

Scope and Influence of Electronic Health Record–Integrated Clinical Decision Support in the Emergency Department: A Systematic Review



Brian W. Patterson, MD, MPH*; Michael S. Pulia, MD, MS; Shashank Ravi, MD; Peter L. T. Hoonakker, PhD; Ann Schoofs Hundt, PhD; Douglas Wiegmann, PhD; Emily J. Wirkus, MPH; Stephen Johnson, MLS; Pascale Carayon, PhD

*Corresponding Author. E-mail: bpatter@medicine.wisc.edu, Twitter: @BPattersonMD.

Study objective: As electronic health records evolve, integration of computerized clinical decision support offers the promise of sorting, collecting, and presenting this information to improve patient care. We conducted a systematic review to examine the scope and influence of electronic health record–integrated clinical decision support technologies implemented in the emergency department (ED).

Methods: A literature search was conducted in 4 databases from their inception through January 18, 2018: PubMed, Scopus, the Cumulative Index of Nursing and Allied Health, and Cochrane Central. Studies were included if they examined the effect of a decision support intervention that was implemented in a comprehensive electronic health record in the ED setting. Standardized data collection forms were developed and used to abstract study information and assess risk of bias.

Results: A total of 2,558 potential studies were identified after removal of duplicates. Of these, 42 met inclusion criteria. Common targets for clinical decision support intervention included medication and radiology ordering practices, as well as more comprehensive systems supporting diagnosis and treatment for specific disease entities. The majority of studies (83%) reported positive effects on outcomes studied. Most studies (76%) used a pre-post experimental design, with only 3 (7%) randomized controlled trials.

Conclusion: Numerous studies suggest that clinical decision support interventions are effective in changing physician practice with respect to process outcomes such as guideline adherence; however, many studies are small and poorly controlled. Future studies should consider the inclusion of more specific information in regard to design choices, attempt to improve on uncontrolled before-after designs, and focus on clinically relevant outcomes wherever possible. [Ann Emerg Med. 2019;74:285-296.]

Please see page 286 for the Editor's Capsule Summary of this article.

0196-0644/\$-see front matter

Copyright © 2018 by the American College of Emergency Physicians.

<https://doi.org/10.1016/j.annemergmed.2018.10.034>

INTRODUCTION

Widespread adoption of electronic health records offers an unprecedented opportunity to apply informatics techniques to clinical and operational data.^{1,2} Although the electronic health record stores a wealth of clinical data that can potentially improve the quality of clinical emergency department (ED) care,¹⁻⁴ this information is often lost in the sea of data collected. In their brief patient encounters, emergency physicians are all too often confronted with poorly organized information, which is difficult to synthesize and act on at the bedside.⁵⁻⁷ As electronic health records evolve, integration of computerized clinical decision support offers the promise of sorting, collecting, and presenting this information to improve patient care.^{8,9} Clinical decision support technologies have demonstrated the ability to improve patient outcomes across a variety of health care settings.^{10,11} Clinical decision support has been

promoted by several organizations such as the Centers for Medicare & Medicaid Services, which will continue to increase implementation.¹²

Considering their promise to improve emergency care, along with regulatory incentives for their adoption, development and implementation of these technologies are proceeding rapidly. Given the complexity of the sociotechnical systems (such as the ED) in which they are implemented,^{13,14} however, clinical decision support technologies have the potential for negative consequences.¹⁵ As we enter an era of increasing clinical decision support development and use in the ED, it is crucial that implementation of these technologies be based on the best available clinical evidence indicating improvements in patient care.¹⁶ Furthermore, development of these technologies may benefit from design principles established in both health care and human factors

Editor's Capsule Summary

What is already known on this topic

Electronic health records are now ubiquitous in US emergency departments. They offer the promise of meaningful decision support, but implementation of effective tools and evaluation of these tools have been sporadic.

What question this study addressed

This systematic review identified all published studies that evaluated decision support systems placed in extant electronic health records to determine their effect on decisionmaking or patient outcome.

What this study adds to our knowledge

The authors found 42 studies of various quality. There were few randomized trials and few studies that assessed patient outcome. Most interventions appeared to improve the process of care, although use of the interventions by physicians was spotty.

How this is relevant to clinical practice

There is a need for better interventions and better research on those interventions if the theoretical benefits of electronic health records are to be translated into improved patient outcomes.

engineering. These range from simple heuristics such as the “5 rights” of decision support (the right information, to the right person, in the right format, through the right channel, at the right time in the work flow)¹⁷ to more comprehensive theories of human factors engineering such as Parasuraman’s model of human interaction with automation.¹⁸

We conducted a systematic review to examine the scope and influence of electronic health record–integrated clinical decision support technologies implemented in the ED. After reviewing the results of the systematic review, we discuss gaps in the current research and propose recommendations for future studies.

MATERIALS AND METHODS

This systemic review follows the Preferred Reporting Items for Systemic Reviews and Meta-analyses guidelines.¹⁹ As a review of existing literature, this study was exempt from institutional review board review.

Consistent with previously published reviews of clinical decision support in the general medical literature, we defined a clinical decision support as any software designed

to directly aid in clinical decisionmaking in which characteristics of individual patients are matched to a computerized knowledge base for the purpose of generating patient-specific assessments or recommendations that are then presented to clinicians for consideration.^{10,11}

Our literature review considered only peer-reviewed studies published in English. Studies were included if

1. they described an intervention that met the above definition of clinical decision support;
2. they described the implementation of a clinical decision support intervention (as opposed to preimplementation testing);
3. the intervention occurred in the ED setting.

During the selection process, we clarified our definition of clinical decision support and added 3 inclusion criteria to narrow our sample to those studies most relevant to emergency medicine practitioners evaluating the effectiveness of decision support interventions:

4. The clinical decision support intervention was integrated within an existing electronic health record. This excluded studies in which tools were piloted without integration into existing work flows (eg, stand-alone Web sites or computers requiring patient information to be entered for the sole purpose of generating a recommendation, systems that may have fulfilled the role of an electronic health record but were used only for the purpose of intervention on specific patient populations).
5. The study reported the effect of an intervention on a care process or patient-related outcome (as opposed to outcomes of interest only to further development of the intervention). For instance, we excluded several studies that created an alert but reported only its “firing rate” or sensitivity and specificity because these evaluated the development of an intervention as opposed to its implementation.
6. We specifically excluded studies whose primary purpose was to perform automatic triaging of patients into Emergency Severity Index or similar categories because these studies are more concerned with automating a care process than supporting a decision.

