Critical Care Explorations

A Scoping Review of Implementation Science in Adult Critical Care Settings

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Objectives: The purpose of this scoping review is to provide a synthesis of the available literature on implementation science in critical care settings. Specifically, we aimed to identify the evidence-based practices selected for implementation, the frequency and type of implementation strategies used to foster change, and the process and clinical outcomes associated with implementation.

Data Sources: A librarian-assisted search was performed using three electronic databases.

Study Selection: Articles that reported outcomes aimed at disseminating, implementing, or sustaining an evidence-based intervention or practice, used established implementation strategies, and were conducted in a critical care unit were included.

Data Extraction: Two reviewers independently screened titles, abstracts, and full text of articles to determine eligibility. Data extraction was performed using customized fields established a priori within a systematic review software system.

Data Synthesis: Of 1,707 citations, 82 met eligibility criteria. Studies included prospective research investigations, quality improvement projects, and implementation science trials. The most common practices investigated were use of a ventilator-associated pneumonia bundle, nutritional support protocols, and the Awakening and Breathing Coordination, Delirium Monitoring/Management, and Early Exercise/Mobility bundle. A variety of implementation strategies were used to facilitate evidence adoption, most commonly educational meetings, auditing and feedback, developing tools, and use of local opinion leaders. The majority of studies (76/82, 93%) reported using more than one implementation strategy. Few studies specifically used implementation science designs and frameworks to systematically evaluate both implementation and clinical outcomes.

Conclusions: The field of critical care has experienced slow but steady gains in the number of investigations specifically guided by implementation science. However, given the exponential growth of evidence-based practices and guidelines in this same period, much work remains to critically evaluate the most effective mechanisms to integrate and sustain these practices across diverse critical care settings and teams.

Key Words: critical care; dissemination science; evidence-based practice; implementation science; intensive care; scoping review

Implementation science (IS) is a field of study that seeks to identify optimal methods for accelerating the systematic uptake of research findings and other evidence-based practices (EBPs) into routine clinical care (1). An evolving area of inquiry and growing priority for health-related funding agencies, IS applies theories borrowed from other disciplines (e.g., psychology, sociology, organizational change) as well as field-specific conceptual models and frameworks. These theories are generally used to: 1) describe the process of translating research into practice (process models), 2) understand what contextual factors serve as barriers and facilitators to implementation (determinant frameworks), 3) provide a structure for evaluating implementation endeavors and outcomes (evaluation frameworks), and 4) describe how change can occur in areas where intention to change is absent (classic theories) (2, 3). The number of theories, models, and frameworks are prolific, and integration of these into complex health systems often requires additional considerations regarding change mechanisms, meditators, moderators, and both proximal and distal outcomes (3, 4). Identification of an applicable model for implementation is critical in complex healthcare systems where sustained application of EBPs can improve quality and safety of care, limit harmful practice variability, and reduce soaring costs. Model-based approaches to evidence implementation and practice change can also be

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considerably effective in high priority, time sensitive initiatives, such as those recently experienced in the setting of the coronavirus disease 2019 pandemic.

IS overlaps with several other fields, including quality improvement (QI), dissemination science, and knowledge translation. Approaches are similar in terms of populations of interest, metrics to evaluate process and clinical outcomes, incorporation of existing clinical data, emphasis on stakeholder involvement, and goal of bridging the research to practice gap to improve health (1). The main distinction between fields lies in their focal intent. IS aims to produce "generalizable knowledge" and evidence about effective strategies and outcomes associated with sustained integration of established but underutilized EBPs into routine practice (1). In contrast, QI mainly aims to streamline processes and eliminate inefficient practices locally, commonly via rapid-cycle improvement. In QI, the change initiative may be linked to a best practice or scientific evidence, but this is not a requirement, as many initiatives focus solely on process improvement. The focus of QI is generally narrower than dissemination and IS. Dissemination science has a broader focus on studying the targeted distribution of information and intervention materials to a specific public health or clinical practice audience and spreading information using communication and education strategies (5). Finally, knowledge translation refers to a dynamic and iterative process of synthesis, dissemination, exchange, and application of knowledge. Knowledge translation promotes information not only from research to practice but also from practice back to research to identify gaps and guide future research priorities (1).

A key development in IS is a common nomenclature for implementation strategy terms, definitions, and categories that can be used to guide implementation research and practice across settings (6). This work evolves from leaders in IS (7) who advocate that knowledge of EBPs must be accompanied by knowledge of implementation in order to successfully integrate evidence-based interventions. Implementation strategies are organized into categories to provide guidance on approaches to successfully implement evidence-based interventions. For example, Flodgren et al (8) used select systematic reviews produced by the Cochrane Effective Practice and Organisation of Care group to identify, define and provide evidence for seven general strategies (i.e., printed educational materials, educational meetings, educational outreach, local opinion leaders, audit and feedback, computerized reminders, and tailored interventions). A separate taxonomy includes four domains (professional, financial, organizational, and regulatory) and 49 distinct strategies (9). Additionally, Powell et al (10) established a compilation of 73 implementation strategies, called the Expert Recommendations for Implementing Change (ERIC) strategies. Ultimately, local contextual need and assessment of facilitators and barriers should be primary drivers influencing selection of implementation strategies (8).

While there is evidence on the effectiveness of certain implementation strategies to increase EBP utilization in a variety of settings, the feasibility of these strategies in critical care units is unknown. In addition to the complexity of interventions, the very nature of the critical care environment poses unique considerations and contexts for EBP integration. A growing body of literature demonstrates a large proportion of critically ill patients do not receive evidence-based or guideline recommended care (11). This failure to apply EBPs during critical illness often leads to significant short- and long-term morbidity and mortality (11). Establishing the current state of knowledge regarding common strategies and IS efforts in critical care settings is an important step in addressing how to best sustain delivery of evidence-based interventions.

The purpose of this scoping review is to provide a synthesis of the available literature related to IS in critical care in terms of the volume, nature, and characteristics of studies conducted to identify existing knowledge gaps. We were specifically interested in identifying which EBPs were targeted for improvement, which implementation strategies were used to foster change, and which outcomes were evaluated.

MATERIALS AND METHODS

This scoping review was conducted by a research team with expertise in IS, critical care, EBP, and systematic review methodology. The review adhered to the process outlined by Grant and Booth (12) and the checklist for Preferred Reporting Items for Systematic reviews and Meta-Analyses extension for Scoping Reviews (13). The Covidence systematic review software was used for all stages of the review process, including title and abstract screening, full text review, and data extraction.

Research Question

The research question guiding the scoping review was, "What are the implementation strategies, associated EBPs, and outcomes evaluated in studies conducted in critical care settings?"

Search Strategy

A librarian-assisted search was performed on October 30, 2019, using three electronic databases: Medline, PubMed, and Cumulative Index to Nursing and Allied Health Literature. The databases were selected to be comprehensive and cover a range of disciplines. The following key words were used: IS, implementation, critical care, ICU, and EBP (**Appendix A**, http://links.lww.com/CCX/A455). The search was limited to articles published between January 1999 and July 2019 to coincide with the EBP movement and development of the relatively new field of IS. Reference lists of included articles were reviewed and hand searching was performed to identify other relevant literature not captured by the electronic search.

Inclusion and Exclusion Criteria

Articles were included if they: 1) reported outcomes of a research study, QI effort, or program aimed at disseminating, implementing, or sustaining an EBP, 2) described use of any of the 73 implementation strategies outlined in the ERIC project (8), 3) were conducted in a critical care unit, and 4) involved adults. Because of limited resources for translation, articles published in languages other than English were excluded. We also excluded reviews, commentaries, editorials, abstracts, and conference proceedings on the basis that these would not provide the level of detail sought in our review. Finally, literature that included work conducted outside

the critical care setting or involving children was excluded, as evidence-based interventions/practices would likely differ by level of care and age.

Data Abstraction

Two reviewers (M.M., M.C.B.) independently screened titles and abstracts of identified articles to determine eligibility. The same two reviewers then performed full text review in duplicate, with conflicts resolved by an independent third reviewer (D.O.). Reviewers customized data extraction fields in Covidence to align with aims of the review. Two reviewers tested extraction fields for consistency and fidelity to project aims (M.M., H.R.). The same two reviewers independently extracted data from articles into required fields. Extracted data were compared between reviewers for consensus prior to finalizing the extraction forms. The following data were extracted from included articles: year and country of publication, project aim, design, theory or framework used to guide the project, setting, EBP implemented, components of the EBP intervention, implementation strategies, and clinical/implementation outcomes.

