QUERI

Effectiveness of Interventions to Improve Emergency Department Efficiency: An Evidence Map

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PREFACE

The VA Evidence-based Synthesis Program (ESP) was established in 2007 to provide timely and accurate syntheses of targeted healthcare topics of particular importance to clinicians, managers, and policymakers as they work to improve the health and healthcare of Veterans. QUERI provides funding for four ESP Centers, and each Center has an active University affiliation. Center Directors are recognized leaders in the field of evidence synthesis with close ties to the AHRQ Evidence-based Practice Centers. The ESP is governed by a Steering Committee comprised of participants from VHA Policy, Program, and Operations Offices, VISN leadership, field-based investigators, and others as designated appropriate by QUERI/HSR&D.

The ESP Centers generate evidence syntheses on important clinical practice topics. These reports help:

- Develop clinical policies informed by evidence;
- Implement effective services to improve patient outcomes and to support VA clinical practice guidelines and performance measures; and
- Set the direction for future research to address gaps in clinical knowledge.

The ESP disseminates these reports throughout VA and in the published literature; some evidence syntheses have informed the clinical guidelines of large professional organizations.

The ESP Coordinating Center (ESP CC), located in Portland, Oregon, was created in 2009 to expand the capacity of QUERI/HSR&D and is charged with oversight of national ESP program operations, program development and evaluation, and dissemination efforts. The ESP CC establishes standard operating procedures for the production of evidence synthesis reports; facilitates a national topic nomination, prioritization, and selection process; manages the research portfolio of each Center; facilitates editorial review processes; ensures methodological consistency and quality of products; produces “rapid response evidence briefs” at the request of VHA senior leadership; collaborates with HSR&D Center for Information Dissemination and Education Resources (CIDER) to develop a national dissemination strategy for all ESP products; and interfaces with stakeholders to effectively engage the program.

Comments on this evidence report are welcome and can be sent to Nicole Floyd, ESP CC Program Manager, at Nicole.Floyd@va.gov.

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This report is based on research conducted by the Evidence-based Synthesis Program (ESP) Center located at the **West Los Angeles VA Medical Center, Los Angeles, CA**, funded by the Department of Veterans Affairs, Veterans Health Administration, Office of Research and Development, Quality Enhancement Research Initiative. The findings and conclusions in this document are those of the author(s) who are responsible for its contents; the findings and conclusions do not necessarily represent the views of the Department of Veterans Affairs or the United States government. Therefore, no statement in this article should be construed as an official position of the Department of Veterans Affairs. No investigators have any affiliations or financial involvement (*eg,* employment, consultancies, honoraria, stock ownership or options, expert testimony, grants or patents received or pending, or royalties) that conflict with material presented in the report.

ABSTRACT

Objective

Emergency departments are seeking ways to improve efficiency, but to be useful to decision-makers, studies of such interventions should report information on utilization, cost, and quality of care. Previous systematic reviews have been limited to specific intervention types, and have not assessed implementation costs. We used evidence mapping to assess knowledge gaps and highlight research priorities.

Methods

A systematic literature scan identified studies testing the effect of an improvement intervention on at least one ED utilization measure (*eg*, length of stay (LOS), waiting-room time (WT), left-without-being-seen (LBWS)). Cost, quality impact, and resource requirement (additional resources needed, existing resources sufficient, unclear) data were abstracted. Studies limited to specific clinical conditions (*eg*, sepsis, acute myocardial infarction) were excluded. Evidence maps were constructed to illustrate intervention type, resource use, data reporting, and effect size graphically.

Results

From 139 titles, N=97 publications were included, describing 17 types of interventions, most commonly physician triage (n=32), nursing scope of practice expansion (n=23), and fast track (n=12). Studies varied in reporting utilization metrics (LOS 69%, WT 38%, LWBS 35%) and implementation costs (20%). Only 3 of 97 studies reported on utilization, resource requirements, costs, and quality measures.

Improvements ranged between 5%-20% for LOS, 10%-50% for WT, and -0.5% to 64.7% for LWBS.

Conclusions

Few studies reported the types of data needed to fully assess the effectiveness of efficiency improvement interventions. Future research should emphasize consistent reporting of resource requirements, cost and quality impact data, and how to achieve efficiency improvements without investing new resources. Filling these gaps will make ED efficiency studies more useful to decision-makers.

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INTRODUCTION

Background

Overcrowding in the emergency department (ED) negatively affects patient outcomes, limits effective treatment for time-sensitive conditions such as pneumonia and sepsis, and reduces the safety and timeliness of care.[1-3] "Efficiency" in ED care is often assessed by using measures of utilization (*eg,* length of stay [LOS] or waiting time), but in order to be relevant to policymakers needs also to include a measure of the unit of resources expended (*eg,* physician full-time-equivalents) to implement the intervention, and some assessment of quality (*eg,* the same or fewer harms and errors). Many ED efficiency interventions have been described, ranging from structural redesign (*eg,* "fast track" units) or staffing changes (*eg,* medical scribes) to technological solutions (*eg,* point-of-care lab testing).

Importance

Given the large number and breadth of interventions described, a systematic scoping review describing the full range of the evidence would be helpful to clinicians, administrators, and researchers. Previous reviews limited their focus to one or several intervention types, such as physician triage[4] or expanding nurses' scope of practice.[5] Some reviews included multiple types[6] but none have sought to purposefully include a broad range of interventions. Simulation of ED throughput is a robust field of inquiry, but few of these models are implemented and tested in real-world settings.[5,7]

Goals of this Investigation

In order to make decisions on strategic priorities, ED leaders need efficiency intervention studies to be clear and specific, to reflect tests in real-world settings, to define the organizational context of the intervention, and to report utilization outcomes, costs, and impacts on quality of care such as harms or errors. We sought to broadly describe a range of ED efficiency improvement studies using evidence mapping. This approach identifies gaps in knowledge by presenting results in a graphical format to highlight future research needs.[8]

METHODS

TOPIC DEVELOPMENT

This topic was developed in response to a nomination by Dr. Michael Ward on behalf of Dr. Chad Kessler, National Director of the VA Emergency Medicine Field Advisory Committee. This report contributed to the Field Advisory Committee's conference "Toward a VA Emergency Medicine Research Agenda: Setting Priorities to Improve the Health of Veterans Seeking Emergency Care." The scope was further developed with input from the topic nominators, the ESP Coordinating Center, the review team, and the technical expert panel (TEP).

The scope of this report includes the following:

- An evidence map that provides a visual overview of the distribution of evidence (both what is known and where there is little or no evidence base) for interventions to improve emergency department (ED) efficiency.

- An accompanying narrative that helps stakeholders interpret the state of the evidence to inform policy and clinical decision-making.

SEARCH STRATEGY

A literature search conducted by the VA Evidence-Based Synthesis Program (ESP) Coordinating Center identified peer-reviewed journal articles reporting ED efficiency improvement interventions, including systematic reviews, which were mined for references. Multiple databases were included: Cochrane Database of Systematic Reviews: Protocols and Reviews (2005 through July 20, 2016), MEDLINE (1996 through July 21, 2016), as well as sources of gray literature (see Appendix A for full search strategy).

INCLUSION/EXCLUSION CRITERIA

To be considered as evidence for inclusion in the evidence map, each study must have tested the effectiveness of an intervention on one or more specific measures of ED utilization, including, but not limited to, length of stay (LOS), waiting room time (WT), or left without being seen (LWBS) rate. These include both randomized controlled trials and observational studies, and comparisons across institutions or within an institution over time. Studies not providing data on outcome measures, focusing only on a single clinical condition (*eg*, acute myocardial infarction), and simply using inpatient units to offload ED functions (*eg*, condition-specific, short-term observation units) were excluded. Studies published more than 20 years ago were excluded.

STUDY SELECTION AND DATA ABSTRACTION

All citations were reviewed by 2 independent reviewers (PGS/SMO or MMG/CPC). Data extraction and full-text review were completed in duplicate as well. Discrepancies were resolved with discussion among the reviewer pairs. Full study selection criteria and data abstraction fields are listed in Appendix B.

We abstracted: unit of analysis, sample size, country, hospital teaching status, type(s) of utilization, cost and quality impact measures reported, and baseline and post-intervention results.

Relative improvement in outcomes was calculated as a positive percentage improvement over baseline (*eg*, a reduction in LOS from 90 minutes to 60 minutes would be a ([90-60]/90 = 33% improvement). If studies presented multiple versions of a particular outcome, we defined LOS as the total time from ED bed assignment to final disposition (*eg*, discharge or transfer to an inpatient unit), WT as the total time from arrival in the waiting room to ED bed assignment, and LWBS rate as the percentage of all analyzed visits in which a patient leaves from the ED before being seen by a physician. While there was heterogeneity in the use of these terms by study authors, we used the data provided by the authors if they reported using the same term.

We identified the measures of implementation cost that were reported and quantified (*eg*, full-time-equivalents [FTEs] added, equipment costs). If costs weren't quantified, we ascertained whether implementation was described as being accomplished by reallocating existing resources, or whether it was described as requiring new resources. Studies that described both reallocation of existing resources and new resources were classified as requiring new resources.