The search was conducted in 4 databases from their inception through January 18, 2018: PubMed, Scopus, the Cumulative Index of Nursing and Allied Health, and Cochrane Central. The search combined terms related to 2 domains, clinical decision support and the ED. Terms from different domains were combined by using the Boolean operator AND; terms within each domain were combined by using the Boolean operator OR. [Figure 1](#) contains the terms used in the search, and [Appendix E1](#) (available online

Search Strategy	
CDS	ED
diagnosis, computer assisted	emergency service, hospital
decision support systems, clinical	emergency medicine
decision-making, computer assisted	emergency department
decision aid	emergency room
decision models	emergency medicine
decision support	
predictive instrument	
diagnostic aid predictive rule	
decision rule	
decision support techniques	

CDS, Clinical decision support.

Figure 1. Search terms included. Terms within columns were linked with an OR statement, with an AND statement between columns. See Appendix E1 (available online at <http://www.annemergmed.com>) for the full search strategy.

at <http://www.annemergmed.com>) contains the full search string. Our initial screening strategy included only the first 3 inclusion criteria. The title and abstract of each study were screened by a single reviewer, with all possibly relevant studies retained for full-text review. Full-text articles were then retrieved for studies retained after the initial screening. These studies were reviewed by 2 paired authors, who excluded studies that clearly did not meet any of the initial 3 inclusion criteria (above). After the first round of full-text review, studies were retained for further screening if either one or both reviewing authors flagged the study article for possible inclusion. At this point, in response to discussions to obtain consensus when reviewing authors disagreed on inclusion, the team refined search criteria by adding selection criteria 4 through 6 (above). These criteria were added to specifically address areas in which the team felt that the original criteria did not clearly include or exclude specific studies. The remaining articles (any for which 1 of the 2 reviewers initially assigned voted to include or keep for further discussion) were then reviewed by 2 emergency physicians (B.W.P. and M.S.P.), who included only studies that met all 6 inclusion criteria. In cases of disagreement between these 2 reviewers, cases were discussed with all study authors until consensus was reached.

Data Collection and Processing

We developed a data collection form that was pilot tested on 3 articles and revised subsequently. Each researcher used the data collection form to extract the following data from each project: study objective, clinical decision support intervention, study design, and outcomes and influence, which were further divided into clinical and process

measures and user experience (eg, perceived usability, acceptance and use). Pairs of researchers reviewed each other’s data collection forms to ensure accurate abstraction.

Studies were assessed for risk of bias with questions selected from a bank proposed by Viswanathan and Berkman.²⁰ Risk-of-bias scoring was completed during the data extraction phase, with the extracting author completing the risk-of-bias form and the paired author reviewing the other’s form. Differences were discussed until consensus was achieved. When consensus could not be reached between the 2 authors, items were discussed with the full team.

RESULTS

After removal of duplicates, a total of 2,558 potential studies were identified. Of these, we retained 296 for full-text review after the initial round of abstract review. We excluded an additional 153 studies in the first round of full-text review, leaving 143 studies. After addition of selection criteria 3 through 6, the final round of full-text review excluded 99 additional articles, leaving 42 articles that were included in the systematic review reported in this article. Figure 2 describes the study screening and inclusion process. Among these 42 articles, there was a trend toward increasing volume by year (Figure 3). We did not identify any studies published before 2005 that met our inclusion criteria.

Characteristics of included studies are shown in Table 1 and Table E1 (available online at <http://www.annemergmed.com>). Although there was a broad range of clinical decision support intervention types and targets described, several themes emerged. Twelve studies (29%) described interventions in the form of alerts or other modifications to computerized physician order entry designed to support decisionmaking surrounding medication ordering.^{21,22} These studies were more prevalent

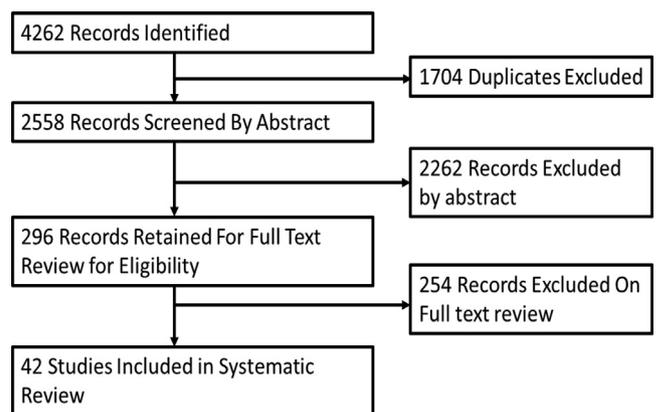


Figure 2. Study screening and inclusion.

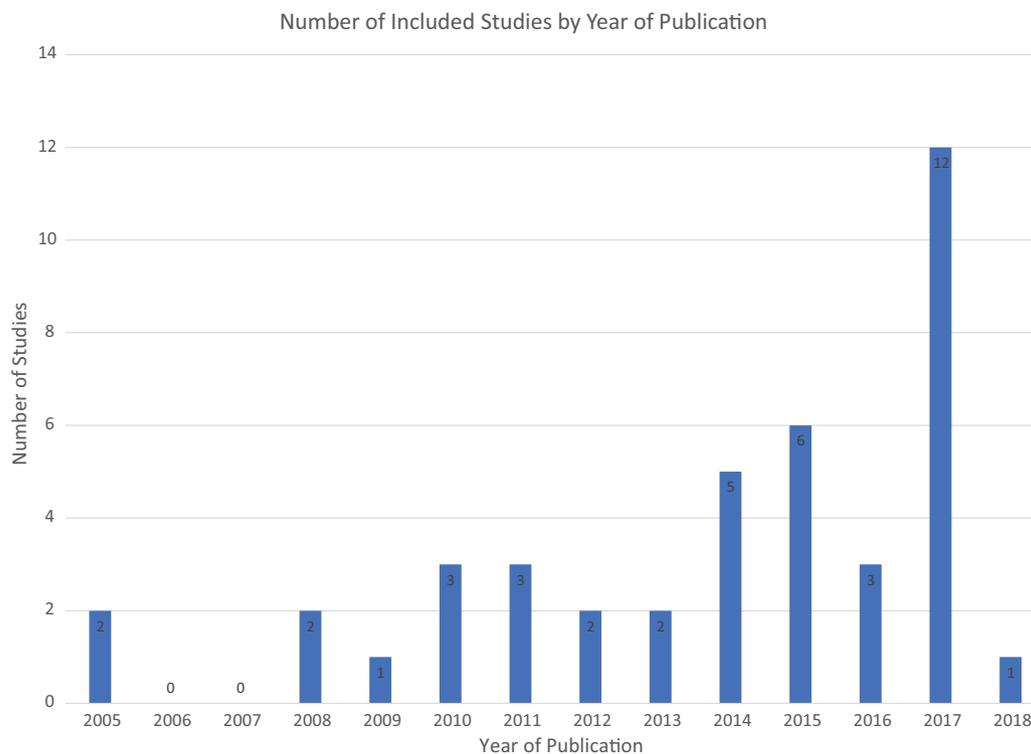


Figure 3. Included studies by year of publication. Only 18 days of 2018 were included in the data collection.

earlier in the review period, with 7 of the 12 published in 2012 or earlier. These interventions generally involved order entry alerts and were designed to prevent administration of inappropriate medications (eg, Beers list for older adults²³),²² prevent dosing errors,²⁴ or ensure guideline-

compliant antibiotic ordering.²⁵ Another focus was clinical decision support interventions that applied decision support at a radiology order entry interface, with the goal of reducing unnecessary or inappropriate imaging for diagnostic evaluation of conditions such as pulmonary embolus^{26,27} or

Table 1. Study characteristics, organized by year of publication.