RESULTS

The combination of search terms with selection criteria and limits yielded 1,707 studies. Of these, 40 duplicates were removed, leaving 1,667 studies for title and abstract screening (**Fig. 1**). Of these, 1,426 were excluded for not meeting initial inclusion criteria (i.e., title or abstract indicated non-adult population, noncritical care setting, or literature review), resulting in 241 articles that underwent full text review, with a moderate level of agreement (κ = 0.450), of which an additional 159 were excluded for the following reasons: literature review (n = 69), non-ICU setting (n = 41), non-eligible study design (n = 31), did not evaluate an implementation strategy (n = 16), or not in English (n = 2). A total of 82 studies were included in the final review.

Characteristics of Included Studies

Of the studies that met inclusion criteria for this review, some (n = 20) were specifically described by the authors as IS studies and a similar number (n = 19) designated as QI projects. The remaining studies (n = 43) were identified neither as IS or QI by their authors but rather described a variety of prospective implementation (PI) evaluations or designs, such as prospective cohort, time series, or pre/post evaluation study designs. Such studies will be referred to here as having PI designs. **Figure 2** displays these design categories according to year of publication. The PI designs were the most common type in every time period, with the largest number occurring during the period 2005–2009. QI designs were used less frequently in the earlier time periods, with substantial increases in recent years. Similarly, there were few IS designs for the initial time periods, but reports have doubled within the last 5 years. None of the studies included in this review examined systematic de-implementation of low value practices.

Supplemental Table 1 (http://links.lww.com/CCX/A456) provides an overview of the studies included in the review according to the design categories. Studies using IS designs were conducted most often in the United States (n = 9) (14–22) and Canada (n = 7) (23–29) followed by Australia (n = 2) (30, 31), the Netherlands (n = 1) (32), and the United Kingdom (n = 1) (33). Within the PI category, studies were conducted most frequently in the United States (n = 25) (34–59) followed by Canada (n = 3) (60–62), Spain (n = 3) (63–65), Germany (n = 2) (66, 67), Norway (n = 2) (68, 69),

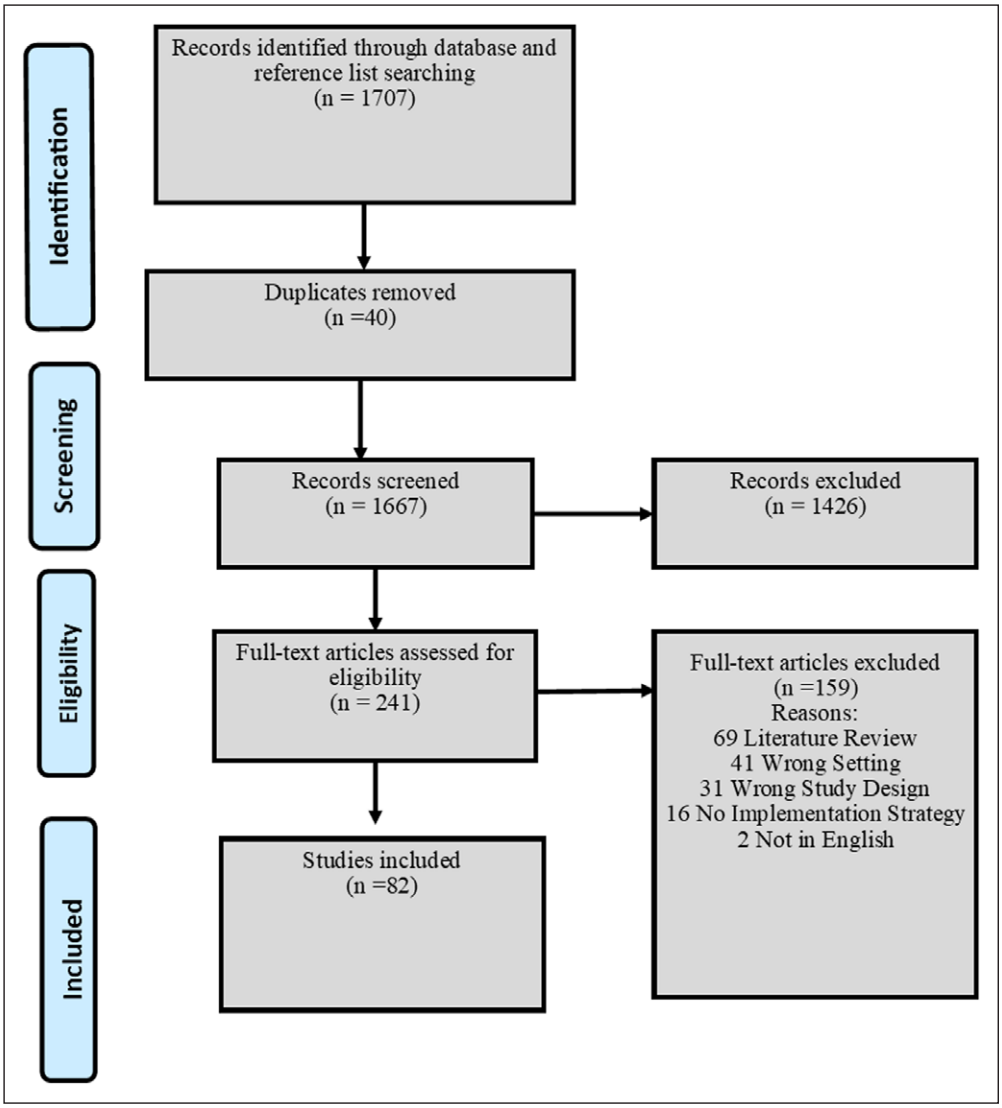

Figure 1. Preferred Reporting Items for Systematic Reviews and Meta-Analyses flow diagram.

and one study each from South Africa (70), Argentina (71), China (72), France (73), The Netherlands (74), Saudi Arabia (75), and the United Kingdom (56). Studies that reported using a QI design were conducted in the United States (n = 11) (76–86), Australia (n = 2) (87, 88), and one each in Brazil (89), Canada (90), China (91), Sweden (92), Taiwan (93), and the United Kingdom (94). Many studies (30/82, 36.5%) included more than one critical care unit in their investigation.

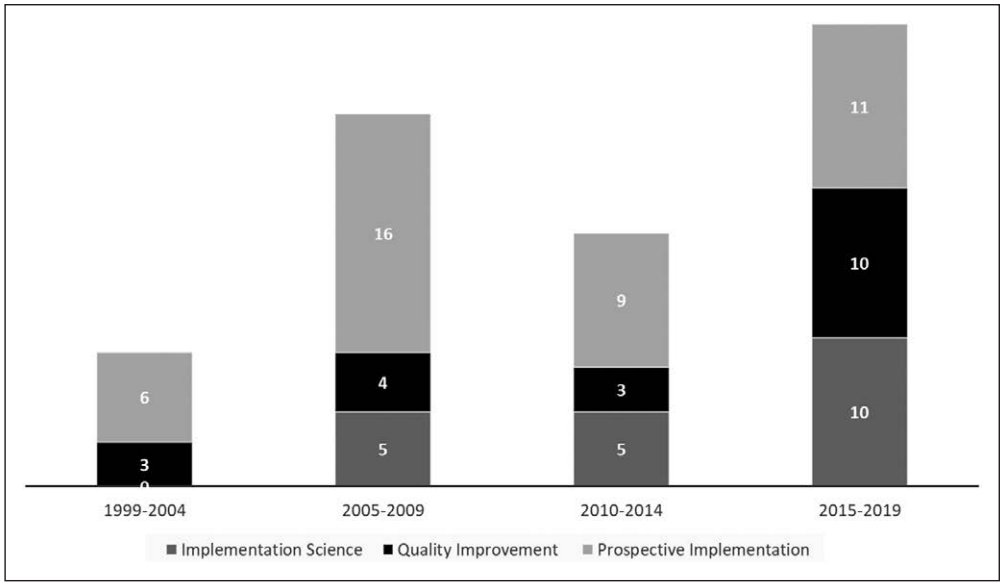

Figure 2. Year and type of publication.

