative study also found a need for early and ongoing training to sustain successful outcomes and support collegial collaboration across staff involved in automated nutrition delivery innovations. Finally, the limited evidence suggests that staff involved with automated nutrition delivery tend to have positive impressions of the impact of these innovations on the care they provide.[40,42,64] We found similar impressions among VHA staff interviewed for our qualitative study, who also reported that automating nutrition delivery had minimal impacts on workload after the initial start-up phase.

Limitations

Our results should be interpreted with caution due to limitations of the identified literature. Specifically, most studies assessing the impact of automated nutrition delivery were uncontrolled study designs, with only 1 identified randomized trial. Yet, the dearth of randomized controlled studies in this area is unsurprising. For complex interventions delivered at a system level, such as automating the delivery of nutrition supports, it may not be practicable to conduct randomized trials in many settings. A majority of the studies were also rated as having considerable ROB concerns, a key factor in the overall very low COE ratings. Populations explored were of limited applicability to hospitalized Veterans. Nearly 70% of the literature we identified centered on the use of automated nutrition delivery innovations among hospitalized children; it is unclear whether those findings would translate to adult hospitalized patients who may have more control or autonomy over their nutritional consumption. Moreover, no studies reported subgroups by patient characteristics. A more robust exploration of patient subgroups (*eg*, by age, health status, comorbidities, length of hospital stay) could indicate which group of patients would benefit from more robust innovations that integrate automatic triggers to monitor nutritional support administration.

While we were able to characterize automation features of such nutrition delivery interventions across the nutrition delivery process (Figure 4), literature identified in this review focused mostly on automating ordering tasks; we have considerably fewer studies evaluating the utility of documenting and monitoring administration of nutritional supports at the bedside found in eMAR and BCMA innovations. We also found no published qualitative studies exploring hospitalized staff perceptions and experiences with automated nutrition delivery. We addressed this weakness in extant literature by conducting our own qualitative study, which to our knowledge is the first of its kind.

We are also limited in our ability to draw strong conclusions about which type of automated nutrition delivery innovation works best for what setting or populations due to heterogeneity across included studies. For any one outcome, there were relatively few studies. Moreover, outcomes and interventions varied widely across included studies, limiting our ability to conduct meta-analysis in many instances. We were also unable to provide direct or indirect comparisons between types of automated nutrition delivery innovations and their comparative impacts on patient, process, and performance outcomes due both to high heterogeneity in outcomes and interventions and incomplete data reporting across studies. While not a specific focus of this review, we did note any use of implementation science strategies (*eg,* implementation facilitation, audit, and feedback) used in the included studies. We found no evidence of their explicit use in facilitating integration of automated nutrition delivery innovations within hospital settings.

FUTURE RESEARCH

This comprehensive review of the literature identified several gaps in the current evidence that warrant future investigation. To inform future work in this area, we consider the PICO framework (Table 15). This approach considers the population, intervention, comparator, and outcome to identify gaps.

Table 15. Overview of Evidence Gaps

Domain	Evidence Gap/Area for Future Exploration

Population	• Adult hospitalized patients
	• Subgroup exploration by key patient populations related to the following:
	  ○ Age
	  ○ Comorbidity
	  ○ Length of hospital stay

Intervention	• Barcode medication administration • Electronic medication administration record • Bundle automation process improvement projects with various implementation strategies such as external facilitation, audit and feedback, or training
Comparator	• Head-to-head comparisons of types CPOE modalities, with and without additional features such as clinical decision supports or integrated calculators • Robust comparative designs including both randomized trials and comparative non-randomized designs meeting Cochrane EPOC standards)
Outcomes	• Rich qualitative explorations of staff experience with automation innovations across diverse service lines (*eg,* pharmacy, nutrition, nursing, food service) • Robust measures of staff satisfaction • Patient-level outcomes such as patient satisfaction, length of hospital stay, and hospital readmissions • Process outcomes, especially delivery errors

Abbreviations. CPOE=computerized provider order entry; EPOC=Effective Practice and Organisation of Care.

CONCLUSIONS

Food is medicine and many hospitalized patients are at risk of malnutrition during their care. Automating nutritional support delivery offers a way to standardize and document the ordering, administration, and monitoring of essential nutritional supports to hospitalized patients. Without such systems, it is difficult to ascertain if the right nutritional products are getting to the right patient at the right time. Automating nutrition support delivery offers additional benefits, such as potential reductions in hospital staff time in ordering nutritional products. Numerous national professional societies have advocated for innovations to support the provision of nutritional products to hospitalized patients to reduce health care errors and maximize safety and quality. Our review provides evidence to support the positive impacts that automated nutrition delivery innovations may have on both hospital staff and the patients under their care. The VHA implemented BCMA software nationwide in 2000; yet it is unclear how the modernization of the VHA electronic health record may impact local automated nutrition delivery innovation. VHA is in a unique position to advance the science on optimizing the safety, accuracy, and efficiency of inpatient nutrition delivery via automation. [25,27-29,57,65-67]

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