Author/Year	Study
Bernstein et al, 2005 ²¹	An electronic chart prompt to decrease proprietary antibiotic prescription to self-pay patients
Kirk et al, 2005 ⁵⁶	Computer-calculated dose in paediatric prescribing
Busing et al, 2008 ³⁷	Improving antibiotic prescribing for adults with community-acquired pneumonia: does a computerized decision support system achieve more than academic detailing alone?
Sard et al, 2008 ⁵⁴	Retrospective evaluation of a CPOE adaptation to prevent prescribing errors in a pediatric ED
Terrell et al, 2009 ²²	Computerized decision support to reduce potentially inappropriate prescribing to older ED patients: a randomized, controlled trial
Melnick et al, 2010 ²⁹	Knowledge translation of the American College of Emergency Physicians' clinical policy on syncope, using computerized CDS
Terrell et al, 2010 ³⁸	Computerized decision support for medication dosing in renal insufficiency: a randomized, controlled trial
Venkat et al, 2010 ⁵²	Feasibility of integrating a CDS tool into an existing CPOE system to increase seasonal influenza vaccination in the ED
Carman et al, 2011 ²⁵	Use of a CDS tool to improve guideline adherence for the treatment of methicillin-resistant <i>Staphylococcus aureus</i> : skin and soft tissue infections
Drescher et al, 2011 ⁵³	Effectiveness and acceptability of a computerized decision support system using modified Wells criteria for evaluation of suspected PE
Nelson et al, 2011 ³⁰	Prospective trial of real-time electronic surveillance to expedite early care of severe sepsis
Griffey et al, 2012 ⁴⁹	Guided medication dosing for elderly emergency patients using real-time, computerized decision support

Table 1. Continued.

Author/Year	Study
Raja et al, 2012 ²⁷	Effect of computerized CDS on the use and yield of CT pulmonary angiography in the ED
Dexheimer and Kennebeck, 2013 ³⁹	Modifications and integration of the electronic tracking board in a pediatric ED
Prevedello et al, 2013 ⁵⁷	Does Clinical Decision Support Reduce Unwarranted Variation in Yield of CT Pulmonary Angiogram?
Demonchy et al, 2014 ⁵⁸	Impact of a computerized decision support system on compliance with guidelines on antibiotics prescribed for urinary tract infections in EDs
Dexheimer et al, 2014 ³¹	Implementation and evaluation of an integrated computerized asthma management system in a pediatric ED: a randomized clinical trial
Fowler et al, 2014 ⁵⁹	Electronic health record: integrating evidence-based information at the point of clinical decision making
Gupta et al, 2014 ³⁵	Effect of CDS on documented guideline adherence for head CT in ED patients with mild traumatic brain injury
Raja et al, 2014 ³⁶	The use of decision support to measure documented adherence to a national imaging quality measure
Carnevale et al, 2015 ⁶⁰	Impact of an emergency medicine decision support and risk education system on CT and MRI use
Dean et al, 2015 ³²	Impact of an electronic CDS tool for ED patients with pneumonia
Faine et al, 2015 ⁶¹	Importance of decision support implementation in ED vancomycin dosing
Ip et al, 2015 ²⁸	Impact of CDS on head CT use in patients with mild traumatic brain injury in the ED
Sethuraman et al, 2015 ⁶²	Prescription errors before and after introduction of electronic medication alert system in a pediatric ED
Stevens et al, 2015 ⁶³	Enhancing the quality of prescribing practices for older veterans discharged from the ED (EQUIPPED)
Kharbanda et al, 2016 ³³	Implementation of electronic CDS for pediatric appendicitis
McGuire and Moore, 2016 ⁵¹	Using a configurable EMR and decision support tools to promote process integration for routine HIV screening in the ED
Silveira et al, 2016 ⁶⁴	Impact of a CDS tool on adherence to the Ottawa Ankle Rules
Austrian et al, 2017 ⁵⁰	Impact of an ED electronic sepsis surveillance system on patient mortality and length of stay
Baird and Rumbarger, 2017 ²⁴	Impact of developing adult ketamine order panels for the ED
Bookman et al, 2017 ⁶⁵	Embedded CDS in EHR decreases use of high-cost imaging in the ED: Emb ED study
Dayan et al, 2017 ⁶⁶	Use of traumatic brain injury prediction rules with CDS
Drescher et al, 2017 ⁶⁷	Knowledge translation of the PERC rule for suspected PE: a blueprint for reducing the number of CT pulmonary angiograms
Hendrickson et al, 2017 ³⁴	Implementation of an electronic CDS tool for pediatric appendicitis within a hospital network
Martin Rico et al, 2017 ⁶⁸	Electronic alerting and decision support for early sepsis detection and management: Impact on clinical outcomes
Mills et al, 2017 ⁶⁹	CDS increases diagnostic yield of CT for suspected PE
Min et al, 2017 ⁷⁰	CDS decreases volume of imaging for Low Back Pain in an urban ED
Nicholson et al, 2017 ⁷¹	The use of a CPOE alert to decrease rates of <i>Clostridium difficile</i> testing in young pediatric patients
Stevens et al, 2017 ⁷²	Enhancing quality of provider practices for older adults in the ED (EQUIPPED)
Yan et al, 2017 ⁷³	Yield of CT pulmonary angiography in the ED when providers override evidence-based CDS
Sharp et al, 2018 ⁷⁴	Implementation of the Canadian CT Head Rule and its association with use of CT among patients with head injury

CPOE, Computerized physician order entry; EHR, electronic health record; MRI, magnetic resonance imaging; PERC, PE ruleout criteria; LBP, lower back pain.

intracranial hemorrhage²⁸; these studies accounted for 17 (40%) of the total articles included in the review. More comprehensive technologies supported several decisions along the diagnostic and treatment pathway to improve both detection and care for specific conditions, including syncope,²⁹ sepsis,³⁰ asthma management,³¹ pneumonia,³² and appendicitis.^{33,34}

Thirty-five studies (83%) reported positive effects on measured outcomes. The most common outcomes were

process measures directly related to work flows altered by clinical decision support interventions, such as rate of compliance with guidelines for imaging^{35,36} and medication orders.³⁷ Nine studies (21%) reported effects on patient-centered clinical outcomes, which we defined as revisits to the ED, hospital or ED length of stay, and admission and mortality rates, with 5 of these reporting improvements. Seven studies (17%) reported at least some evaluation of the clinical decision support

Table 2. Risk-of-bias assessment results by study.