EBPs Implemented

Figure 3 displays the EBPs implemented in the 82 studies. The studies addressed a variety of EBPs, classified into 18 categories. The most common EBPs included: ventilator-associated pneumonia (VAP) prevention bundles (12/82, 14.6%) (14, 33, 39, 49, 54, 55, 57, 59, 60, 63, 73, 86), nutritional support/management protocols (9/82, 10.9%) (25, 26, 30, 35, 38, 40, 61, 88, 90), the Awakening and Breathing Coordination, Delirium Monitoring/Management, and Early Exercise/Mobility (ABCDE/ABCDEF) bundle (7/82, 8.5%) (15–19, 47, 76), central line-associated bloodstream infection (CLABSI) prevention bundles (6/82, 7.3%) (22, 37, 42, 52, 53, 80), and mechanical ventilation liberation/weaning protocols (6/82, 7.3%) (36, 62, 69, 72, 90, 93). Sixteen studies involved ICU mobilization protocols (4/82, 4.8%) (34, 46, 70, 78), use of checklists (4/82, 4.8%) (41, 81, 84, 89), hand hygiene/infection control bundles (n = 4/82, 4.8%) (21, 66, 71, 95), and initiatives targeting multiple EBPs (4/82, 4.8%) (24, 51, 56, 77). The remaining studies focused on antibiotic stewardship (3/82, 3.6%) (22, 65, 67), analgesia/sedation protocols (3/82, 3.6%) (68, 75, 96), palliative/end-of-life care bundles (3/82, 3.6%) (20, 32, 85), pressure ulcer prevention (3/82, 3.6%) (43, 83, 94), venous thromboembolism (VTE) prophylaxis (2/82, 2.4%) (28, 29), laboratory reduction guidelines (2/82, 2.4%) (48, 87), the surviving sepsis campaign bundles (2/82, 2.4%) (64, 82), interdisciplinary rounding/handover tools (2/82, 2.4%) (31, 58), and "other" EBPs (7/82, 8.5%) (27, 44, 45, 50, 74, 79, 92).

Temporal trends were noted by EBP category. For example, studies involving nutritional support and management, VAP, and CLABSI prevention practices were more commonly published between 2004 and 2011, while those focusing on palliative/end-of-life care, the ABCDE/ABCDEF bundle, and interdisciplinary rounding were more recent. Similarly, the complexity and number of components included in the EBP change initiatives appeared to change over time. For example, early VAP prevention bundles targeted the use of head of bed elevation, oral care, ventilator tubing condensate removal, and hand hygiene/glove use, while more recent bundles added sedation and mechanical ventilation liberation procedures and protocols. Similarly, more recent studies generally included EBPs involving members of an interdisciplinary team working together to deliver the EBP, rather than a single discipline.

Implementation Strategies

Figure 4 displays implementation strategies used in the included studies. Sixteen different ERIC strategies were described and include: educational meetings, audit and feedback, develop tools, local opinion leaders, develop effective materials, inform stakeholders, ongoing consultation, distribute materials, ongoing training, develop systems, facilitators and barriers, scale up, academic partnerships, financial incentives, and building a coalition. Of these strategies, educational meetings (56/82, 68.2%), auditing and feedback (55/82, 67.1%), developing tools (26/82, 31.7%), and use of local opinion leaders (18/82, 21.9%) were used most frequently. Most studies (76/82, 92.6%) reported using more than one strategy when implementing an EBP. Twelve studies reported use of a single strategy for EBP implementation. Single strategy approaches included auditing and feedback (23, 26, 27, 65, 66), facilitators and barriers (15, 16, 18, 32), financial incentives (36), building a coalition (19), and educational training (72). Across all types of designs, none specifically explored the role of mediators for their effect on implementation or clinical outcomes or as causal components in the relationship between implementation strategies and outcomes.

Outcomes Evaluated

Studies reported both clinical and implementation outcomes (**Supplemental Table 2**, http://links.lww.com/CCX/A457). Across all study designs, many reported only clinical outcomes (44/82, 53.6%) (22, 34, 36–38, 40, 41, 43–50, 52, 54–56, 60–66, 68, 70, 72, 75, 77–81, 83, 85, 87, 88, 90–94), while few reported solely implementation outcomes (15/82, 18.3%) (15–20, 24, 27, 28, 32, 51, 57, 67, 95, 96), and some reported both clinical and implementation outcomes (22/82, 26.8%) (14, 21, 23, 25, 26, 29, 30, 32, 39, 42, 53, 58, 59, 62, 71, 73, 74, 76, 82, 84, 86, 89). Primary clinical outcomes were most often linked to the EBP that was evaluated (e.g., VAP bundle implementation reported VAP rates), rather than solely surrogate metrics such as mortality or length of stay. The most frequently reported primary clinical outcomes included VAP rates

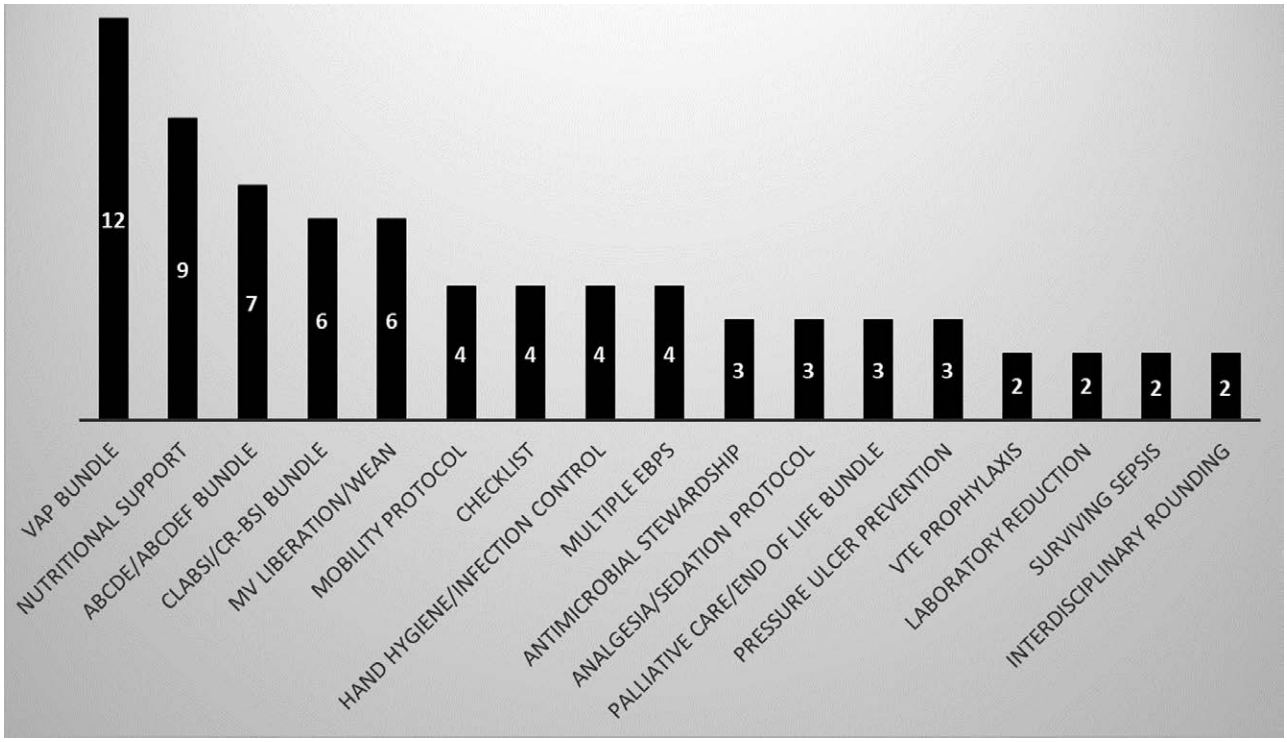

Figure 3. Evidence-based practices evaluated. ABCDE/ABCDEF = Awakening and Breathing Coordination, Delirium Monitoring/Management, and Early Exercise/Mobility, CLABSI = central line-associated bloodstream infection, CR-BSI = catheter-related bloodstream infection, EBPS = evidence-based practices, MV = mechanical ventilation, VAP = ventilator-associated pneumonia, VTE = venous thromboembolism.