Studies were classified by intervention, each study was assigned to one intervention type to produce exhaustive and mutually exclusive categories. In cases where studies could overlap categories, best fit was determined with group review. We used categories from previous systematic reviews when possible and pile sort techniques otherwise.

QUALITY ASSESSMENT

This is not applicable for an evidence map.

DATA SYNTHESIS

An evidence map is a systematic search of a broad field to identify gaps in knowledge and future research needs, which presents the results in a user-friendly format, often a visual figure or graph, or a searchable database.[8] In our case, an overview map plotted the distribution of intervention types (x-axis) with resources required for implementation (y-axis). Studies were grouped according to these dimensions and plotted as bubbles, the size of which represented the number of studies in that group. The color of the bubble additionally corresponds to the nature of resource use of a study.

A second set of evidence maps illustrated intervention types (x-axis, major sections), resources required for implementation (color and x-axis, minor sections), effect size (y-axis), and study size (diameter of markers). These maps are not intended to pool data, but to illustrate the evidentiary landscape in regard to interventions to improve ED efficiency. Findings from these maps were derived through observation and discussion among co-authors.

NARRATIVE SYNTHESIS

The narrative synthesis complements the visual evidence maps to provide more details from the included literature.

TECHNICAL EXPERT PANEL

The technical expert panel (TEP) for the project included: Chad S. Kessler, MD, National Program Director, VA Emergency; Michael Ward, MD, Department of Emergency Medicine,

Vanderbilt University Medical Center, VA; Kristina Cordasco, MD, Core Investigator, VA Greater Los Angeles Center for the Study of Healthcare Innovation, Policy and Practice.

PEER REVIEW

A draft version of the report was reviewed by technical experts and clinical leadership. Reviewer comments and our responses are documented in Appendix C.

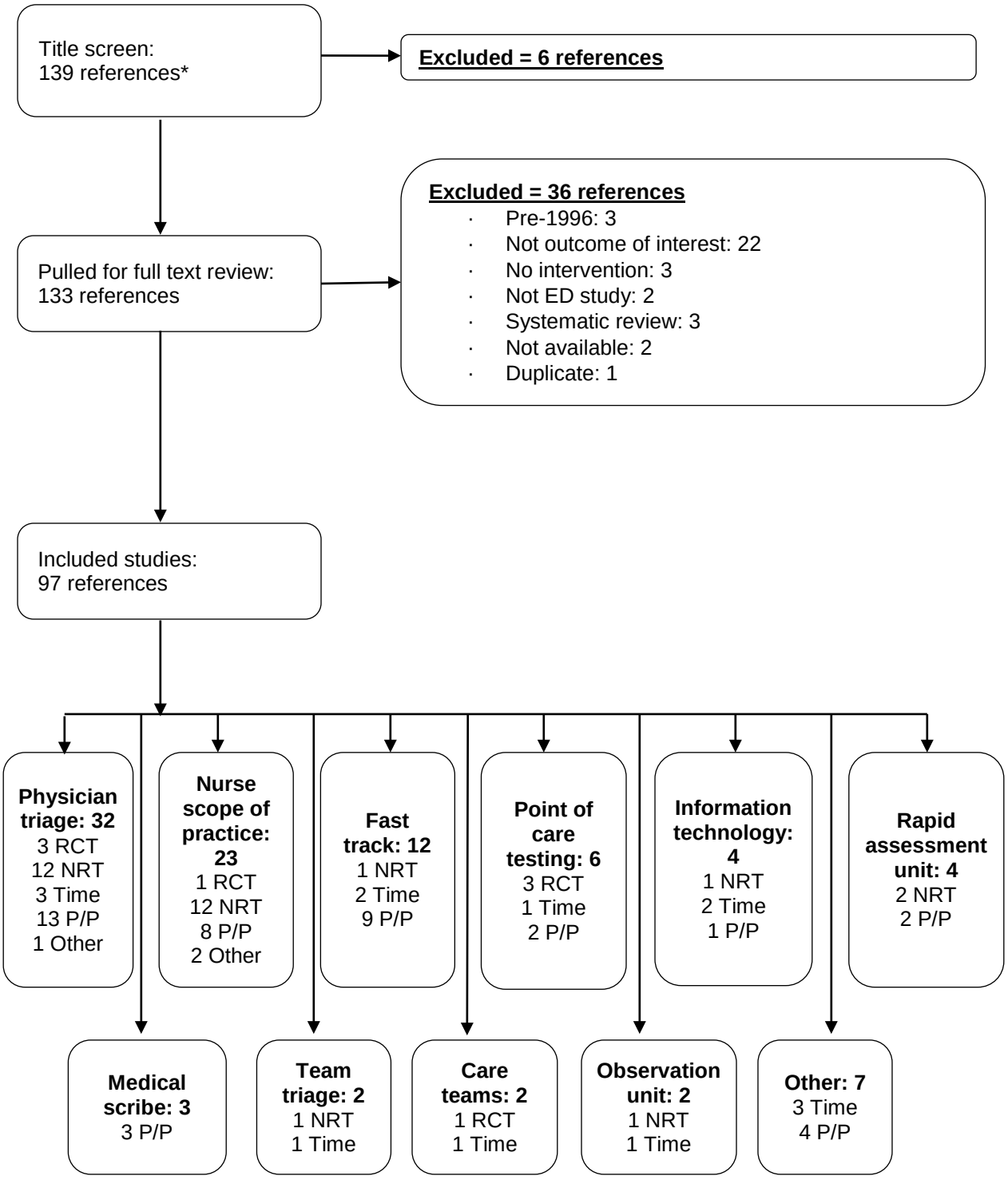
RESULTS

LITERATURE FLOW

Our literature searches identified 139 titles as potentially relevant for this evidence map. From these titles, 133 references were included for full-text review. Six were excluded from full-text review because 5 were pre-1996 and one was unavailable. When reviewing full texts, 36 publications were rejected for the following reasons: 3 were pre-1996; 15 did not have an outcome of interest (*ie,* study focused on improvements for a single condition only or no ED outcome was measured); 12 did not include an ED efficiency intervention; 3 did not have an intervention; 2 were not an ED study; 3 were systematic reviews; 2 were not retrievable; and one was a duplicate of another publication included for review. A full list of studies excluded at full-text review is included in Appendix E.

The 97 included publications described 11 categories of interventions: 32 described triage by a physician, 23 described expanding nurse scope of practice (SOP), 12 described fast track interventions, 6 described point of care (POC) testing, 4 described information technology-based (IT) interventions, 4 described rapid assessment units, 3 described the use of medical scribes, 2 described observation units, 2 described team triage, and 7 described other interventions that only appeared once. Examples of intervention types reported in one study each included sharing individual performance data to all providers, intensive bed occupancy tracking, geriatric focused areas, and comprehensive department re-engineering. A full list of included studies is included in Appendix D. See Figure 1 for the Literature Flow.

Figure 1. Literature Flow Chart



RCT = randomized controlled trial
NRT = non-randomized concurrently controlled trial
Time = time-series
P/P = pre/post

Table 1 presents descriptive information about the 97 included studies. Studies originated from the United States (41%), Australia (19%), Canada (11%), the United Kingdom (9%), and 13 other nations (19%). Studies were usually located at academically affiliated sites (73%), and 93% were single-site interventions. Samples sizes ranged, with 60% of studies including more than 1,000 patients, 37% of studies including more than 10,000 patients, and 14% of studies using shifts or facilities as the unit of analysis. Only one study was at a VA site. The most common study design was pre/post design (43%).

Table 1. Descriptive Information about the Studies

Country of Origin	Sample size = 97
USA	40
Australia	19
Canada	11
UK	9
Other	18
Site Academically Affiliated	
Yes	69
No	11
Both	2
Not reported	15
Sites Involved	
One site	90
Multi-site	6
Not reported	1
Sample Sizes	
>10,000 patients	36
1,000-9,999 patients	22
500-999 patients	7
100-499 patients	16
Other unit (shift, facility)	14
Unclear	2
VA Setting	
No	96
Yes	1
Study Design	
Randomized controlled trial	7
Non-randomized concurrently controlled trial	31
Time series	14
Pre/post	42
Other	3

UTILIZATION, QUALITY, AND SAFETY REPORTED

Reporting of ED utilization outcomes varied, with LOS reported by 69% (n=67), WT by 38% (n=37), and LWBS by 35% (n=34). Other outcomes reported included the inpatient admission rate (33% of studies, n=32), other clinical outcomes such as unplanned revisit rate (13%; n=13), and clinical harms (8%; n=8). In terms of data showing impact on clinical quality, 13% reported clinical measures (*eg*, health status or patient satisfaction). 13% reported unplanned revisit rates, and 8% reported clinical harms.

COSTS AND RESOURCE USE REPORTED

Reporting of costs was limited, as 20% of studies provided a quantitative estimate of implementation requirements (n=19). We were necessarily generous when determining that studies met the criterion for quantifying costs. Table 3 presents abridged examples of actual text from articles, while Appendix F presents the unabridged examples. These varied from formal cost-effectiveness analyses, such as in the study by Soremekun,[9] to stating a physician was added and what amount of time was necessary (such as in the study by Han[10]). In reporting implementation resource requirements: 44 studies described adding new resources (45%), 18 studies described reallocating existing resources (19%), and 35 studies were unclear in regard to net resource expenditure (36%, lacked sufficient description).