Author/Year	Prospective, Retrospective, or Mixed?	Are Inclusion/Exclusion Clearly Stated?	Are Inclusion/Exclusion Applied Uniformly?	Sufficient Sample Size of Outcome of Interest?	Level of Detail Describing Intervention?	Are Outcomes Prespecified?	Is the Selection of Comparison Group Appropriate?	Was an Attempt Made to Balance Allocation Between Groups?	Did Researchers Isolate Effect From Unintended Exposure With Multivariate Analysis or Stratification?
Bernstein et al, 2005 ²¹	Unknown	Yes	Yes	Yes	High	Yes	Yes	No	No
Kirk et al, 2005 ⁵⁶	Prospective	Partially	Yes	No	High	Yes	UK	No	No
Buising et al, 2008 ³⁷	Unknown	Yes	NA	Yes	Medium	Yes	UK	NA	Yes
Sard et al, 2008 ⁵⁴	Retrospective	Yes	Yes	Yes	High	Yes	Yes	NA	No
Terrell et al, 2009 ²²	Prospective	Yes	Yes	Yes	High	Yes	Yes	Yes	UK
Melnick et al, 2010 ²⁹	Mixed	Yes	Yes	Yes	High	Yes	Yes	NA	UK
Terrell et al, 2010 ³⁸	Prospective	Yes	Yes	Yes	High	Yes	Yes	Yes	Yes
Venkat et al, 2010 ⁵²	Prospective	Yes	Yes	Yes	Medium	Yes	Yes	NA	Partially
Carman et al, 2011 ²⁵	Mixed	Yes	Yes	Yes	Medium	Yes	No	No	No
Drescher et al, 2011 ⁵³	Mixed	Yes	Part	Yes	High	Yes	Yes	NA	No
Nelson et al, 2011 ³⁰	Unknown	Yes	Yes	UC	High	Yes	Yes	No	UK
Griffey et al, 2012 ⁴⁹	Prospective	Yes	Yes	Yes	High	Yes	Yes	Yes	Yes
Raja et al, 2012 ²⁷	Unknown	Yes	Yes	Yes	Yes	Yes	Yes	No	No
Dexheimer et al, 2013 ³⁹	NA	No	NA	UK	Low	Yes	Yes	No	No
Prevedello et al, 2013 ⁵⁷	Retrospective	Yes	Yes	Yes	High	Yes	Yes	NA	No
Demonchy et al, 2014 ⁵⁸	Prospective	Yes	Yes	No	Medium	Yes	Yes	No	Yes
Dexheimer et al, 2014 ³⁷	Prospective	Yes	Yes	Yes	High	Yes	Yes	Yes	Yes
Fowler et al, 2014 ⁵⁹	NA	No	NA	No	Medium	No	NA	NA	No
Gupta et al, 2014 ³⁵	Unknown	Yes	Yes	Yes	High	Yes	Yes	Yes	UK
Raja et al, 2014 ³⁶	Prospective	Yes	Yes	Yes	High	Yes	Yes	NA	No
Carnevale et al, 2015 ⁶⁰	Mixed	Partially	Yes	Yes	Low	Yes	Yes	No	Partially
Dean et al, 2015 ³²	Prospective	Yes	Yes	Yes	Medium	Partially	Yes	No	Yes
Faine et al, 2015 ⁶¹	Retro	Yes	NA	No	High	Yes	Yes	NA	Yes
Ip et al, 2015 ²⁸	Mixed	Yes	Yes	Yes	High	Yes	Yes	Yes	Yes
Sethuraman et al, 2015 ⁶²	Prospective	Yes	Yes	Yes	High	Yes	Yes	NA	UK
Stevens et al, 2015 ⁶³	Prospective	Yes	NA	Yes	Medium	Yes	NA	NA	Partially
Kharbanda et al, 2016 ³³	Prospective	Yes	Yes	Yes	High	Yes	Yes	NA	Yes
McGuire et al, 2016 ⁵¹	Prospective	Yes	Yes	Yes	High	Yes	UK	NA	Partially
Silveira et al, 2016 ⁶⁴	Prospective	Yes	Yes	Yes	High	Yes	Yes	NA	UK
Austrian et al, 2017 ⁵⁰	Retrospective	Yes	Yes	Yes	High	Yes	Yes	No	No
Baird et al, 2017 ²⁴	Mixed	Yes	Yes	No	Medium	Yes	Yes	No	No
Bookman et al, 2017 ⁶⁵	Mixed	No	Yes	Yes	High	Yes	UK	Yes	No
Dayan et al, 2017 ⁶⁶	Prospective	Yes	Yes	Yes	High	Yes	Yes	No	No
Drescher et al, 2017 ⁶⁷	Mixed	Yes	Yes	Yes	Medium	Yes	Yes	No	UK
Hendrickson et al, 2017 ³⁴	Retrospective	Yes	Yes	Yes	High	Yes	Yes	Yes	Yes
Martin Rico et al, 2017 ⁶⁸	Retrospective	Yes	Yes	Yes	Low	Yes	Yes	No	No
Mills et al, 2017 ⁶⁹	Prospective	Yes	Yes	Yes	High	Yes	Yes	Yes	No
Min et al, 2017 ⁷⁰	Retrospective	No	Yes	Yes	High	Yes	Yes	Yes	Yes
Nicholson et al, 2017 ⁷¹	Retrospective	Yes	Yes	Yes	Medium	Yes	Yes	Yes	Yes
Stevens et al, 2017 ⁷²	Mixed	Yes	Yes	Yes	Medium	Yes	Yes	No	No
Yan et al, 2017 ⁷³	Retrospective	Yes	NA	Yes	High	Yes	NA	Yes	NA
Sharp et al, 2018 ⁷⁴	Prospective	Yes	Yes	Yes	Medium	Yes	Yes	Yes	No

NA, not applicable; UK, unknown.

Table 2. Continued.