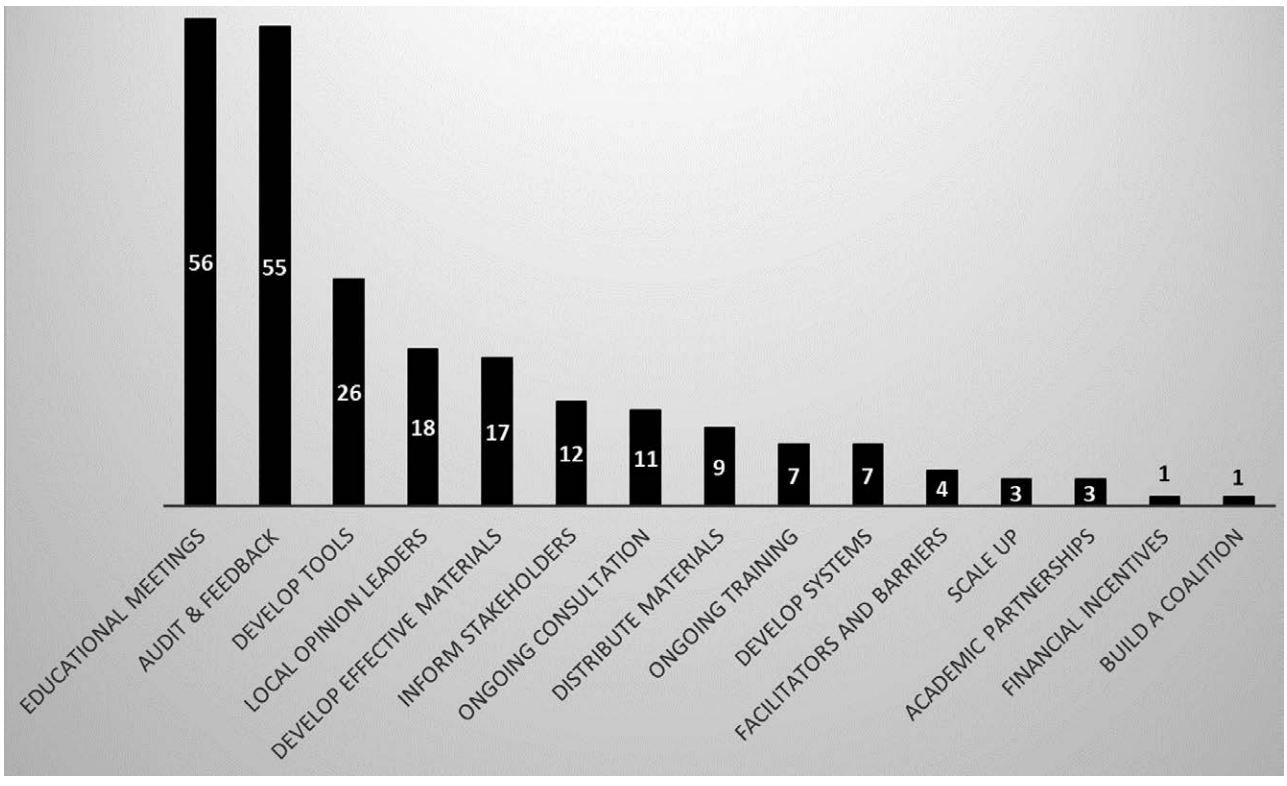

Figure 4. Implementation strategies.

(14, 33, 39, 54, 55, 59, 60, 62, 63, 75, 86), ventilator days/duration of mechanical ventilation (33, 34, 38, 46, 47, 62, 68, 72, 75, 78, 91), catheter-related bloodstream infection/CLABSI (21, 22, 37, 42, 52, 53, 81, 83), nutrition adequacy (25, 26, 40, 61), or time/duration of nutrition therapy (35, 38, 44, 88, 90). Primary clinical outcomes were reported as rates or continuous values, rather than through use of standardized outcome scales. Implementation outcomes are those identified by Proctor et al (97) and include acceptability, adoption, appropriateness, feasibility, fidelity, cost, penetration, and sustainability. The most frequently reported implementation outcome was fidelity, often reported as either percentage of adherence or compliance to the EBP that was implemented, rather than through use of standardized tools or scales (14, 18–26, 29, 30, 32, 33, 39, 42, 51, 53, 57–59, 62, 67, 71, 73, 74, 76, 82, 84, 86, 89, 95, 96). Other implementation outcomes included adoption (14, 22, 23, 30, 31), or qualitative evaluations of facilitators/barriers and perceptions of the EBP, and descriptions of team composition/building a coalition (15–17, 19, 26–28, 31). For both clinical and implementation outcomes, reporting of the various metrics across all study types was substantially heterogeneous by measurement type, duration, and frequency, rendering pooling of data difficult. However, the majority of studies reported positive improvements in both clinical and/or implementation outcomes, regardless of study design.

Specific IS Investigations

Given our specific interest in IS in critical care units, we identified a subset of articles (n = 20) as having a specific IS design, including an established IS framework, and evaluating effectiveness of implementation strategies specifically on implementation outcomes (97). The frameworks, aims, strategies, and outcomes of these studies are listed in **Table 1**. Various models or frameworks guided the implementation studies, with the Knowledge to Action Framework used most often (25, 26, 31), followed by The Grol Model of Implementation (21, 32). Other implementation models are listed in Table 1. Many of the studies (n = 11) included multiple ICUs. Specific EBPs evaluated in these studies included VAP prevention bundles (14, 33), ABCDEF bundle (15–19), nutrition therapy (25–27, 30), antibiotic use (23), communication practices (31), palliative care consultation (20), CLABSI prevention (21, 22), VTE prophylaxis (28, 29), and multiple EBPs (24). One additional study specifically evaluated readiness for and barriers to implementation of EBPs (32).

A variety of implementation strategies were evaluated within this subset of IS specific designs (Table 1). The majority of studies (n = 13) evaluated more than one IS strategy, with auditing and feedback incorporated most often across studies (n = 13) (14, 17, 20–22, 25–27, 29–31, 33). Eight studies evaluated a single implementation strategy (15, 16, 18, 19, 23, 26, 27, 32), namely identifying facilitators and barriers (15, 16, 18, 32), building a coalition (19), and auditing and feedback (22, 26, 27).

Outcomes evaluated across the IS studies included implementation and clinical outcomes as described by Proctor et al (97). The most frequent implementation outcome evaluated was fidelity (reported as adherence) to the EBP (17, 19–21, 23, 24, 26, 29–33). Only one study included adoption as an implementation outcome (14). Additionally, a subset of studies specifically evaluated facilitators and barriers to implementation (15, 16), effective implementation strategies (28), or perceptions of auditing and feedback as a strategy using a qualitative approach (27). In addition to implementation outcomes, five of the studies also evaluated clinical outcomes; these included VAP rates and/or ventilator days (14, 33), mortality (30), and CLABSI rates (21, 22).

DISCUSSION

This is one of the first reviews to synthesize the available literature related to IS in critical care. We found significant variability in project nomenclature and designs aimed at evaluating strategies to implement an EBP and determine effect on outcomes. Despite these variations, findings across all project designs did demonstrate positive effects on clinical outcomes, highlighting the importance of EBPs in critical care. Within the dates of our review, the number of published studies in the critical care literature that reported being guided by IS has increased steadily, doubling in the last 5 years. The complexity and number of components included in the EBPs selected for improvement has similarly increased over time. Most of the EBPs studied required the input, decision-making, and performance of tasks by multiple ICU team members, rather than relying on a single disciple for implementation. While a variety of methods were used to foster adoption of these EBPs into critical care, a limited number of ERIC strategies were used (16/73), and few projects evaluated implementation outcomes, making it difficult to definitely conclude which strategies were most effective.