Table 2. Abridged Examples of Key Text Counted as "Quantifying Costs"

Fernandez, 1996[11]	Prior to the present study, no nurse was assigned solely to the FT area. "… addition of an extra admitting clerk; … addition of an FT nurse; … we expanded our FT area to include more rooms and stretchers, … having a full-time FT nurse"
Partovi, 2001[12]	"The cost of additional faculty coverage was estimated to be $11.98/patient seen in ED. … If this is to be implemented on a fulltime basis, the cost per patient would rise to $19.35. The annual cost will be more than a million dollars for full-time faculty triage."
Ardagh, 2002[13]	"an additional nurse and an additional ED registrar were rostered"
Richardson, 2004[14]	"… it was necessary to increase the evening consultant cover from one to two consultants… Staff were educated... the department was modified to include a desktop working area for the MDT doctor and a mini assessment/treatment cubicle behind the triage desk… A diagnostic set and X-ray viewing box was installed on the wall."
Terris, 2004[15]	"Funding was allocated for senior clinicians (medical and nursing) to staff the triage area for 16 hours per week for three months. An emergency medicine consultant and a senior ED nurse (G or F grade) were chosen as the preferred team."
Rodi, 2006[16]	"The only new cost of the intervention was hiring a dedicated technician to support the PA."
Levsky, 2008[17]	"…an emergency physician or physician's assistant, a registered nurse, and a medic or civilian emergency medical technician… During the intervention, the TNT team was used 4 days a week: Monday, Tuesday, Thursday, and Sunday from 10:00 a.m. to 6:00 p.m. …Specifically, during PI, five new registered nurses were hired, as were three new medical support assistants (clerks), which increased nurse and clerk coverage by approximately 7% and 15%, respectively. No ED operations or staffing changes occurred between P2 and P3, other than the addition of TNT."
Ieraci, 2008[18]	"The net result of the remodelling was a reduction in the total number of treatment spaces (beds plus chairs) from 25 to 24… Separate clinical resources were provided

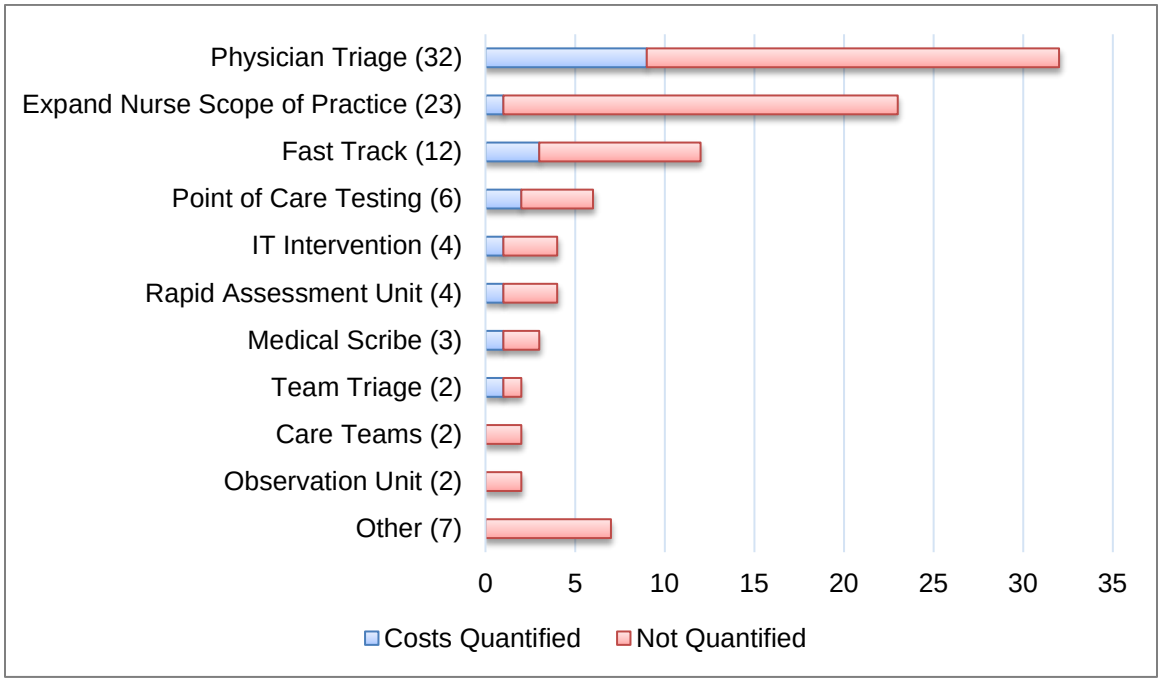
	to staff the FT area with two nurses round the clock, and one senior doctor (career medical officer, CMO) for 16 h/day."
Singer, 2008[19]	"The third phase involved hiring seven personnel, at a laboratory technologist level, so that a new workstation could be covered 24 hours per day in the central laboratory, 7 days per week. It also involved the purchase of new analyzers, at a cost of about $46,000, and installation of a dedicated pneumatic tube, at a cost of about $150,000."
Gerton, 2009[20]	"The PIT provided additional coverage that replaced a triage nurse, but did not change the physician staffing of the ED… During PIT hrs, 11.5 RVUs more were billed on average than without PIT (384 vs. 373; 95% CI +/-41). With RVU estimated at $38.08, charges increased by $438 / 8hr shift. If PIT were 5 d/wk for 1 yr, increased billing would be $118,000. This would not offset the cost of a physician."
Arya, 2010[21]	"The scribe training program is 60 hours in length." "The RVU/hr increased by 0.18 (95% confidence interval [CI] = 0.04 to 0.32, p = 0.0067) units when the percentage of a shift for which a scribe was utilized increases by 10%... If a physician in our department changed from 0% to 100% of the patients seen with a scribe, 0.8 additional patients per hour can be evaluated in a 10-hour shift, and 24 (2.4/hr) additional RVUs would be generated… Based on the 2008 Medicare RVU reimbursement rate of $38 for one RVU, a scribe being utilized to full capacity, resulting in an additional 2.4 RVUs/hr generated, could result in an additional 91 billed dollars per hour. Scribes at our institution are salaried at approximately $16–$19 per hour…"
Han, 2010[10]	Physician triage was initiated on July 11, 2005, 7 days a week from 1:00 p.m. to 9:00 p.m. A dedicated board certified or board-eligible emergency physician initiated diagnostic evaluation and treatment of patients in the waiting room after the triage nurse performed his or her initial evaluation. The triage physician was an additional physician to the existing staffing model.
Fry, 2011[22]	"The TENP role, in July 2006, commenced with the employment of 3 full time equivalent positions, which provided a TENP on duty for 15 h a day Monday—Sunday (eight o'clock am to eleven o'clock pm)." (TENP = Transitional Emergency Nurse Practitioner)
Imperato, 2012[23]	"…required the addition of two full-time equivalent attending physicians, at a total cost of $490,000 in additional salary costs per year plus fringe benefits. The nurse and technician assigned to the PIT were reallocated from another part of the ED, so no additional nursing staffing cost was incurred."
Soremekun, 2012[9,24]	"Three components of the financial impact of the physician triage were considered: revenue, operational costs, and capital expenditure… The incremental revenue and operational expense projection generated from physician screening using aforementioned assumptions are depicted in Table 4. In year 1, the estimated ED contribution margin from discharged patients is $1 324 338 (growth in medium acuity patients, $1 137 234; LWBS patients, $187 104) and the estimated contribution margin from admitted patients is $1 384 718. The estimated operational expense associated with the physician screening system at year 1 is $1 864 104 ($1 624 104 in salary costs; $240 000 in depreciation costs). The total earnings and CF projection at year 1 are $844 952 and $1 084 952, respectively. Based on the CF projections and a discount rate of 5%, the NPV of physician screening was $2 816 263 and the internal rate of return is 85%, with time to break even of 13 months."
Soremekun, 2014[25]	"The midtrack area, however, was staffed with two additional registered nurses (RNs) for an additional 16 hours or a 3.4% increase in total nursing clinical hours per day."
Inokuchi, 2015[26]	"… the system can be built for less than 5000 US dollars"

Utilization data, resource requirements, quantifiable input costs, and quality outcome measures were reported together by 3 of 97 studies (3%). All three were single-site studies, and all three required the addition of new resources. A pre/post study of emergency nurse practitioners from an Australian academic medical center[22]required the addition of 3 FTE nurse practitioners, and yielded a 3% improvement in LOS (207 vs 213 minutes, $p < .0001$), a 36% improvement in WT (38 vs 60 minutes, $p < .000$), and a 44% reduction in LWBS (8.1% vs 4.5%, $p < .0001$). Of 5,248 patients seen by nurse practitioners, there was one case of missed early appendicitis, and one case of missed nondisplaced hand fracture, but no adverse outcomes. A fast track intervention, using a pre/post study design at an Australian academic medical center[18] required an increase in total staff time of 16%, and yielded an 19% improvement in LOS (194 vs 241 minutes, $p < .001$), a 42% improvement in WT (32 vs 55 minutes, $p < .001$), and a 50% improvement in LWBS (3.1% vs 6.2%, $p < .001$). However, re-presentation to the ED within 48 hours increased slightly (4.4% vs 3.7%, $p = .056$). A new EMR deployment at a Japanese academic medical center[26]yielded a 19% reduction in length of stay (108 mins vs 134 mins, $p < .001$), with no significant change in 28-day mortality (0.4% vs 0.7%, $p = .62$). This study used a crossover design to provide a concurrent comparison group.