Did Execution of Intervention Vary From Protocol?	Were Outcome Assessors Blinded?	Were Outcome Measurements Valid and Reliable?	Was Length of Follow-up the Same for All Groups?	Was Follow-up Sufficient to Evaluate Outcomes?	Are Important Primary Outcomes Missing From Results?	Are the Statistical Methods Used Appropriate?	Are Any Important Harms Missing From the Results?	Are Results Believable, Taking Study Limitations Into Consideration?	Is the Funding Source Identified?
No	NA	Yes	NA	Yes	No	Yes	No	Yes	Yes
No	NA	No	Yes	Partially	No	Partially	No	Partially	Yes
UK	No	Yes	NA	Partially	UK	Yes	UK	Yes	Yes
No	No	Yes	NA	NA	No	Yes	Yes	Yes	Yes
No	NA	Yes	NA	NA	No	Yes	Yes	Yes	Yes
No	No	UK	Yes	Yes	No	Yes	Yes	Yes	Yes
No	Yes	Yes	NA	NA	No	Yes	No	Yes	Yes
Yes	NA	Yes	NA	NA	Yes	Partially	Yes	Yes	Yes
Unknown	No	UK	NA	NA	No	No	Partially	Yes	No
UK	No	Yes	NA	NA	No	UK	NA	Yes	No
No	No	Yes	NA	NA	No	Yes	Yes	Yes	Yes
No	Yes	Yes	Yes	Yes	No	Yes	No	Yes	Yes
No	No	Yes	NA	NA	No	Yes	Yes	Yes	Yes
UK	NA	UK	NA	NA	UK	No	NA	Yes	No
No	NA	Yes	Yes	Yes	No	Yes	No	Yes	Yes
No	No	Yes	NA	NA	No	Yes	No	Yes	Yes
UK	No	Yes	NA	NA	No	Yes	NA	Yes	Yes
NA	No	UK	NA	NA	UK	No	UK	Yes	No
UK	No	Yes	Yes	Yes	No	Yes	No	Yes	Yes
No	No	Yes	NA	NA	No	Yes	Partially	Yes	Yes
UK	No	Yes	NA	NA	No	Yes	Yes	Yes	No
No	No	Yes	Yes	Yes	No	Yes	No	Yes	No
UK	UK	Yes	NA	NA	No	Yes	NA	Yes	No
UK	No	Yes	Yes	Yes	No	Yes	No	Yes	No
No	No	Yes	NA	NA	No	Yes	Yes	Yes	Yes
No	NA	Yes	NA	NA	No	Yes	NA	Yes	Yes
No	NA	Yes	Yes	Yes	No	Yes	No	Yes	Yes
No	NA	UK	Yes	Partially	No	Yes	Yes	Yes	Yes
No	No	Yes	NA	NA	No	Yes	Yes	Yes	Yes
No	No	Yes	Yes	Yes	No	Yes	No	Yes	Yes
No	No	Yes	NA	No	No	No	No	Yes	Yes
No	No	Yes	Yes	Yes	No	Yes	No	No	No
No	No	Yes	Yes	Yes	No	Yes	Yes	Yes	Yes
No	No	Yes	Yes	Yes	Yes	Yes	No	Yes	Yes
UK	UK	Yes	No	Yes	No	Yes	No	Yes	Yes
No	No	UK	Yes	Yes	No	Yes	No	Partially	No
No	No	Yes	Yes	Yes	No	Yes	No	Yes	Yes
No	No	Yes	Yes	Yes	No	Yes	No	Yes	No
No	No	Yes	Yes	Yes	No	Yes	No	Yes	Yes
No	No	Yes	Yes	Yes	Yes	Yes	No	Yes	Yes
No	NA	Yes	NA	NA	No	Yes	No	Yes	Yes
No	No	Yes	Yes	Yes	No	Yes	No	Yes	Yes

intervention's usability or acceptance, including either user feedback or adoption rates for optional interventions.

Thirty-two of the included studies (76%) used a before-after experimental design, with only 3 randomized controlled trials (7%). Most studies were single center. Table 2 shows the results of the bias assessment for each study. We chose not to explicitly score studies but noted that studies varied greatly in quality, from randomized controlled trials with overall low risk of bias^{22,38} to uncontrolled observational studies with higher risk of bias.³⁹

LIMITATIONS

As in all systematic reviews, decisions made in regard to inclusion and exclusion criteria influenced our sample. Given the volume of literature and the motivation for our study, we chose to focus only on computerized decision support integrated with electronic health record technology. Although this limitation was useful in defining a more cohesive cohort of studies, a few recent, high-quality studies involving clinical decision support tools that were not integrated into an electronic health record were excluded, including a randomized controlled trial.⁴⁰ Also excluded were several early studies in which investigators created clinical decision support systems to promote guideline-based documentation and computer-aided diagnosis before the era of modern electronic health records.⁴¹⁻⁴³ Furthermore, our decision to include only studies that reported the influence of an intervention on a care process or patient-related outcome excluded literature from our current analysis that evaluated either the design or acceptability of clinical decision support systems in isolation, without evaluation of the effects of implementation.

DISCUSSION

Our Preferred Reporting Items for Systemic Reviews and Meta-analyses–based systematic review identified 42 studies that explicitly measured the clinical effect of electronic health record–integrated clinical decision support implemented in the ED. The majority of these studies (83%) reported positive effect, although few addressed patient-centered clinical outcomes or long-term sustainability. Studies were mixed in quality and many had relatively high risk of bias. Commonly identified biasing factors included uncontrolled or historically controlled designs, lack of blinding to outcome assessment, and lack of inclusion of important potential positive and negative outcomes in evaluation of program influence. Among studies reporting intervention uptake and acceptance, clinical decision support use was often low, even in cases in

which interventions had positive effects. Our ED-specific results echo those found in the overall health informatics literature: although numerous studies report a positive influence on process or outcome, well-controlled trials examining clinical outcomes are relatively rare^{8,44} and uptake and acceptance of health information technology can be challenging. Given the widespread clinical rollout of clinical decision support systems driven by health policy,⁴⁵ the relatively small number of studies identified calls attention to the paucity of high-quality literature evaluating actual implementation of these systems in the ED.

Our systematic review adds new knowledge in regard to the scope and effects of clinical decision support in the ED. Bennett and Hardiker⁴⁶ conducted a review of the literature published between 1994 and 2015 to identify the body of clinical decision support research undertaken in EDs, the research methods used, their quality, and the effect of clinical decision support on clinical care in EDs. Although their review had somewhat similar inclusion criteria, it did not specify that clinical decision support must be integrated into the electronic health record and did not explicitly define clinical decision support for the purpose of inclusion and exclusion. The authors included 23 studies, with some overlap of our sample, and noted a lower rate of studies with positive influence, at 50%; however, this was due to exclusion of studies that reported outcomes that were deemed not clinically relevant as opposed to identification of a higher rate of negative-result studies.