An inherent challenge to advancing IS work in critical care settings is the vast heterogeneity of strategies and outcomes used across projects that precludes pooling and synthesis of findings. Many projects in this review evaluated specific IS strategies, yet used a variety of terms to describe the project, and did not use consistent mechanisms for measuring and evaluating the strategies. The field of IS has had major gains in this area by using concept mapping, developing operational definitions and categories for implementation strategies, and establishing measurement tools to provide a consistent and scientific approach to these investigations. Nevertheless, this review confirms mixed evidence as to which design approach is most effective, which specific strategies are superior, and whether multiple strategies versus a single strategy is effective for successful practice change (6). In addition, the extent to which mediating factors are present and influence effectiveness of strategies warrants consideration, given the complexity of critical care environments. Ultimately, a systematic approach is needed using standardized designs, strategies, and both clinical and implementation outcomes in critical care settings to increase widespread adoption of EBPs.

We also found significant variation in outcomes evaluated in our review. Across all project designs, many only reported clinical outcomes. Among the few that reported implementation outcomes, these were limited to fidelity (adherence and compliance) and adoption. While these are certainly important components of initial EBP implementation, other outcomes such as acceptability, appropriateness, penetration, and sustainability would yield critical information on characteristics of the EBP that would advance widespread integration over time and across settings. Integration

TABLE 1. Summary of Implementation Science Specific Designs and Studies ($n = 20$)

References	Country	Framework	Study Aim	Strategies	Study Outcome
Abbott et al (14)	United States	Academic Center for Evidence-Based Practice star model; Predisposing, reinforcing, enabling constructs in educational diagnosis and evaluation/policy, regulatory, and organizational constructs in educational and environmental development	Determine effect of VAP prevention bundle on VAP rates	Stakeholders, audit and feedback, education, develop systems	VAP frequency: Variable across three ICUs; initial decrease below benchmark but not sustained Adoption: head of bed 77–69%; oral care 22–30%; empty condensate 94–93%; gloves 74–90%
Balas et al (15)	United States	Consolidated framework for implementation research	Identify facilitators and barriers to awakening and breathing coordination, delirium monitoring/management, and early exercise mobility bundle adoption; evaluate if bundle implementation was effective, sustainable, and conducive to dissemination	Assess readiness and barriers	Facilitators: Evidence, leadership Barriers: Adaptability, complexity, workload, staff, communication, documentation
Boehm et al (17)	United States	Outcome production model	Understand the relationship between organizational domains and provider attitudes towards implementation of the ABCDEF bundle	Develop tools, audit and feedback, local opinion leader, education	Adherence: Increased with use of tools (protocols) ($r = 0.37–0.58$), role clarity ($r = 0.38–0.59$), training ($r = 0.33–0.46$), local opinion leaders ($r = 0.37–0.48$), teamwork ($r = 0.36–0.44$)
Boltey et al (16)	United States	Shared mental model	Examine how components of shared mental model impact implementation of ABCDEF bundle	Assess readiness and barriers	Facilitators: Awareness of shared mental model can impact routine implementation Adherence via self-report (84% adherence sometimes; 51% routine adherence)
Carrothers et al (18)	United States	Not stated; survey	Identify which contextual factors facilitate/hinder implemen tation of ABCDE bundle in four San Francisco Bay ICUs	Assess readiness and barriers	Facilitators: Leadership, culture, champion, training, and support Barriers: Resources, turnover, knowledge, staffing
Costa et al (19)	United States	Not stated; survey	The purpose of this study was to describe team composition in ABCDE delivery and test the hypothesis that frequent involvement of a diverse team was associated with high levels of ABCDE implementation	Implementation teams	Adherence: Higher odds of adherence to spontaneous awakening trials (OR, 4.2), delirium management (OR, 3.6), and mobility (OR, 2.3) when team approach utilized
Doig et al (30)	Australia and New Zealand	Browman's clinical practice guideline development cycle	Determine whether evidence-based feeding guidelines could be implemented using a multifaceted practice chance strategy to improve feeding and mortality among ICU patients	Local opinion leader education, reminders audit and feedback, ongoing training	Mortality: Similar between guideline vs control groups (28.9% vs 27.4%, respectively) Days to initiate feed: 0.75 d for guideline group vs 1.37 d for control group Adherence: 94% for guideline group; 72% for control group

(*Continued*)

TABLE 1. (*Continued*). Summary of Implementation Science Specific Designs and Studies (*n* = 20)

References	Country	Framework	Study Aim	Strategies	Study Outcome
Elligsen et al (23)	Canada	Not stated	Evaluate the impact of prospective audit and feedback on broad spectrum antimicrobial use among critical care patients	Audit and feedback	Antibiotic use: Decreased from 644 to 503 d of therapy per 1,000 patient-days
Hawe et al (33)	United Kingdom	Not stated	Describe the effects of an active multifaceted implementation of a VAP prevention bundle designed to improve staff compliance with evidence-based actions and reduce the frequency of VAP	Education, written materials, auditing and feedback; passive (phase I) vs active implementation (phase II)	Adherence: Increased from 0% to 54% VAP frequency: Decreased from 19.2 to 7.5 per 1,000 ventilator days Ventilator days: Decreased from 2,556 to 1,327
Ilan et al (24)	Canada	Not stated	Describe prescription rates of commonly recommended best practices for critically ill patients and determine factors associated with increased rates of prescription	Standardized order sets, specialty consultation	Adherence: VTE prophylaxis: 95.3% Antibiotic prophylaxis: 94.1% Stress ulcer prophylaxis: 89.7% Enteral nutrition: 72.4% Insulin infusion: 58.8% Low tidal ventilation: 53.8% Perioperative beta blockers: 40% Steroids for shock: 20% Specialty mattress: 17.6% Interruption of sedation: 8.3%
Jain et al (25)	Canada	Knowledge to action framework	Compare the effectiveness of active to passive dissemination of the Canadian clinical practice guidelines for nutrition support for the mechanically ventilated critically ill adult patient	Local opinion leader, education, audit and feedback, develop tools, tailor strategies, education, distribute materials, develop effective materials, ongoing consultation	Enteral nutrition adequacy: Increased from 42% to 50% Enteral nutrition initiation: Increased from 52% to 58%
Noome et al (32)	The Netherlands	Grol and Grimshaw model for implementation	Examine the effectiveness of supporting ICUs on implementing the guidelines	Assess readiness and barriers	Adherence: 0.71 mean scores for control; 0.72 mean scores for intervention group
Penrod et al (20)	United States	Provonost model for knowledge translation	Evaluate implementation of care and communication bundle for palliative care	Audit and feedback, develop tools, education, ongoing consultation	Bundle adherence: Increased from a range of 13–40% to 20–60%
Reynolds et al (21)	United States	Grol and Wensing model of implementation	Determine whether using tailored, multifaceted strategies would improve implementation of daily chlorhexidine bathing and decrease CLABSIs	Educational outreach, audit and feedback, local opinion leaders, printed educational materials	Compliance: Increased from 57% to 80% CLABSI rates: Decreased from 2.8 to 1.2 per 1,000 central line days
Sauro et al (28)	United States	TRIP model	Describe use of IS at the unit level and organizational level to guide an intervention to reduce CLABSI in BICU	Inform/engage stakeholder, develop systems, audit and feedback, develop tools	CLABSI rates: Decreased from 15.5 to 0 per 1,000 central line days
Sinuff et al (27)	Canada	Qualitative/IS	Identify clinician perspectives of auditing and feedback	Audit and feedback	Perceptions of audit and feedback: Poor transparency, feedback should be timely, communication should be continuous, encourage peer to peer discussion/leadership engagement

(*Continued*)

TABLE 1. (*Continued*). Summary of Implementation Science Specific Designs and Studies (*n* = 20)