DESCRIPTION OF RESOURCE USE BY INTERVENTION TYPE

Physician triage was the most commonly studied intervention, and nearly half of the studies where costs were quantified were from physician triage studies (47%, see Figure 2). Expanding nurses' scope of practice was the next most common intervention, but only one study quantified costs.

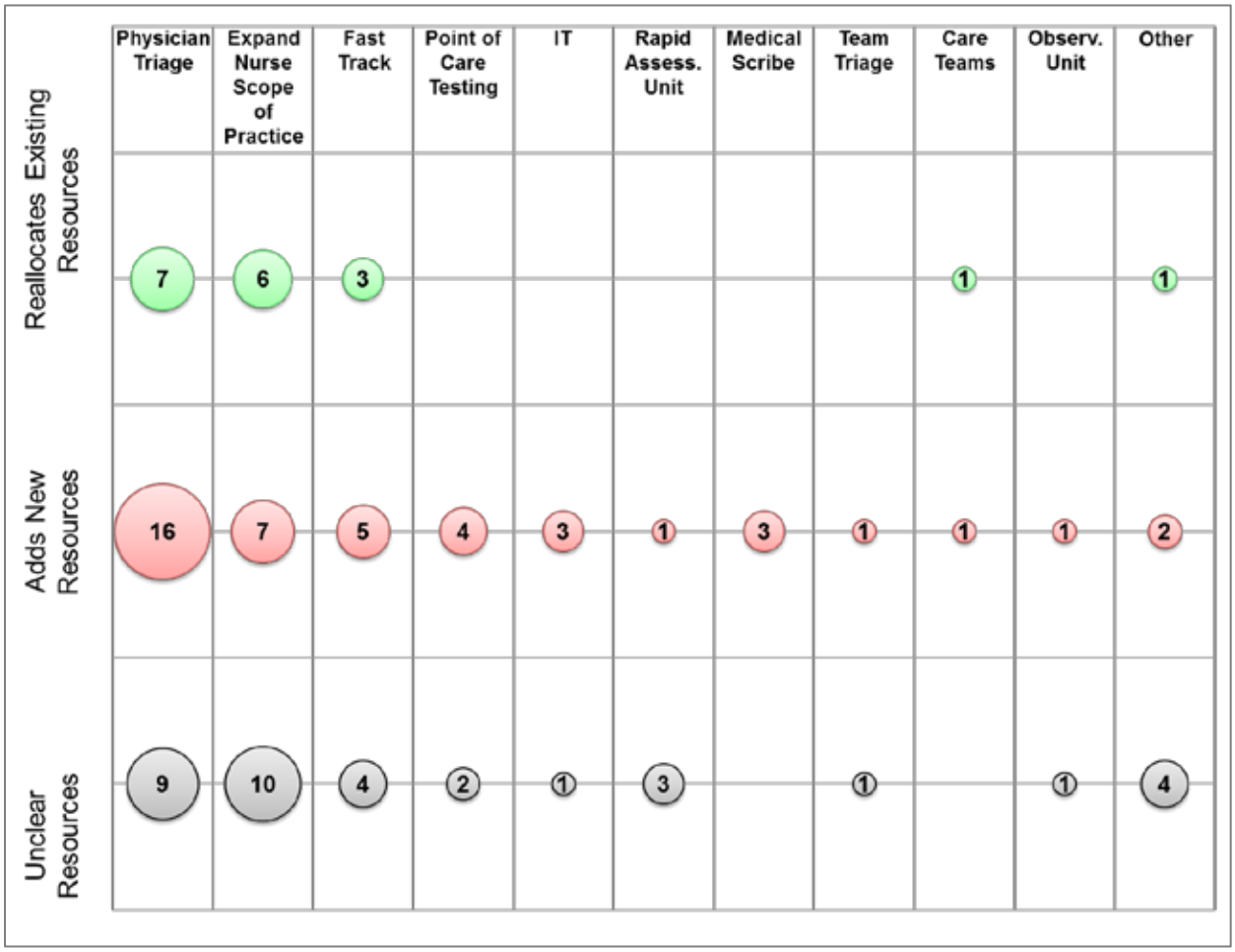
Figure 2. Intervention Type with Costs Quantified



Our first evidence map presents the studies by intervention type and description of resource use (Figure 3). Four intervention types (physician triage, expanding nurses' scope of practice, fast track, and care teams) were implemented at least once without requiring the

addition of new resources to the ED. However, for each of these types, it was more commonly reported that additional resources were required. There were 6 intervention types that were never implemented through reallocating existing resources only: point of care testing, rapid assessment units, information technology (IT) interventions, medical scribes, team triage, and observation units.

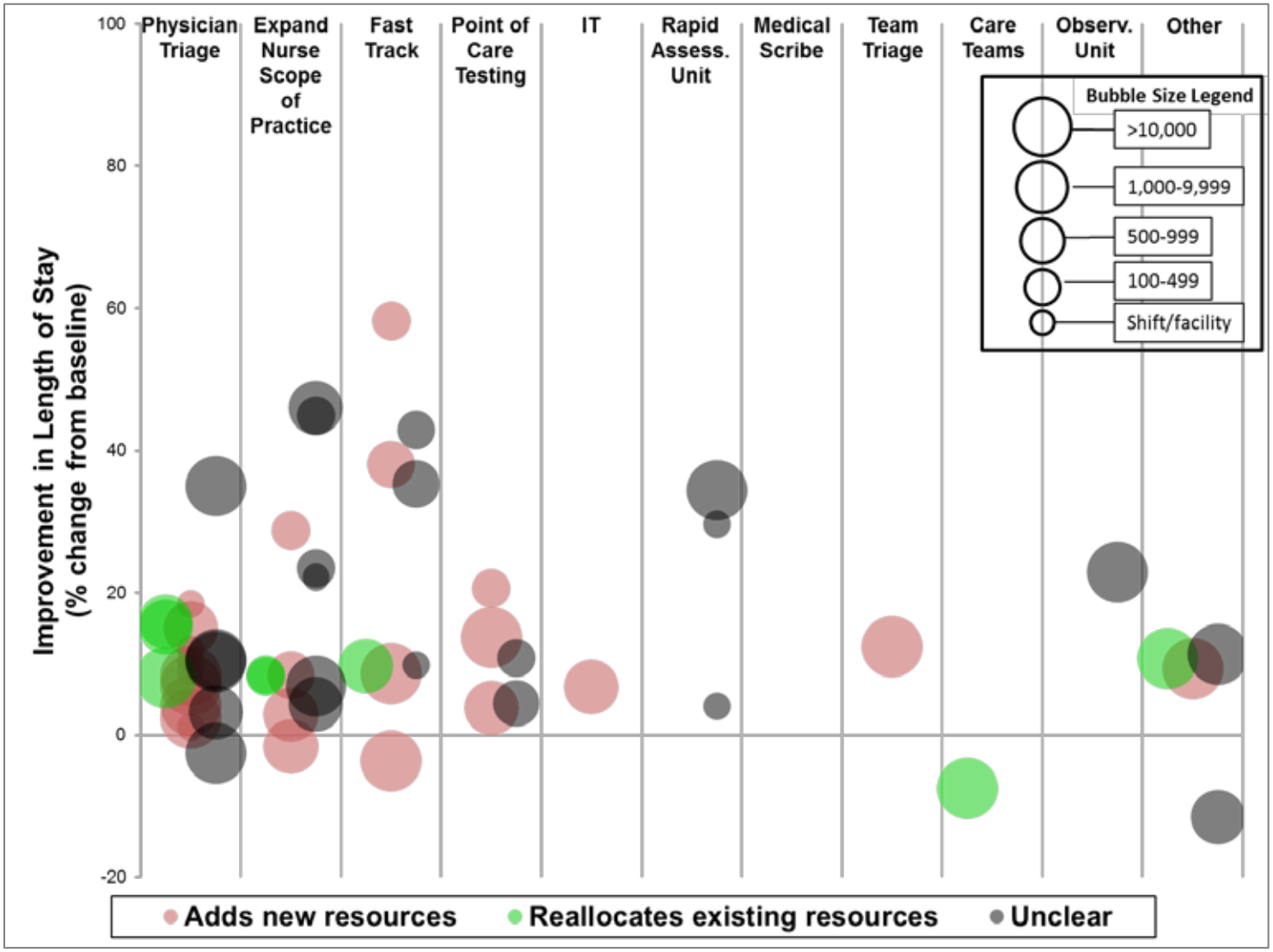
Figure 3. Evidence Map Displaying Amount of Literature by Intervention and Resource Use Reported (n=97)



EFFECT ON LENGTH OF STAY BY INTERVENTION TYPE

Most studies that reported changes in length of stay (n=67) improved mean LOS by between 10 and 40 minutes. When these improvements are displayed as a percentage relative to baseline LOS, improvements tended to range between 5% and 20% (Figure 4). Fast Track and Nurse Scope of Practice interventions had the highest frequency of studies that were able to yield improvements greater than 30%. No Medical Scribe studies reported Length of Stay outcomes.