The preponderance of studies included used a before-after study design. This is undoubtedly a convenient design for studying a single-center intervention, and often the only possible design to use for evaluating an intervention that will be implemented solely for quality improvement purposes. Unfortunately, this study design has several disadvantages.^{47,48} Uncontrolled before-after studies are often confounded by changes in practice pattern over time and in the specific setting of clinical decision support interventions. For example, they can be confounded by education and attention surrounding the rollout of a new intervention focused on a condition or process. Fortunately, the included studies also provide proof of concept that more rigorous designs such as randomized controlled trials^{22,31,38} and interrupted time series analyses^{37,49} are feasible for the study of clinical decision support interventions. Furthermore, several studies were able to use a multisite design to provide better experimental control and generalizability.^{24,32,50}

Many of the outcomes studied were process measures immediately downstream from implemented interventions, including documentation, prescribing or ordering of tests in a manner adherent to guidelines, and timing of

interventions supported by clinical decision support systems. Although these are useful because they provide evidence that a given clinical decision support modifies behavior, they do not make a strong case for the utility of clinical decision support in improving patient outcomes. Furthermore, few studies explicitly discussed the potential harms of recommendations from clinical decision support systems, including potential negative effects on patients when a given practice guideline is complied with. The combination of reporting only process measures while not considering potential harms lays the groundwork for a potentially misleading assessment of a given intervention's overall effect. Several studies did report significant improvement in patient-centered outcomes, including an improved 30-day mortality among pneumonia patients,³² improved rates of screening tests and immunizations,^{51,52} and decreased imaging use coupled with consistent diagnostic performance for various conditions.^{28,33}

Overall, few articles discussed explicit human factors design considerations or usability evaluation of clinical decision support interventions. This was likely due in part to our exclusion of articles that did not report the effect of clinical decision support implementation; many articles were excluded because they described only the design, without testing, of an intervention. Despite this, among the included articles there was a notable lack of emphasis on human factors and design considerations before implementation, or usability as an influence measure along with clinical outcomes. Among studies that did report data on acceptance of clinical decision support, intervention uptake was often poor.^{49,53} Several studies described resistance to use of clinical decision support tools, and among those that were optional, rates of clinical decision support use were often low^{25,54} despite positive outcomes when they were used. This finding is concordant with a recently published review focusing specifically on acceptance of cognitive support technologies at ED point of care, which found that, although clinicians acknowledge the value of these technologies, actual use rates are often low.⁵⁵ This highlights the importance of careful design of interventions and consideration of human factors design principles and usability evaluation in the design and implementation phases.

In accordance with our review of the available literature, we propose that authors of future studies of clinical decision support interventions consider the following:

1. Although uncontrolled before-after trials remain common, the literature demonstrates the feasibility of more robust experimental designs, including interrupted time series, controlled before-after studies using multiple sites, and randomized controlled trial designs.

2. Although process outcomes are often the most convenient from a study design perspective, potentially influential studies increasingly are focusing on more patient-centered outcomes. Furthermore, although uncommonly included, potential negative consequences (eg, missed diagnoses, return ED visits), as well as positive ones, of recommendations should be included in studies of clinical decision support implementation.
3. Given low acceptance rates even among potentially influential interventions, usability and acceptance outcomes remain an important component of clinical decision support evaluation. Additionally, further attention and effort should be dedicated toward human-centered design and implementation of clinical decision support to improve acceptance and uptake.

In conclusion, literature evaluating the implementation of clinical decision support technologies within the ED is expanding as hospitals and physicians take advantage of supportive systems within electronic health records to drive patient-specific recommendations. Numerous studies suggest that clinical decision support interventions are effective in changing physician practice with respect to process outcomes such as guideline adherence; however, many studies are small and poorly controlled. Continuing to move from single-center to multicenter study designs will offer the ability to use improved experimental designs. Although the results of the current literature review highlight the promise of decision support for improving care, future studies should consider the inclusion of more specific information about design choices, attempt to improve on uncontrolled before-after designs, and focus on clinically relevant outcomes wherever possible.

Supervising editor: David L. Schriger, MD, MPH. Specific detailed information about possible conflict of interest for individual editors is available at <https://www.annemergmed.com/editors>.

Author affiliations: From the BerbeeWalsh Department of Emergency Medicine, School of Medicine and Public Health (Patterson, Pulia), the Center for Quality and Productivity Improvement (Patterson, Hoonakker, Schoofs Hundt, Wiegmann, Wirkus, Carayon), Ebling Library (Johnson), and Department of Industrial and Systems Engineering (Wiegmann, Carayon), University of Wisconsin–Madison, Madison, WI; and the Department of Emergency Medicine, Yale University School of Medicine, New Haven, CT (Ravi).

Author contributions: BWP, PLTH, ASH, and PC conceived and designed the study. BWP and SJ designed the search strategy, which was executed by SJ. BWP, MSP, SR, PLTH, ASH, DW, EJW, and PC participated in review and selection of studies and data abstraction from studies. BWP drafted the article, and all authors contributed substantially to its revision. BWP takes responsibility for the paper as a whole.

All authors attest to meeting the four [ICMJE.org](http://www.icmje.org) authorship criteria: (1) Substantial contributions to the conception or design of the work; or the acquisition, analysis, or interpretation of data for the work; AND (2) Drafting the work or revising it critically for important intellectual content; AND (3) Final approval of the version to be published; AND (4) Agreement to be accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved.

Funding and support: By *Annals* policy, all authors are required to disclose any and all commercial, financial, and other relationships in any way related to the subject of this article as per ICMJE conflict of interest guidelines (see www.icmje.org). The authors have stated that no such relationships exist. This research was supported by funding from the Agency for Healthcare Research and Quality (AHRQ), grants R01HS022086 (PC), K08HS024558 (BP), and K08HS024342(MSP); and was supported by the Clinical and Translational Science Award program through the National Institutes of Health (NIH) National Center for Advancing Translational Sciences, grant UL1TR000427.

Publication dates: Received for publication July 20, 2018. Revision received October 8, 2018. Accepted for publication October 29, 2018.

The content of this article is solely the responsibility of the authors and does not necessarily represent the official views of the AHRQ or the NIH.