References	Country	Framework	Study Aim	Strategies	Study Outcome
Sinuff et al (26)	Canada	Knowledge to action framework	Determine whether auditing practice and providing feedback in the form of benchmarked reports site reports is an effective strategy to improve adherence to nutrition guidelines	Audit and feedback, develop tools, education, develop systems, develop effective materials	Adherence: Increased from 71% to 81%
Sood et al (22)	United States	TRIP model	Describe use of IS at the unit level and organizational level to guide an intervention to reduce CLABSI in BICU	Inform/engage stakeholder, develop systems, audit and feedback, develop tools	CLABSI rates decreased from 15.5 to 0 per 1,000 central line days
Spooner et al (31)	Australia	Know to action framework	Implement and evaluate an evidence-based electronic minimum data set for nursing team leader shift to shift handover in the ICU using the knowledge to action framework	Assess readiness and barriers, tailor strategies, education, local opinion leaders, develop tools, develop effective materials, audit and feedback	Adherence: 78%
Stelfox et al (29)	Canada	Theoretical domains framework	Test whether a multicomponent intervention would increase use of low-molecular-weight heparin over unfractionated heparin for VTE prophylaxis in critically ill patients	Education, develop tools, reminders, audit and feedback	Adherence: Increased for intervention group: 45.9–78.3%; increased for control group: 37.9–53.3% VTE: Remained same for intervention group: 3–3%; decreased slightly for control group: 2.4–2.1% Deep vein thrombosis: Increased for intervention group: 1.9–2.1%; remained same for control group: 1.4–1.4% Pulmonary embolism: Decreased for intervention group: 1.3–1.1%; decreased for control group: 1.2–0.8%

ABCDEF = Awakening and Breathing Coordination, Delirium Monitoring/Management, and Early Exercise/Mobility, BICU = burn ICU, CLABSI = central line-associated bloodstream infection, IS = implementation science, OR = odds ratio, TRIP = translating research into practice, VAP = ventilator-associated pneumonia, VTE = venous thromboembolism.

of these additional outcomes using an IS approach can generate important data on effective mechanisms for EBP change that is sustainable in complex critical care environments. The field of IS allows multiple approaches to project evaluation, including hybrid designs that establish priorities for clinical and implementation outcomes, and mechanisms for systematically measuring and reporting findings. Many IS approaches also include a QI component to integrate rapid cycle change and streamline processes to improve both clinical and implementation outcomes under investigation. This systematic approach to implementation becomes critical when working to develop a body of generalizable evidence on the most effective strategies to promote EBP utilization and evaluate impact on clinicians, organizations, patients, and populations.

Among the specific IS designs in critical care, the most comprehensively investigated EBP was the ABCDE/F bundle. Although investigations were guided by different frameworks or models, all systematically contributed information on factors influencing successful uptake of the ABCDE/F bundle into routine clinical care. Various strategies were evaluated and formal investigations into assessment of readiness and barriers were performed. This body of knowledge regarding implementation of the bundle has resulted in development of toolkits to guide clinicians through the implementation process.

As a result of this review, there are several priority areas that should be addressed to move the science of implementation forward in critical care. First, clinicians and scientists are encouraged to use established models or frameworks for implementation of best practices to provide a systematic approach to implementation and increase likelihood of generalizability and sustainability over time. Second, selection, measurement, and reporting of implementation strategies should align with current nomenclature to provide consistency of methods across studies and build evidence regarding effectiveness. Third, outcome reporting should extend

beyond solely clinical outcomes and include measures of implementation outcomes using established terminology and mechanisms. There is a need for additional investigations to explore the role of mediators on clinical and implementation outcomes, as well as systematic approaches to de-implementation of low value or wasteful practices in critical care settings. Dissemination of these conceptual and methodological efforts is critical to advance widespread integration of EBPs into routine clinical care.

CONCLUSIONS

Having a structured and systematic approach to integrating EBPs into practice using an IS approach holds great potential in critical care settings and should remain a key component of critical care research agendas for all EBPs. The work should not cease upon publication of study findings on clinical effectiveness or upon publication of an evidence-based guideline. Rather, the next logical step scientifically is to identify optimal strategies to embed the findings into routine clinical care. Evaluation and dissemination of the effectiveness of these strategies on both clinical and implementation outcomes then generates evidence to promote sustainable practice change. This is exactly the aim of IS and must be addressed by developing critical care teams who are experienced in IS methodology and committed to advancing the science specifically related to acceleration of adoption and uptake of evolving effective critical care interventions that optimize patient outcomes.

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REFERENCES

1. Eccles MP, Mittman BS: Welcome to implementation science. *Implement Sci* 2006; 1:1
2. Nilsen P: Making sense of implementation theories, models and frameworks. *Implement Sci* 2015; 10:53
3. Esmail R, Hanson HM, Holroyd-Leduc J, et al: A scoping review of full-spectrum knowledge translation theories, models, and frameworks. *Implement Sci* 2020; 15:11
4. Lewis CC, Boyd MR, Walsh-Bailey C, et al: A systematic review of empirical studies examining mechanisms of implementation in health. *Implement Sci* 2020; 15:21
5. Bauer MS, Kirchner J: Implementation science: What is it and why should I care? *Psychiatry Res* 2020; 283:112376
6. Powell BJ, Fernandez ME, Williams NJ, et al: Enhancing the impact of implementation strategies in healthcare: A research agenda. *Front Public Health* 2019; 7:3
7. Grol R, Grimshaw J: Evidence-based implementation of evidence-based medicine. *Jt Comm J Qual Improv* 1999; 25:503–513
8. Flodgren G, Hall AM, Goulding L, et al: Tools developed and disseminated by guideline producers to promote the uptake of their guidelines. *Cochrane Database Syst Rev* 2016; 22:Cd010669
9. Mazza D, Bairstow P, Buchan H, et al: Refining a taxonomy for guideline implementation: Results of an exercise in abstract classification. *Implement Sci* 2013; 8:32
10. Powell BJ, Waltz TJ, Chinman MJ, et al: A refined compilation of implementation strategies: Results from the expert recommendations for implementing change (ERIC) project. *Implement Sci* 2015; 10:21
11. Weiss CH, Krishnan JA, Au DH, et al; ATS Ad Hoc Committee on Implementation Science: An official American Thoracic Society research statement: Implementation science in pulmonary, critical care, and sleep medicine. *Am J Respir Crit Care Med* 2016; 194:1015–1025
12. Grant MJ, Booth A: A typology of reviews: An analysis of 14 review types and associated methodologies. *Health Info Libr J* 2009; 26:91–108
13. Tricco AC, Lillie E, Zarin W, et al: PRISMA extension for scoping reviews (PRISMA-ScR): Checklist and explanation. *Ann Intern Med* 2018; 169:467–473
14. Abbott CA, Dremsa T, Stewart DW, et al: Adoption of a ventilator-associated pneumonia clinical practice guideline. *Worldviews Evid Based Nurs* 2006; 3:139–152
15. Balas MC, Burke WJ, Gannon D, et al: Implementing the awakening and breathing coordination, delirium monitoring/management, and early exercise/mobility bundle into everyday care: Opportunities, challenges, and lessons learned for implementing the ICU pain, agitation, and delirium guidelines. *Crit Care Med* 2013; 41:S116–S127
16. Boltey EM, Iwashyna TJ, Hyzy RC, et al: Ability to predict team members' behaviors in ICU teams is associated with routine ABCDE implementation. *J Crit Care* 2019; 51:192–197
17. Boehm LM, Vasilevskis EE, Dietrich MS, et al: Organizational domains and variation in attitudes of intensive care providers toward the ABCDE bundle. *Am J Crit Care* 2017; 26:e18–e28
18. Carrothers KM, Barr J, Spurlock B, et al: Contextual issues influencing implementation and outcomes associated with an integrated approach to managing pain, agitation, and delirium in adult ICUs. *Crit Care Med* 2013; 41:S128–S135
19. Costa DK, Valley TS, Miller MA, et al: ICU team composition and its association with ABCDE implementation in a quality collaborative. *J Crit Care* 2018; 44:1–6
20. Penrod JD, Luhrs CA, Livote EE, et al: Implementation and evaluation of a network-based pilot program to improve palliative care in the intensive care unit. *J Pain Symptom Manage* 2011; 42:668–671
21. Reynolds SS, Sova C, McNalty B, et al: Implementation strategies to improve evidence-based bathing practices in a neuro ICU. *J Nurs Care Qual* 2019; 34:133–138
22. Sood G, Caffrey J, Krout K, et al: Use of implementation science for a sustained reduction of central-line–associated bloodstream infections in a high-volume, regional burn unit. Infection Control & Hospital. *Epidemiology* 2017; 38:1306–1311
23. Elligsen M, Walker SA, Pinto R, et al: Audit and feedback to reduce broad-spectrum antibiotic use among intensive care unit patients: A controlled interrupted time series analysis. *Infect Control Hosp Epidemiol* 2012; 33:354–361
24. Ilan R, Fowler RA, Geerts R, et al: Knowledge translation in critical care: Factors associated with prescription of commonly recommended best practices for critically ill patients. *Crit Care Med* 2007; 35:1696–1702
25. Jain MK, Heyland D, Dhaliwal R, et al: Dissemination of the Canadian clinical practice guidelines for nutrition support: Results of a cluster randomized controlled trial. *Crit Care Med* 2006; 34:2362–2369
26. Sinuff T, Cahill NE, Dhaliwal R, et al: The value of audit and feedback reports in improving nutrition therapy in the intensive care unit: A multicenter observational study. *JPEN J Parenter Enteral Nutr* 2010; 34:660–668
27. Sinuff T, Muscedere J, Rozmovits L, et al: A qualitative study of the variable effects of audit and feedback in the ICU. *BMJ Qual Saf* 2015; 24:393–399
28. Sauro KM, Brundin-Mather R, Parsons Leigh J, et al: Improving the adoption of optimal venous thromboembolism prophylaxis in critically ill patients: A process evaluation of a complex quality improvement initiative. *J Crit Care* 2019; 50:111–117
29. Stelfox HT, Brundin-Mather R, Soo A, et al: A multicentre controlled pre-post trial of an implementation science intervention to improve venous thromboembolism prophylaxis in critically ill patients. *Intensive Care Med* 2019; 45:211–222