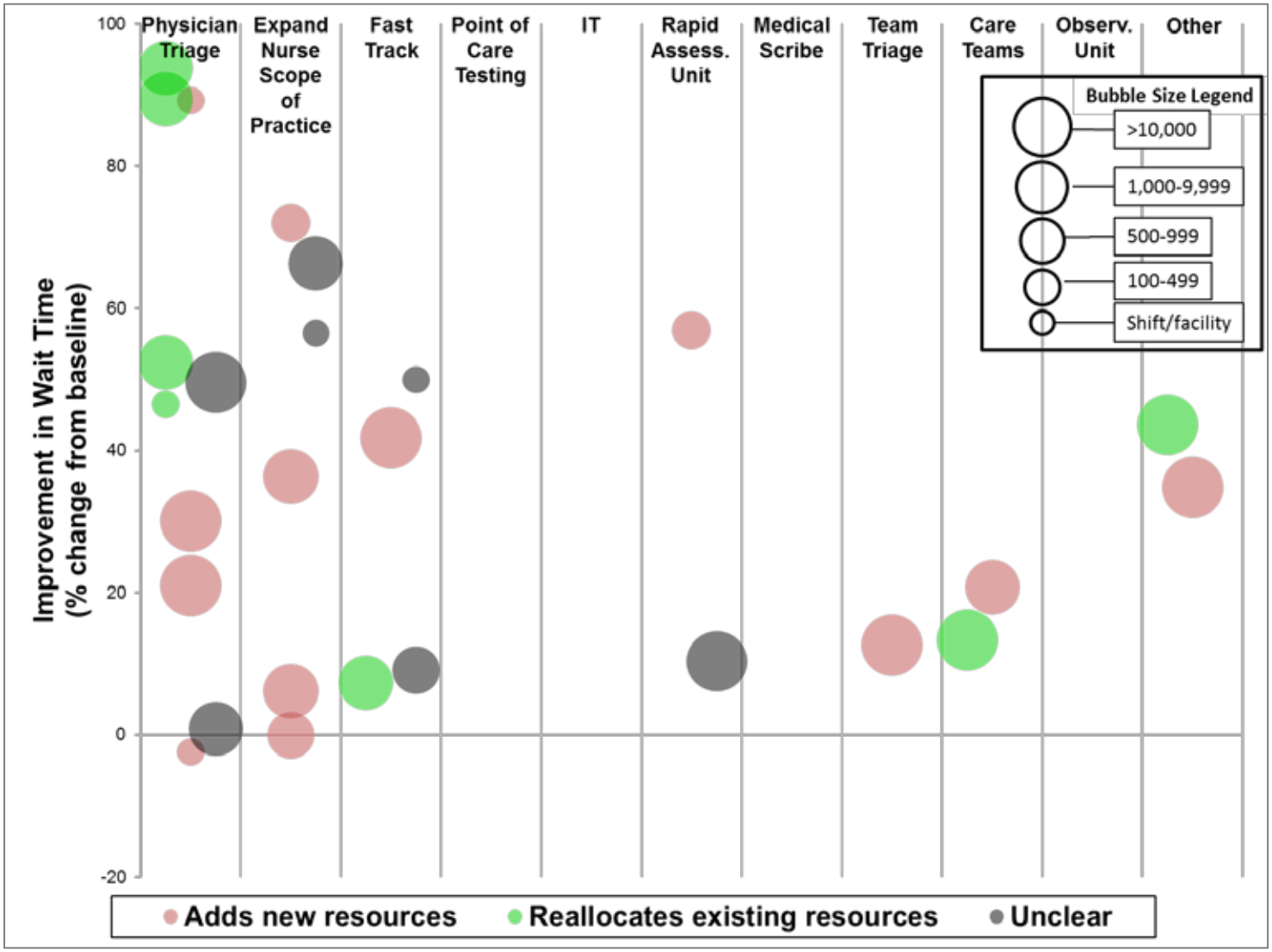
Figure 4. Evidence Map Displaying Improvement in Length of Stay (Percent Change from Baseline)



EFFECT ON WAIT TIME BY INTERVENTION TYPE

Improvements in wait time tended to range between 10 and 40 minutes, or 10% to 50% of baseline (Figure 5). Physician Triage and Nurse SOP had the highest number of studies with very high improvements of more than 60%. No IT, Medical Scribe, Observation Unit, or Point of Care Testing interventions reported effects on Wait Time.

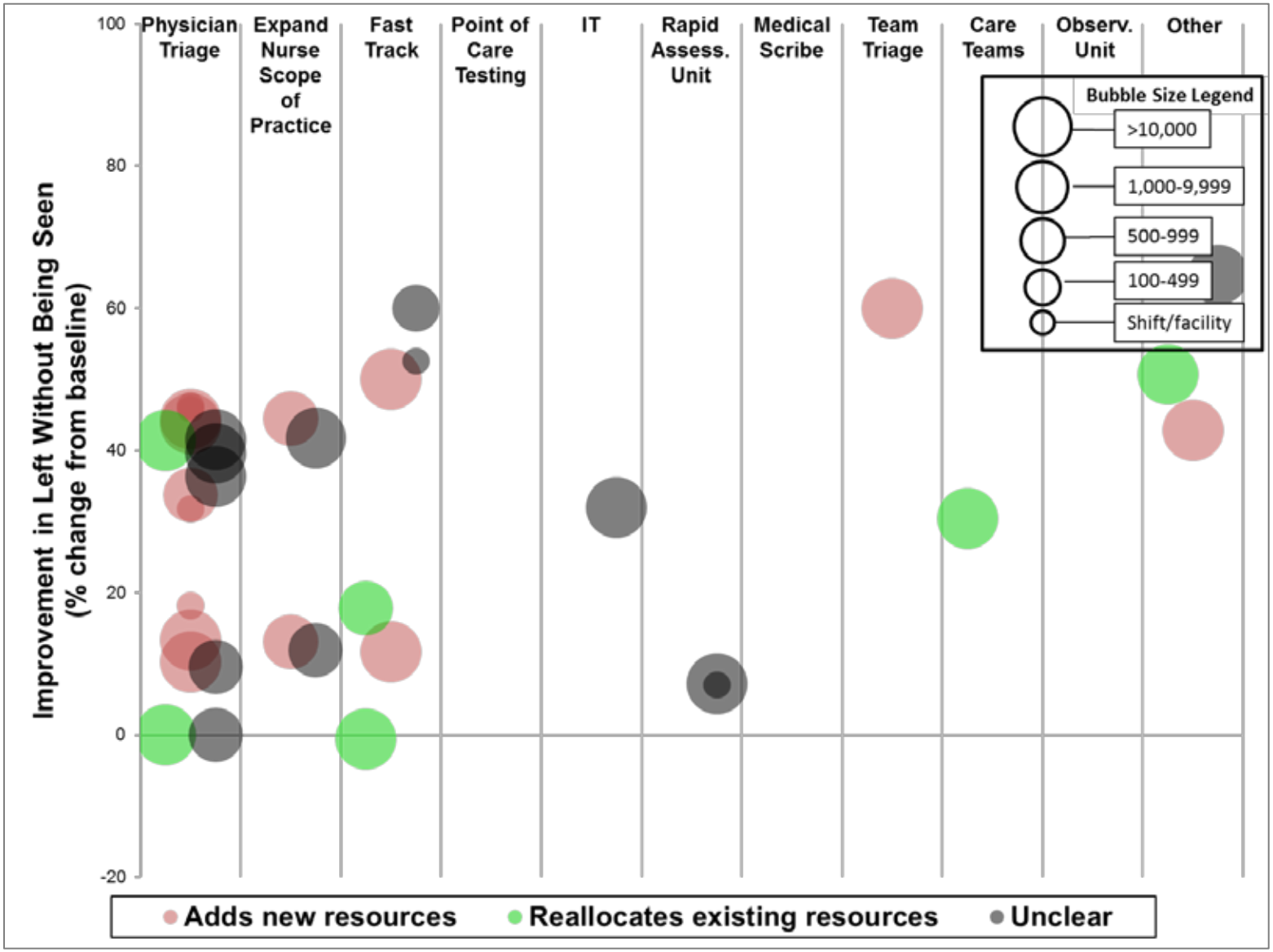
Figure 5. Evidence Map Displaying Improvement in Wait Time (Percent Change from Baseline)



EFFECT ON LWBS BY INTERVENTION TYPE

Most interventions yielded reductions in LWBS ranging between 0 and 5 absolute percentage points from their baseline rate. Compared to baseline LWBS, improvements ranged from -0.5% to 64.7% (Figure 6). Physician Triage and Nurse Scope of Practice had the most number of consistently positive results. Fast Track yielded both strongly positive and negative results. No Medical Scribe, Observation Unit, or Point of Care Testing interventions reported effects on LWBS rate.