REFERENCES

- Bates DW, Saria S, Ohno-Machado L, et al. Big data in health care: using analytics to identify and manage high-risk and high-cost patients. *Health Aff (Millwood)*. 2014;33:1123-1131.
- Hayrinen K, Saranto K, Nykanen P. Definition, structure, content, use and impacts of electronic health records: a review of the research literature. *Int J Med Inform*. 2008;77:291-304.
- Roque FS, Jensen PB, Schmock H, et al. Using electronic patient records to discover disease correlations and stratify patient cohorts. *PLoS Comput Biol*. 2011;7:e1002141.
- Stewart WF, Shah NR, Selna MJ, et al. Bridging the inferential gap: the electronic health record and clinical evidence. *Health Aff (Millwood)*. 2007;26:w181-w191.
- Rosenbaum L. Transitional chaos or enduring harm? the EHR and the disruption of medicine. *N Engl J Med*. 2015;373:1585-1588.
- Wachter RM. Why Health Care Tech Is Still So Bad. March 21, 2015; Available at: <https://www.nytimes.com/2015/03/22/opinion/sunday/why-health-care-tech-is-still-so-bad.html>. Accessed December 12, 2018.
- Wachter R. *The Digital Doctor: Hope, Hype, and Harm at the Dawn of Medicine's Computer Age*. New York, NY: McGraw Hill Education; 2015.
- Garg AX, Adhikari NKJ, McDonald H, et al. Effects of computerized clinical decision support systems on practitioner performance and patient outcomes: a systematic review. *JAMA*. 2016;293:1223-1238.
- Lobach DF, Hammond WE. Computerized decision support based on a clinical practice guideline improves compliance with care standards. *Am J Med*. 1997;102:89-98.
- Garg AX, Adhikari NK, McDonald H, et al. Effects of computerized clinical decision support systems on practitioner performance and patient outcomes: a systematic review. *JAMA*. 2005;293:1223-1238.
- Hunt DL, Haynes RB, Hanna SE, et al. Effects of computer-based clinical decision support systems on physician performance and patient outcomes: a systematic review. *JAMA*. 1998;280:1339-1346.
- Blumenthal D, Tavenner M. The "meaningful use" regulation for electronic health records. *N Engl J Med*. 2010;363:501-504.
- Carayon P, Hundt AS, Karsh B-T, et al. Work system design for patient safety: the SEIPS model. *Qual Saf Health Care*. 2006;15:i50-i58.
- Karsh B, Weinger MB, Abbott PA, et al. Health information technology: fallacies and sober realities. *J Am Med Inform Assoc*. 2010;17:617-623.
- Ash JS, Sittig DF, Campbell EM, et al. Some unintended consequences of clinical decision support systems. *AMIA Annu Symp Proc*. 2007;2007:26-30.
- Landman AB. The potential for clinical decision support to improve emergency care. *Ann Emerg Med*. 2015;66:521-522.
- Campbell R. The five "rights" of clinical decision support. *J AHIMA*. 2013;84:42-47.
- Parasuraman R, Sheridan TB, Wickens CD. A model for types and levels of human interaction with automation. *IEEE Trans Syst Man Cybern A Syst Hum*. 2000;30:286-297.
- Moher D, Shamseer L, Clarke M, et al. Preferred Reporting Items for Systematic Review and Meta-analysis Protocols (PRISMA-P) 2015 statement. *Syst Rev*. 2015;4:1.
- Viswanathan M, Berkman ND. Development of the RTI item bank on risk of bias and precision of observational studies. *J Clin Epidemiol*. 2012;65:163-178.
- Bernstein SL, Whitaker D, Winograd J, et al. An electronic chart prompt to decrease proprietary antibiotic prescription to self-pay patients. *Acad Emerg Med*. 2005;12:225-231.
- Terrell KM, Perkins AJ, Dexter PR, et al. Computerized decision support to reduce potentially inappropriate prescribing to older emergency department patients: a randomized, controlled trial. *J Am Geriatr Soc*. 2009;57:1388-1394.
- American Geriatrics Society 2015 Beers Criteria Update Expert Panel. American Geriatrics Society 2015 updated Beers criteria for potentially inappropriate medication use in older adults. *J Am Geriatr Soc*. 2015;63:2227-2246.
- Baird H, Rumbarger R. Impact of developing adult ketamine order panels for the emergency department. *Hosp Pharm*. 2017;52:483-487.
- Carman MJ, Phipps J, Raley J, et al. Use of a clinical decision support tool to improve guideline adherence for the treatment of methicillin-resistant *Staphylococcus aureus*: skin and soft tissue infections. *Adv Emerg Nurs J*. 2011;33:252-266.
- Prevedello LM, Raja AS, Ip IK, et al. Does clinical decision support reduce unwarranted variation in yield of CT pulmonary angiogram? *Am J Med*. 2013;126:975-981.
- Raja AS, Ip IK, Prevedello LM, et al. Effect of computerized clinical decision support on the use and yield of CT pulmonary angiography in the emergency department. *Radiology*. 2012;262:468-474.
- Ip IK, Raja AS, Gupta A, et al. Impact of clinical decision support on head computed tomography use in patients with mild traumatic brain injury in the ED. *Am J Emerg Med*. 2015;33:320-325.
- Melnick ER, Genes NG, Chawla NK, et al. Knowledge translation of the American College of Emergency Physicians' clinical policy on syncope using computerized clinical decision support. *Int J Emerg Med*. 2010;3:97-104.
- Nelson JL, Smith BL, Jared JD, et al. Prospective trial of real-time electronic surveillance to expedite early care of severe sepsis. *Ann Emerg Med*. 2011;57:500-504.
- Dexheimer JW, Abramo TJ, Arnold DH, et al. Implementation and evaluation of an integrated computerized asthma management system in a pediatric emergency department: a randomized clinical trial. *Int J Med Inform*. 2014;83:805-813.