30. Doig GS, Simpson F, Finfer S, et al; Nutrition Guidelines Investigators of the ANZICS Clinical Trials Group: Effect of evidence-based feeding guidelines on mortality of critically ill adults: A cluster randomized controlled trial. *JAMA* 2008; 300:2731–2741
31. Spooner AJ, Aitken LM, Chaboyer W: Implementation of an evidence-based practice nursing handover tool in intensive care using the knowledge-to-action framework. *Worldviews Evid Based Nurs* 2018; 15:88–96
32. Noome M, Dijkstra BM, van Leeuwen E, et al: Effectiveness of supporting intensive care units on implementing the guideline 'End-of-life care in the intensive care unit, nursing care': A cluster randomized controlled trial. *J Adv Nurs* 2017; 73:1339–1354
33. Hawe CS, Ellis KS, Cairns CJ, et al: Reduction of ventilator-associated pneumonia: Active versus passive guideline implementation. *Intensive Care Med* 2009; 35:1180–1186
34. Anderson RJ, Sparbel K, Barr RN, et al: Electronic health record tool to promote team communication and early patient mobility in the intensive care unit. *Crit Care Nurse* 2018; 38:23–34
35. Baldonado A, Naqvi Mugler A, Garland A, et al: Evidence-based practice strategy: Increasing timely nutrition in mechanically ventilated trauma surgical patients. *Dimens Crit Care Nurs* 2011; 30:346–355
36. Barbash IJ, Pike F, Gunn SR, et al: Effects of physician-targeted pay for performance on use of spontaneous breathing trials in mechanically ventilated patients. *Am J Respir Crit Care Med* 2017; 196:56–63
37. Barsuk JH, Cohen ER, Feinglass J, et al: Use of simulation-based education to reduce catheter-related bloodstream infections. *Arch Intern Med* 2009; 169:1420–1423
38. Barr J, Hecht M, Flavin KE, et al: Outcomes in critically ill patients before and after the implementation of an evidence-based nutritional management protocol. *Chest* 2004; 125:1446–1457
39. Bingham M, Ashley J, De Jong M, et al: Implementing a unit-level intervention to reduce the probability of ventilator-associated pneumonia. *Nurs Res* 2010; 59:S40–S47
40. Bowman A, Greiner JE, Doerschug KC, et al: Implementation of an evidence-based feeding protocol and aspiration risk reduction algorithm. *Crit Care Nurs Q* 2005; 28:324–333; quiz 334–335
41. Byrnes MC, Schuerer DJ, Schallom ME, et al: Implementation of a mandatory checklist of protocols and objectives improves compliance with a wide range of evidence-based intensive care unit practices. *Crit Care Med* 2009; 37:2775–2781
42. Coopersmith CM, Zack JE, Ward MR, et al: The impact of bedside behavior on catheter-related bacteremia in the intensive care unit. *Arch Surg* 2004; 139:131–136
43. Gray-Siracusa K, Schrier L: Use of an intervention bundle to eliminate pressure ulcers in critical care. *J Nurs Care Qual* 2011; 26:216–225
44. Goldberg PA, Siegel MD, Sherwin RS, et al: Implementation of a safe and effective insulin infusion protocol in a medical intensive care unit. *Diabetes Care* 2004; 27:461–467
45. Hall DK, Zimbro KS, Maduro RS, et al: Impact of a restraint management bundle on restraint use in an intensive care unit. *J Nurs Care Qual* 2018; 33:143–148
46. Hester JM, Guin PR, Danek GD, et al: The economic and clinical impact of sustained use of a progressive mobility program in a neuro-ICU. *Crit Care Med* 2017; 45:1037–1044
47. Kram SL, DiBartolo MC, Hinderer K, et al: Implementation of the ABCDE bundle to improve patient outcomes in the intensive care unit in a rural community hospital. *Dimens Crit Care Nurs* 2015; 34:250–258
48. Kumwilaisak K, Noto A, Schmidt UH, et al: Effect of laboratory testing guidelines on the utilization of tests and order entries in a surgical intensive care unit. *Crit Care Med* 2008; 36:2993–2999
49. Mangino JE, Peyrani P, Ford KD, et al; IMPACT-HAP Study Group: Development and implementation of a performance improvement project in adult intensive care units: Overview of the Improving Medicine Through Pathway Assessment of Critical Therapy in Hospital-Acquired Pneumonia (IMPACT-HAP) study. *Crit Care* 2011; 15:R38
50. Murphy DJ, Pronovost PJ, Lehmann CU, et al: Red blood cell transfusion practices in two surgical intensive care units: A mixed methods assessment of barriers to evidence-based practice. *Transfusion* 2014; 54:2658–2667
51. Plost G, Nelson DP: Empowering critical care nurses to improve compliance with protocols in the intensive care unit. *Am J Crit Care* 2007; 16:153–156; quiz 157
52. Pronovost P: Interventions to decrease catheter-related bloodstream infections in the ICU: The Keystone Intensive Care Unit Project. *Am J Infect Control* 2008; 36:S171.e1–e5
53. Render ML, Brungs S, Kotagal U, et al: Evidence-based practice to reduce central line infections. *Jt Comm J Qual Patient Saf* 2006; 32:253–260
54. Resar R, Pronovost P, Haraden C, et al: Using a bundle approach to improve ventilator care processes and reduce ventilator-associated pneumonia. *Jt Comm J Qual Patient Saf* 2005; 31:243–248
55. Ross A, Crumpler J: The impact of an evidence-based practice education program on the role of oral care in the prevention of ventilator-associated pneumonia. *Intensive Crit Care Nurs* 2007; 23:132–136
56. Bourdeaux CP, Davies KJ, Thomas MJ, et al: Using 'nudge' principles for order set design: A before and after evaluation of an electronic prescribing template in critical care. *BMJ Qual Saf* 2014; 23:382–388
57. Tolentino-DelosReyes AF, Ruppert SD, Shiao SY: Evidence-based practice: Use of the ventilator bundle to prevent ventilator-associated pneumonia. *Am J Crit Care* 2007; 16:20–27
58. Urisman T, Garcia A, Harris HW: Impact of surgical intensive care unit interdisciplinary rounds on interprofessional collaboration and quality of care: Mixed qualitative-quantitative study. *Intensive Crit Care Nurs* 2018; 44:18–23
59. Zaydfudim V, Dossett LA, Starmer JM, et al: Implementation of a real-time compliance dashboard to help reduce SICU ventilator-associated pneumonia with the ventilator bundle. *Arch Surg* 2009; 144:656–662
60. Baxter AD, Allan J, Bedard J, et al: Adherence to simple and effective measures reduces the incidence of ventilator-associated pneumonia. *Can J Anaesth* 2005; 52:535–541
61. Mackenzie SL, Zygun DA, Whitmore BL, et al: Implementation of a nutrition support protocol increases the proportion of mechanically ventilated patients reaching enteral nutrition targets in the adult intensive care unit. *JPEN J Parenter Enteral Nutr* 2005; 29:74–80
62. McLean SE, Jensen LA, Schroeder DG, et al: Improving adherence to a mechanical ventilation weaning protocol for critically ill adults: Outcomes after an implementation program. *Am J Crit Care* 2006; 15:299–309
63. Álvarez-Lerma F, Palomar-Martínez M, Sánchez-García M, et al: Prevention of ventilator-associated pneumonia: The multimodal approach of the Spanish ICU "Pneumonia Zero" program. *Crit Care Med* 2018; 46:181–188
64. Castellanos-Ortega A, Suberviola B, García-Astudillo LA, et al: Impact of the surviving sepsis campaign protocols on hospital length of stay and mortality in septic shock patients: Results of a three-year follow-up quasi-experimental study. *Crit Care Med* 2010; 38:1036–1043
65. Ruiz J, Ramirez P, Gordon M, et al: Antimicrobial stewardship programme in critical care medicine: A prospective interventional study. *Med Intensiva* 2018; 42:266–273
66. Lemmen SW, Zolldann D, Gastmeier P, et al: Implementing and evaluating a rotating surveillance system and infection control guidelines in 4 intensive care units. *Am J Infect Control* 2001; 29:89–93
67. Mutters NT, De Angelis G, Restuccia G, et al: Use of evidence-based recommendations in an antibiotic care bundle for the intensive care unit. *Int J Antimicrob Agents* 2018; 51:65–70
68. Brattebø G, Hofoss D, Flaatten H, et al: Effect of a scoring system and protocol for sedation on duration of patients' need for ventilator support in a surgical intensive care unit. *BMJ* 2002; 324:1386–1389
69. Hansen BS, Severinsson E: Dissemination of research-based knowledge in an intensive care unit-a qualitative study. *Intensive Crit Care Nurs* 2009; 25:147–154
70. Hanekom S, Louw QA, Coetzee AR: Implementation of a protocol facilitates evidence-based physiotherapy practice in intensive care units. *Physiotherapy* 2013; 99:139–145
71. Rosenthal VD, Guzman S, Safdar N: Reduction in nosocomial infection with improved hand hygiene in intensive care units of a tertiary care hospital in Argentina. *Am J Infect Control* 2005; 33:392–397