Figure 6. Evidence Map Displaying Change in Left Without Being Seen Rate (Percent Change from Baseline)



VA PUBLICATIONS

Of the 97 included publications, there was one study conducted in the VA from the St. Louis VA Medical Center.[27] This single-site study included 2,194 patient visits pre-intervention and 2,154 patient visits post-intervention and describes the reassignment of a physician and nurse practitioner to triage, as well as the results of a discrete event simulation modelling the same conditions. The modelling accurately predicted the effect of the intervention, which decreased the daily mean LOS from 247 to 210 minutes ($p < .001$) and the number of patients with LOS above 6 hours from 19.9 percent to 14.3% ($p < .0001$).

SUMMARY AND DISCUSSION

This review illustrates several gaps in the evidence base for interventions improving ED efficiency. First, very few studies reported utilization, cost, and quality of care outcomes together. Two-thirds of studies reported data for LOS, and less than half reported data for WT or LWBS. Only a small fraction reported on patient harms or medical errors. When authors do not provide a full accounting of an intervention's effects, this limits the ability of other leaders to apply the findings of an improvement study.[3]

Second, only a minority of studies quantified the resources required to implement an intervention. One-third were unclear even as to whether additional resources would be needed. Costly interventions are not necessarily more effective in improving efficiency. For example, simply increasing ED capacity is thought to be a straightforward fix for overcrowding, but this is expensive, rarely practical in the short-term, and not always beneficial.[28] As ED leaders and decision-makers are often faced with resource constraints, more accurate reporting of resource requirements is imperative.

Lastly, we found 7 studies that demonstrated improvements in efficiency outcomes solely through reallocating existing resources. These studies represented 4 different intervention types (physician triage, fast track, nurse scope of practice expansion, and care teams). Researchers should prioritize understanding how these interventions effected improvements at relatively little cost. Generalizing these lessons could be transformative in improving ED throughput. That said, most studies using these 4 intervention types actually added resources, emphasizing the need to describe organizational context in better detail. If more resources were needed, why? And if existing resources could be reallocated, what factors within the organization helped facilitate this? The SQUIRE guidelines for quality improvement interventions provide a model for reporting contextual information.[8]

LIMITATIONS

Several factors may limit interpretation of this report. We excluded simulation studies from the evidence map, as we focused on interventions tested in the real world, which are likely more useful to decision-makers. Additionally, the results of simulation studies are not directly comparable to results from implementations in practice, as a recent review of operations research/operations management (OR/OM) in regard to ED overcrowding suggests that a disconnect between theory and practice remains,[5] and it would be inappropriate to display them together in the evidence map. Regardless, simulation and OR/OM approaches have been beneficial for predicting the effects of policy changes, especially in resource-poor environments like EDs that may not have the resources to formally test many interventions or policies. For

example, a recent simulation study based on one urban level 1 trauma center with 85,000 annual visits examined the effect of "flexing" a certain number of Fast Track beds (where Fast Track can be used to accommodate higher-acuity patients according to operational demands) on ED LOS.[29] For their 50-bed ED with a 10-bed Fast Track, they found that allowing up to 3 Fast Track beds to be "flexed" resulted in an optimal improvement in ED LOS. There is a role for simulation approaches, provided that the findings can be subsequently tested in actual practice settings.

The outcome measures included in this synthesis raise challenges as well. Outcomes like LOS can be measured in different ways (e.g., bed assignment to final disposition, arrival-to-exit, *etc*), introducing issues with cross-study comparisons. The included publications varied both in the extent to which they provided definitions for the outcome measures they used, and in how they measured outcomes when this was reported. Outcomes that are relatively rare, such as LWBS, or outcomes that may have distributional challenges such as outliers, require additional consideration. Inspecting both the definitions of outcome measures and the measures of variability would be important data to gather in a formal systematic review, but would require detailed reading of each included study that goes beyond the scope of the data abstraction for an evidence map. This type of analysis would typically focus on a more narrow scope, such as a particular intervention or particular outcome.

While data limitations and the broad scope of inquiry for this mapping synthesis prevent us from performing statistical tests of publication bias, such bias is almost certainly present, as ED efficiency is an issue fundamental to the operations of any ED, and it is unlikely that all experiences have been written up for publication. Less successful implementations of interventions to improve ED efficiency may be the most vulnerable to being excluded from formal publication and consequently from our synthesis, but even successful implementations may not be published, so we cannot speculate as to how these interventions might impact the findings we present. Also, while the evidence map approach can generate insights into the state of the literature, they are not an exhaustive systematic review or meta-analysis, and do not provide the degree of comprehensiveness or statistical precision expected of those types of reviews. Despite these limitations, this review has highlighted several important gaps in the literature and identified priorities for future research efforts.

FUTURE WORK

To better understand the value of ED efficiency interventions, increased measurement and reporting of costs or value-related data is necessary. The large variability in wait times and length of stay data also suggest that these may be measured different ways in different studies, and standardization in future work, or more detailed description about these calculations, would also be helpful. Most data came from single sites, which may have unique circumstances, so larger studies of multiple sites would also increase knowledge in this area. In addition, to better connect theory and practice, a greater understanding of why particular interventions are expected to improve efficiency is needed. Finally, because VA is a unique context with only one publication describing an ED efficiency intervention, more work within VA would be helpful in understanding which of the various interventions might work best in VA's particular circumstances. As health care needs continue to increase, EDs are likely to face ever-growing patient loads, so finding and describing the best practices for optimizing ED efficiency remains imperative.

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APPENDIX A. SEARCH STRATEGY

1. Search for systematic reviews currently under development (includes forthcoming reviews & protocols) Date Searched: 7/20/16	
A. Required sources:	Evidence:
AHRQ topics in development (EPC Status Report)	https://www.epc-src.org/src/logon.cfm
PROSPERO (SR registry)	http://www.crd.york.ac.uk/PROSPERO/
DoPHER (SR Protocols)	http://eppi.ioe.ac.uk/webdatabases4/Intro.aspx?ID=9

2. Search for current systematic reviews (limited to last five years) Date Searched:	
A. Required sources:	Evidence:
AHRQ: evidence reports, technology assessments, DEcIDE projects	http://effectivehealthcare.ahrq.gov/index.cfm/search-for-guides-reviews-and-reports/ None found http://www.ahrq.gov/research/findings/ta/index.html None found
CADTH	https://www.cadth.ca Patient Wait Time Monitors: Clinical Evidence Published on: April 13, 2011 Product Line: Rapid Response Project Status: Complete Report Type: Summary of Abstracts Result type: Report Question 1. What is the clinical evidence on displaying patient wait time monitors in emergency department waiting rooms? Key Message No relevant evidence-based studies were identified pertaining to displaying patient wait time monitors in emergency department waiting rooms.

	https://www.cadth.ca/patient-wait-time-monitors-clinical-evidence
Cochrane Database of Systematic Reviews: Protocols & Reviews	http://www.ohsu.edu/xd/education/library/ **Database: EBM Reviews - Cochrane Database of Systematic Reviews <2005 to July 20, 2016>** **Search Strategy:** **----------** **1 (emergency department or emergency room or emergency services).mp. [mp=title, short title, abstract, full text, keywords, caption text] (511)** **2 (efficiency or wait* time* or length* of stay or patient satisfaction or leaving without being seen).mp. [mp=title, short title, abstract, full text, keywords, caption text] (2664)** **3 1 and 2 (234)** **4 limit 3 to last 5 years (155)** **5 (efficiency or wait* time* or length* of stay or patient satisfaction or leaving without being seen).ti,ab,kw. (401)** **6 1 and 5 (48)** **7 limit 6 to last 5 years (31)** ****************************** **One systematic review identified**
ECRI Institute	https://www.ecri.org/Pages/default.aspx None found
HTA: Health Technology Assessments	http://www.ohsu.edu/xd/education/library/
MEDLINE:	http://www.ohsu.edu/xd/education/library/

Systematic Reviews	None found (primary studies below)
NHS Evidence	http://www.evidence.nhs.uk/default.aspx
NLM	http://www.ncbi.nlm.nih.gov/pubmedhealth/ None found http://www.ncbi.nlm.nih.gov/books
VA Products - VATAP, PBM and HSR&D publications	A. http://www.hsrd.research.va.gov/research/default.cfm None found B. http://www.research.va.gov/research_topics/

3. Current Guidelines	
National Guideline Clearinghouse	http://www.guideline.gov/
USPSTF	http://www.uspreventiveservicestaskforce.org/uspstopics.htm

B. Secondary sources*	Evidence
Bluecross Blueshield Foundation Massachusetts	http://bluecrossfoundation.org/publications
Campbell Collaboration	http://www.campbellcollaboration.org/lib/?go=browse
CMS Policies	http://www.cms.gov/Research-Statistics-Data-and-Systems/Statistics-Trends-and-Reports/Reports/Research-Reports-List.html
Hayes	http://www.hayesinc.com/hayes/
Institute for Clinical Evaluative Sciences	http://www.ices.on.ca/Publications/Atlases-and-Reports
IOM	http://www.iom.edu/Reports.aspx
McMaster Health Systems Evidence	http://www.healthsystemsevidence.org/open-search.aspx

NIH Consensus Statement	http://consensus.nih.gov/previous.htm
Robert Wood Johnson	http://www.rwjf.org/en/research-publications.html
Systematic Reviews (Journal): Protocols & Reviews	http://link.springer.com/journal/13643
UBC Centre for Health Services and Policy Research	http://chspr.ubc.ca/pubs/pub-search
WHO Health Evidence Network	http://www.euro.who.int/en/what-we-do/data-and-evidence/health-evidence-network-hen/publications/by-keyword