32. Dean NC, Jones BE, Jones JP, et al. Impact of an electronic clinical decision support tool for emergency department patients with pneumonia. *Ann Emerg Med.* 2015;66:511-520.
33. Kharbanda AB, Madhok M, Krause E, et al. Implementation of electronic clinical decision support for pediatric appendicitis. *Pediatrics.* 2016;137:e20151745.
34. Hendrickson MA, Wey AR, Gaillard PR, et al. Implementation of an electronic clinical decision support tool for pediatric appendicitis within a hospital network. *Pediatr Emerg Care.* 2017;34:10-16.
35. Gupta A, Ip IK, Raja AS, et al. Effect of clinical decision support on documented guideline adherence for head CT in emergency department patients with mild traumatic brain injury. *J Am Med Inform Assoc.* 2014;21:e347-e351.
36. Raja AS, Gupta A, Ip IK, et al. The use of decision support to measure documented adherence to a national imaging quality measure. *Acad Radiol.* 2014;21:378-383.
37. Buising KL, Thursky KA, Black JF, et al. Improving antibiotic prescribing for adults with community acquired pneumonia: does a computerised decision support system achieve more than academic detailing alone? a time series analysis. *BMC Med Inform Decis Mak.* 2008;8:35.
38. Terrell KM, Perkins AJ, Hui SL, et al. Computerized decision support for medication dosing in renal insufficiency: a randomized, controlled trial. *Ann Emerg Med.* 2010;56:623-629.
39. Dexheimer JW, Kennebeck S. Modifications and integration of the electronic tracking board in a pediatric emergency department. *Pediatr Emerg Care.* 2013;29:852-857.
40. Kline JA, Zeitouni RA, Hernandez-Nino J, et al. Randomized trial of computerized quantitative pretest probability in low-risk chest pain patients: effect on safety and resource use. *Ann Emerg Med.* 2009;53:727-735.e721.
41. Schriger DL, Baraff LJ, Hassanvand M, et al. EDECS: the emergency department expert charting system. *Medinfo.* 1995;8(pt 2):1665.
42. Wellwood J, Johannessen S, Spiegelhalter DJ. How does computer-aided diagnosis improve the management of acute abdominal pain? *Ann R Coll Surg Engl.* 1992;74:40-46.
43. Schriger DL, Baraff LJ, Rogers WH, et al. Implementation of clinical guidelines using a computer charting system. Effect on the initial care of health care workers exposed to body fluids. *JAMA.* 1997;278:1585-1590.
44. Moja L, Kwag KH, Lytras T, et al. Effectiveness of computerized decision support systems linked to electronic health records: a systematic review and meta-analysis. *Am J Public Health.* 2014;104:e12-e22.
45. Healthcare Information and Management Systems Society. Clinical Decision Support and Meaningful Use. Available at: <https://www.himss.org/library/clinical-decision-support/meaningful-use>. Accessed November 30, 2018.
46. Bennett P, Hardiker NR. The use of computerized clinical decision support systems in emergency care: a substantive review of the literature. *J Am Med Inform Assoc.* 2017;24:655-668.
47. Goodacre S. Uncontrolled before-after studies: discouraged by Cochrane and the EMJ. *Emerg Med J.* 2015;32:507-508.
48. Sacks H, Chalmers TC, Smith H Jr. Randomized versus historical controls for clinical trials. *Am J Med.* 1982;72:233-240.
49. Griffey RT, Lo HG, Burdick E, et al. Guided medication dosing for elderly emergency patients using real-time, computerized decision support. *J Am Med Inform Assoc.* 2012;19:86-93.
50. Austrian JS, Jamin CT, Doty GR, et al. Impact of an emergency department electronic sepsis surveillance system on patient mortality and length of stay. *J Am Med Inform Assoc.* 2017;25:523-529.
51. McGuire R, Moore E. Using a configurable EMR and decision support tools to promote process integration for routine HIV screening in the emergency department. *J Am Med Inform Assoc.* 2016;23:396-401.
52. Venkat A, Chan-Tompkins NH, Hegde GG, et al. Feasibility of integrating a clinical decision support tool into an existing computerized physician order entry system to increase seasonal influenza vaccination in the emergency department. *Vaccine.* 2010;28:6058-6064.
53. Drescher FS, Chandrika S, Weir ID, et al. Effectiveness and acceptability of a computerized decision support system using modified Wells criteria for evaluation of suspected pulmonary embolism. *Ann Emerg Med.* 2011;57:613-621.
54. Sard BE, Walsh KE, Doros G, et al. Retrospective evaluation of a computerized physician order entry adaptation to prevent prescribing errors in a pediatric emergency department. *Pediatrics.* 2008;122:782-787.
55. Jun S, Plint AC, Campbell SM, et al. Point-of-care cognitive support technology in emergency departments: a scoping review of technology acceptance by clinicians. *Acad Emerg Med.* 2018;25:494-507.
56. Kirk RC, Li-Meng Goh D, Packia J, et al. Computer calculated dose in paediatric prescribing. *Drug Saf.* 2005;28:817-824.
57. Prevedello LM, Raja AS, Ip IK, et al. Does Clinical Decision Support Reduce Unwarranted Variation in Yield of CT Pulmonary Angiogram? *Am J Med.* 2013;126(11):975-981.
58. Demonchy E, Dufour JC, Gaudart J, et al. Impact of a computerized decision support system on compliance with guidelines on antibiotics prescribed for urinary tract infections in emergency departments: a multicentre prospective before-and-after controlled interventional study. *J Antimicrob Chemother.* 2014;69:2857-2863.
59. Fowler SA, Yaeger LH, Yu F, et al. Electronic health record: integrating evidence-based information at the point of clinical decision making. *J Med Libr Assoc.* 2014;102:52-55.
60. Carnevale TJ, Meng D, Wang JJ, et al. Impact of an emergency medicine decision support and risk education system on computed tomography and magnetic resonance imaging use. *J Emerg Med.* 2015;48:53-57.
61. Faine B, Mohr N, Harland KK, et al. Importance of decision support implementation in emergency department vancomycin dosing. *West J Emerg Med.* 2015;16:557-564.
62. Sethuraman U, Kannikeswaran N, Murray KP, et al. Prescription errors before and after introduction of electronic medication alert system in a pediatric emergency department. *Acad Emerg Med.* 2015;22:714-719.
63. Stevens MB, Hastings SN, Powers J, et al. Enhancing the Quality of Prescribing Practices for Older Veterans Discharged From the Emergency Department (EQUIPPED): preliminary results from enhancing quality of prescribing practices for older veterans discharged from the emergency department, a novel multicomponent interdisciplinary quality improvement initiative. *J Am Geriatr Soc.* 2015;63:1025-1029.
64. Silveira PC, Ip IK, Sumption S, et al. Impact of a clinical decision support tool on adherence to the Ottawa Ankle Rules. *Am J Emerg Med.* 2016;34:412-418.
65. Bookman K, West D, Ginde A, et al. Embedded clinical decision support in electronic health record decreases use of high-cost imaging in the emergency department: EmbED study. *Acad Emerg Med.* 2017;24:839-845.
66. Dayan PS, Ballard DW, Tham E, et al. Use of traumatic brain injury prediction rules with clinical decision support. *Pediatrics.* 2017;139:e20162709.
67. Drescher MJ, Fried J, Brass R, et al. Knowledge translation of the PERC rule for suspected pulmonary embolism: a blueprint for reducing the number of CT pulmonary angiograms. *West J Emerg Med.* 2017;18:1091-1097.
68. Martin Rico P, Valdivia Pérez A, Lacalle Martínez JM, et al. Electronic alerting and decision support for early sepsis detection and management: impact on clinical outcomes. *Eur J Clin Pharmacol.* 2017;19:33-40.
69. Mills AM, Ip IK, Langlotz CP, et al. Clinical decision support increases diagnostic yield of computed tomography for suspected pulmonary embolism. *Am J Emerg Med.* 2017;36:540-544.
70. Min A, Chan VWY, Aristizabal R, et al. Clinical decision support decreases volume of imaging for low back pain in an urban emergency department. *J Am Coll Radiol.* 2017;14:889-899.

71. Nicholson MR, Freswick PN, Di Pentima MC, et al. The use of a computerized provider order entry alert to decrease rates of *Clostridium difficile* testing in young pediatric patients. *Infect Control Hosp Epidemiol.* 2017;38:542-546.
72. Stevens M, Hastings SN, Markland AD, et al. Enhancing Quality of Provider Practices for Older Adults in the Emergency Department (EQUIPPED). *J Am Geriatr Soc.* 2017;65:1609-1614.
73. Yan Z, Ip IK, Raja AS, et al. Yield of CT pulmonary angiography in the emergency department when providers override evidence-based clinical decision support. *Radiology.* 2017;282:717-725.
74. Sharp AL, Huang BZ, Tang T, et al. Implementation of the Canadian CT Head Rule and its association with use of computed tomography among patients with head injury. *Ann Emerg Med.* 2018;71:54-63.e52.

Clinical Resources in *Annals* Systematic Review Snapshots

The Systematic Review Snapshot (SRS) articles select and summarize systematic reviews from the current literature to highlight for readers of *Annals*. Over 200 SRS articles are available on 18 categories of the EM model. Find the best evidence in a quickly digestible format today; go to the Collections pull down menu and click on EBEM Systematic Review Snapshots on the *Annals* Web site (www.annemergmed.com).