72. Chan PK, Fischer S, Stewart TE, et al: Practising evidence-based medicine: The design and implementation of a multidisciplinary team-driven extubation protocol. *Crit Care* 2001; 5:349–354
73. Bouadma L, Mourvillier B, Deiler V, et al: A multifaceted program to prevent ventilator-associated pneumonia: Impact on compliance with preventive measures. *Crit Care Med* 2010; 38:789–796
74. van der Kolk M, van den Boogaard M, Ter Brugge-Speelman C, et al: Development and implementation of a clinical pathway for cardiac surgery in the intensive care unit: Effects on protocol adherence. *J Eval Clin Pract* 2017; 23:1289–1298
75. Arabi Y, Haddad S, Hawes R, et al: Changing sedation practices in the intensive care unit - protocol implementation, multifaceted multidisciplinary approach and teamwork. *Middle East J Anesthesiol* 2007; 19:429–447
76. Barnes-Daly MA, Phillips G, Ely EW: Improving hospital survival and reducing brain dysfunction at seven California community hospitals: Implementing PAD guidelines via the ABCDEF bundle in 6,064 patients. *Crit Care Med* 2017; 45:171–178
77. Clemmer TP, Spuhler VJ, Oniki TA, et al: Results of a collaborative quality improvement program on outcomes and costs in a tertiary critical care unit. *Crit Care Med* 1999; 27:1768–1774
78. Dammeyer JA, Baldwin N, Packard D, et al: Mobilizing outcomes: Implementation of a nurse-led multidisciplinary mobility program. *Crit Care Nurs Q* 2013; 36:109–119
79. Dlugacz YD, Stier L, Lustbader D, et al: Expanding a performance improvement initiative in critical care from hospital to system. *Jt Comm J Qual Improv* 2002; 28:419–434
80. Frankel HL, Crede WB, Topal JE, et al: Use of corporate six sigma performance-improvement strategies to reduce incidence of catheter-related bloodstream infections in a surgical ICU. *J Am Coll Surg* 2005; 201:349–358
81. Joseph K, Gupta S, Yon J, et al: The "TRAUMA LIFE" initiative: The impact of a multidisciplinary checklist process on outcomes and communication in a trauma intensive care unit. *Am J Surg* 2018; 215:1024–1028
82. Levy MM, Dellinger RP, Townsend SR, et al: The Surviving Sepsis Campaign: Results of an international guideline-based performance improvement program targeting severe sepsis. *Intensive Care Med* 2010; 36:222–231
83. Padula CA, Paradis H, Goodwin R, et al: Prevention of medical device-related pressure injuries associated with respiratory equipment use in a critical care unit: A quality improvement project. *J Wound Ostomy Continence Nurs* 2017; 44:138–141
84. Teixeira PG, Inaba K, Dubose J, et al: Measurable outcomes of quality improvement using a daily quality rounds checklist: Two-year prospective analysis of sustainability in a surgical intensive care unit. *J Trauma Acute Care Surg* 2013; 75:717–721
85. Vuong C, Kittelson S, McCullough L, et al: Implementing primary palliative care best practices in critical care with the care and communication bundle. *BMJ Open Qual* 2019; 8:e000513
86. Youngquist P, Carroll M, Farber M, et al: Implementing a ventilator bundle in a community hospital. *Jt Comm J Qual Patient Saf* 2007; 33:219–225
87. Dhanani JA, Barnett AG, Lipman J, et al: Strategies to reduce inappropriate laboratory blood test orders in intensive care are effective and safe: A before-and-after quality improvement study. *Anaesth Intensive Care* 2018; 46:313–320
88. Ferrie S, McWilliam D: Failure of a quality improvement process to increase nutrition delivery to intensive care patients. *Anaesth Intensive Care* 2006; 34:191–196
89. Cavalcanti AB, Bozza FA, Machado FR, et al; Writing Group for the CHECKLIST-ICU Investigators ane the Brazilian Research in Intensive Care Network (BRICNet): Effect of a quality improvement intervention with daily round checklists, goal setting, and clinician prompting on mortality of critically ill patients: A randomized clinical trial. *JAMA* 2016; 315:1480–1490
90. Martin CM, Doig GS, Heyland DK, et al; Southwestern Ontario Critical Care Research Network: Multicentre, cluster-randomized clinical trial of algorithms for critical-care enteral and parenteral therapy (ACCEPT). *CMAJ* 2004; 170:197–204
91. Zhu B, Li Z, Jiang L, et al: Effect of a quality improvement program on weaning from mechanical ventilation: A cluster randomized trial. *Intensive Care Med* 2015; 41:1781–1790
92. Ersson A, Beckman A, Jarl J, et al: Effects of a multifaceted intervention QI program to improve ICU performance. *BMC Health Serv Res* 2018; 18:838
93. Chao CM, Lai CC, Chan KS, et al: Multidisciplinary interventions and continuous quality improvement to reduce unplanned extubation in adult intensive care units: A 15-year experience. *Medicine (Baltimore)* 2017; 96:e6877
94. Richardson A, Peart J, Wright SE, et al: Reducing the incidence of pressure ulcers in critical care units: A 4-year quality improvement. *Int J Qual Health Care* 2017; 29:433–439
95. Eldridge NE, Woods SS, Bonello RS, et al: Using the six sigma process to implement the Centers for Disease Control and Prevention Guideline for Hand Hygiene in 4 intensive care units. *J Gen Intern Med* 2006; 21(Suppl 2):S35–S42
96. Olsen BF, Rustøen T, Sandvik L, et al: Implementation of a pain management algorithm in intensive care units and evaluation of nurses' level of adherence with the algorithm. *Heart Lung* 2015; 44:528–533
97. Proctor E, Silmere H, Raghavan R, et al: Outcomes for implementation research: Conceptual distinctions, measurement challenges, and research agenda. *Adm Policy Ment Health* 2011; 38:65–76