**Search secondary sources of systematic review as needed, depending on results of search of required sources and topic*

C. Results of Search for SR and Protocols	Next Step
√ No relevant systematic reviews	Locate primary Literature
□ Relevant systematic review	See if it fills need
□ Relevant systematic review – out of date	Locate primary literature since SR search date
□ Many semi-relevant systematic reviews	Consider Review of Reviews or Evidence Map
□ Semi-relevant systematic review(s)	Consider revising scope if SR covers some KQ ; locate primary literature with revised scope

4. Search for primary literature
Date searched: 7/21/2016

A. MEDLINE Search Strategy

Database: Ovid MEDLINE(R) without Revisions <1996 to July Week 2 2016>, Ovid MEDLINE(R) In-Process & Other Non-Indexed Citations <July 21, 2016>

Search Strategy:

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1 emergency department.mp. or exp Emergency Service, Hospital/ (72136)

2 exp Efficiency/ (4763)

3 1 and 2 (68)

4 leaving without being seen.mp. (51)

5 1 and 4 (50)

6 limit 5 to (english language and yr="2011 -Current") (30)

7 wait* time*.mp. (8132)

8 Patient Satisfaction/ (60618)

9 "Length of Stay"/ (52297)

10 4 or 7 or 8 or 9 (118303)

11 1 and 10 (5354)

12 limit 11 to (english language and yr="2011 -Current") (2332)

13 limit 12 to (clinical trial, all or comparative study or controlled clinical trial or "corrected and republished article" or evaluation studies or government publications or guideline or journal article or meta analysis or multicenter study or observational study or practice guideline or pragmatic clinical trial or "review" or systematic reviews or twin study or validation studies or video-audio media) (2243)

14 limit 13 to (clinical trial, all or comparative study or evaluation studies or meta analysis or multicenter study or systematic reviews) (757)

15 (children or pediatric).mp. [mp=title, abstract, original title, name of substance word, subject heading word, keyword heading word, protocol supplementary concept word, rare disease supplementary concept word, unique identifier] (620022)

16 14 not 15 (646)

17 (length of stay or leaving without being seen or patient satisfaction or wait time).ab,hw,ti. (138340)

18 leaving without being seen.ab,ti. (51)

19 "wait* time*".ab,ti. (8109)

20 length of stay.ab,ti. (31922)

21 patient satisfaction.ab,ti. (22515)

22 18 or 19 or 20 or 21 (61189)

23 1 and 22 (4363)

24 limit 23 to (english language and yr="2011 -Current") (2266)

25 limit 24 to (clinical trial, all or comparative study or evaluation studies or journal article or meta analysis or multicenter study or randomized controlled trial or systematic reviews) (2233)

26 25 not 15 (1903)

27 limit 26 to (clinical trial, all or comparative study or evaluation studies or meta analysis or multicenter study or randomized controlled trial or systematic reviews) (537)

537 CITATIONS IDENTIFIED

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B. Results of search for primary literature	Evidence
MEDLINE - Trials	
MEDLINE - Other controlled studies	
MEDLINE - Background	
C. Other sources (search as needed)	
CINAHL	
PsycINFO	
CCRCT	
Google Scholar	
Other specialty databases	
C. Results of search for ongoing primary research	Evidence
VA ART database (Captures HSR&D funded projects)	http://art.puget-sound.med.va.gov/default.cfm
Clinicaltrials.gov	

5. Final check for current systematic reviews or protocols for forthcoming systematic reviews (to see if anything has been posted since the topic work-up began and to account for shifting scope of topic) Date Searched:	
Source:	Evidence:
EPC topics in development	https://www.epc-src.org/src/logon.cfm
AHRQ	http://effectivehealthcare.ahrq.gov/index.cfm/search-for-guides-reviews-and-reports/ http://www.ahrq.gov/research/findings/ta/index.html
CADTH	https://www.cadth.ca

Cochrane Database of Systematic Reviews	http://www.ohsu.edu/xd/education/library/
DoPHER (SR Protocols)	http://eppi.ioe.ac.uk/webdatabases4/Intro.aspx?ID=9
ECRI Institute	https://www.ecri.org/Pages/default.aspx
Health Technology Assessments	http://www.ohsu.edu/xd/education/library/
MEDLINE: Systematic Reviews	http://www.ohsu.edu/xd/education/library/
National Guideline Clearinghouse	http://www.guideline.gov/
NHS Evidence	http://www.evidence.nhs.uk/default.aspx
NLM	http://www.ncbi.nlm.nih.gov/pubmedhealth/ http://www.ncbi.nlm.nih.gov/books
PROSPERO (SR registry)	http://www.crd.york.ac.uk/PROSPERO/
USPSTF	http://www.uspreventiveservicestaskforce.org/uspstopics.htm
VA Products - VATAP, PBM and HSR&D publications	A. http://www.hsrd.research.va.gov/research/default.cfm B. http://www.research.va.gov/research_topics/

APPENDIX B. STUDY SELECTION CRITERIA

1. What is the study design?
   - Hypothesis testing
   - Other design, STOP (note if reference mining or relevant to background)

2. Should this article be excluded because:
   - 1996 publication or earlier, STOP
   - Single condition, STOP (NOTE: chest pain short stay units and studies assessing system effects are includes)
   - Related to clinical management rather than efficiency intervention, STOP
   - short stay or observation unit, no ED system outcome (*eg*, outcomes compared to admitted patients)
   - Include

3. What is the sample size?
   - <100
   - 100-499
   - 500-999
   - 1,000-9,999
   - >10,000

4. What is the analytic unit?
   - Patients
   - providers
   - shifts
   - facilities

5. Is the setting academically affiliated?
   - Yes
   - No
   - Both
   - Not Reported

6. Is the setting VA?
   - Yes
   - No or Not reported

7. Study setting is:
   - One site
   - Multi-site
   - Not reported

8. Country of origin:_____

9. Which outcomes are reported?

- Clinical outcomes (*eg*, health outcomes, patient satisfaction, provider satisfaction, *etc*)
- LWBS/Did Not Attend/Did Not Wait
- Time to be seen/Wait times
- Length of stay/time spent in the ED
- Number or Proportion of patients admitted
- Adverse events/harms/errors

10. Does this publication discuss at least one of the following (check ALL that apply)?
    - Cost compared to inpatient admission
    - Charges to patient
    - Reimbursement
    - Accounting within hospital
    - Other cost
    - Other resource use (*eg*, personnel time)
    - Other efficiency or value-related data
    - Unsure

11. Does the article indicate that the intervention
    - Reallocates existing resources
    - Adds new resources/ Both adds new resources and reallocates existing resources
    - Unclear

12. Input costs quantified?
    - Yes
    - No or Not reported

APPENDIX C. PEER REVIEW COMMENTS/AUTHOR RESPONSES

Comment	Response
Definitions -- Including definitions of key terms, such as "ED efficiency" and "evidence" would help make the paper's contributions more clear and concise. These terms are often used without us being absolutely certain what they mean. For example, in the manuscript, length-of-stay (LOS) is cited as a core efficiency metric. Why is that? Efficiency is typically defined as the amount of output produced relative to the inputs consumed. Length-of-stay says nothing about either of these. An operationally "efficient" ED (i.e., one that serves many patients well at a low operating cost) could have a longer LOS due solely to having sicker patients or a lack of consulting resources from the larger hospital, which can delay disposition while not saying anything about the "efficiency" of the ED. Perhaps "operational performance" would be a better term than "efficiency" if accuracy is valued.	We have updated our introduction to better discuss the term “ED efficiency” as it is used for our report. We agree that efficiency is a ratio of output to input, and to convey this ratio we have presented the core metrics you describe with the categorizations of inputs in the maps. While we describe the input and output data separately in this report, the intent of the maps is to visually integrate the two parts of the ratio to start to describe the distribution of evidence (i.e., where there is evidence of potential efficiency vs where less evidence exists). We disagree that LOS says nothing about the amount of output. An airplane flight that is direct and takes 4 hours in one plane, and another flight that requires a 2 hour layover with total transit time of 6 hours both get one traveler to the same destination in a safe manner, but the former is considered by most travelers and workers to be a more efficient means than the latter to get from point A to point B. Typically these efficiency interventions are implemented in overcrowded EDs with an appreciable percentage of patients who leave without being seen, We agree that LOS is not a very good measure of outputs, since there is no assessment of the quality of the output. We can’t switch to “operational performance” because the title was given to us by VA policymakers. What we consider to be evidence is described in the “Inclusion/Exclusion Criteria” subsection of the methods, and we have more formally introduced the term evidence now.
Definitions: Did these studies routinely and clearly define each of the measures they used? In addition, measures of variability (SD, IQR) may be useful to include in reporting results.	The included publications varied both in the extent to which they provided definitions for the outcome measures they used, and how they measured outcomes when this way reported. Both the definitions and the measures of variability would be important data to gather in a formal systematic review of some piece of this overarching evidence map, but would require detailed reading of each included article/study that goes beyond the scope of the data abstraction for an evidence map. These points are now raised in the discussion.

Comment	Response
Survivor Bias -- The collection of papers used to generate the "evidence maps" suffers from survivor bias in that they were all successfully published. We know that journals favor studies that have positive results (vs. those that find policy X had no effect). It would be like, for example, a therapeutic efficacy study that tossed out the data from every patient who died before the final reporting period. Therefore, the validity of this manuscript is somewhat suspect and likely overstates the improvements garnered by the various interventions. However, since we cannot know what isn't published, there isn't an ideal strategy for dealing with this problem, but it should be acknowledged in the report as a significant limitation.	Thank you for pointing out this important omission, we have now included a description of the publication bias issue you raise here. Note that the existence of publication bias on the basis of results (positive results being more likely to get published) is a matter of controversy with respect to it being the fault of journals. Kay Dickersin has done extensive work in this area and concluded that in one of the most careful assessments of this ever done, and concluded that to a large extent the lack of publication of negative studies is because the investigators lost interest in it and never submitted the results to a journal.
Categories -- On page 4, the paper says it "...ordered these [intervention] categories according to their usefulness to ED leaders..." How does the research team know this? Moreover, the categories are treated as mutually exclusive, but actually have the potential to overlap. The categories are "quantified description of resource expenditures," "reallocation of resources," "addition of resources," and "unclear." Isn't it possible for an ED to expend resources during the reallocation of resources (e.g., mroe scheduling effort, cross-training, etc.)? Or, more clearly, if a facility adds resources and quantifies them, shouldn't it be in both categories? This categorization seems somewhat arbitrary and, because it is highly unlikely to be generalizable from one facility to another, largely unhelpful. Despite those limitations, it is used in every "evidence map" (via bubble colors), suggesting that some other dimension (e.g., improvement range) might be a better choice.	We agree, and have updated our categories and removed the phrase to which you refer. The categories are now mutually exclusive, and in combination with other peer reviewer comments, this new categorization addresses the issues raised.
Improvement Concepts -- There is little effort in this manuscript to extract from the original papers the thinking behind the interventions that were tested. What underlying concept was being drawn upon to motivate a facility to implement a fast track or to put an MD in triage? Were they all the same? Or did they arrive at those interventions from different lines of thinking? Until we understand WHY an intervention is expected to improve the operational performance of an ED, we cannot make a good guess as to whether or not it makes sense in any particular ED's context. This may be criticized as being too theoretical, but theory is what makes modern medicine work...should expect anything less for how we manage our EDs?	This is an important consideration, and this type of detailed analysis would be important work for a formal systematic review of some piece of this overarching evidence map, but would require a more detailed analysis of individual publications than provided by the scope of an evidence map. Our goal was to map the extent of research in a broad topic, and these next questions would be a natural extension to our preliminary work. This point is now raised in the future work section of the report.

Comment	Response
Minor issue -- On page 10, it says "Physician triage was the most commonly studied intervention, and the one with the most studies where costs were quantified." That second phrase is true because of the first phrase -- even small percentages of large numbers can result in large numbers. Perhaps it would be more useful to look at which types of interventions had the highest _proportions_ of different categories (assuming these categories are useful in the first place, which is suspect).	We have updated this phrasing and our categories.
Lit Stats -- A significant portion of the manuscript is statistics about the literature gathered by the team (e.g., Map 1), which do not actually do much to help ED managers make decisions about how to operate more effectively and efficiently. Pages 10-17 do not seem to contribute substantially to the mission of the report.	We think there is a misunderstanding of the goal of the report. The goal is not to report a detailed analysis of the evidence of one or more ED interventions. The goal was to create an evidence map that quantifies this corpus of literature by a few categorical variables. As such, these maps are intended to show the work that has been done in a snapshot across a broad set of work, and are not intended to do a more detailed analysis of the interventions identified. Future work would be necessary to address this question. We have removed the set of maps with raw change values (*eg,* wait time in minutes) to reduce the amount of data and focus on the more salient points
Summarize & Synthesize -- Could the 2-page excerpt from Soremekum (2012) on pages 15-17 be condensed somehow? This seems like a lot to read for relatively little benefit (vis-a-vis the report's objectives).	We agree, and have updated/abridged this table and put the full contents in an appendix.
Scope -- Limiting the scope of the document to only those papers that have implemented interventions leaves a large amount of evidence out of consideration, to the study's (and the VA's) detriment. For example, the one study cited in this manuscript that was carried out in a VA ED found that discrete-event simulation accurately predicted the operational improvements that were realized when the new policy was actually implemented. Not every policy can be implemented, even if the simulation or modeling suggests it would help significantly. Ignoring those papers in a summary of "the evidence" will only perpetuate the "disconnect between theory and practice" cited in this manuscript (page 24). Moreover, as many EDs are in fact "resource-poor environments" (page 2), the ability to model new policies to estimate their impact on practice becomes even more important.	The inclusion criterion of requiring that an intervention was applied in an ED (thereby rejecting simulation studies) was made at the direction of our operational partners and technical experts. Reviewing such studies would need to be the focus of some future review. We have revised our discussion of simulation studies in the limitations to include your point.

Comment	Response
Usefulness -- The "evidence maps" on pages 18-22 do not seem to yield many useful conclusions about what changes ED managers should make to how their EDs operate. These maps are not an adequate substitute for an actual meta-analysis (as mentioned in the limitations on page 24) or other analyses that might extract out some clear insights. For example, looking at Map 2 on page 18, what should the take-away be for an ED manager? I honestly can't tell. Perhaps it would be better to pull out each type of intervention (e.g., MD in triage) and then produce a graph that has an improvement metric on one axis and resource use (or a contrasting improvement metric) on the other. Different studies would have different positions in that graph, yielding insights related to questions like "Does greater expense tend to produce greater improvements?" and "Are these two performance outcomes trade-offs or are they complementary?" That would be substantially more useful to VAs than these plots, yet could be generated using the same data presented in these maps.	We agree that these maps are not serving the same purpose as meta-analyses, and our intention is to highlight the types of ED efficiency work that has been done, and identify areas where future research may be needed. This map was requested for the VA Emergency Medicine Field Advisory Committee field-based meeting “Toward a VA Emergency Medicine Research Agenda: Setting Priorities to Improve the Health of Veterans Seeking Emergency Care.” We have added this to our topic development section to better describe our scope.
ED overcrowding is mentioned prominently in the report. Were any studies encountered that measured facility level ED census outcomes; *eg,* proportion of time above capacity? If there was a decision to focus on patient-level outcomes, which would make sense, would be useful to state this.	We did not capture this data, as we focused on the six outcomes listed in the Study Selection Criteria appendix.
I appreciate the focus on resource reporting as I do think it’s an important point. However I think the data presentation in Table 2 could be misleading. It seems to me that almost all (maybe all? Defer to authors on this point) of papers that quantify costs, are describing additional resources. It seems to the 3 main groups to readers are 1) Adds Resources; 2) Reallocated Resources; 3) Not enough information to classify. The Costs quantified vs. qualitatively described seem like subcategories. It may be more informative to report as: Adds New Resources - Cost quantified - Cost qualitatively described Reallocated Resources - Cost quantified (if there are any in this category) - Cost qualitatively described Unclear	We have simplified our categorizations to align with your suggestions, and rather than add sub-categories that may be confusing in such a rich data presentation, we have discussed this separately.
Can you say more about the comparison conditions for the observational studies? Were these all pre-post designs, or did any use external or contemporaneous controls?	We have added information on study design to our report.

Methods: Lines 40-41. Studies had to include LOS, WT, OR LWBS? At this stage of paper I was unclear as to whether the requirement was for ALL or ANY of these to be reported for inclusion. It's clear in the Abstract but less so here.	The “and” in the phrasing has been changed to an “or” for greater clarity. We required ANY outcome, not ALL.
Line 48. Studies that did not in any way describe the resources expended were excluded but in Results section there is no mention of studies being excluded on this basis. Is this correct that no studies were excluded on this basis?	This text was incorrect, and has been updated, since no studies were excluded on this basis.
Line 54. Agree with exclusion of modeling and simulation studies; not sure what is meant by “theoretical interventions”	This section has been re-written, and the language about “theoretical interventions” has been removed.
Effect on LOS by intervention type: lines 10-12 No Medical Scribe studies reported positive effects or measured this outcome at all?	No medical scribe studies measured this outcome, text has been updated to clarify this point.
Search strategy tables have some terms like ‘patient satisfaction’. Was this dropped or no relevant studies identified?	We decided not to abstract information on this outcome, and chose to focus on the six outcomes listed in our Study Selection Criteria appendix.
Suggest more discussion of the recommendations around measurement. In the Summary and Discussion section I’m not sure what is meant by saying the Doupe paper recommends reporting ‘all necessary metrics..” do you mean the efficiency metrics you’ve measured here? I would imagine there are cautions here around also whether studies reporting relatively rare outcomes like LWBS or continuous metrics that may have distributional challenges due to outliers, etc. are adequately powered.	The discussion section has been reworded, and we have incorporated your cautions as an important consideration for future work in this area.
p.4 para 1 line 5: I find it surprising that you were able to consistently define LOS as “bed assignment to final disposition” as this is not routinely available. Typically, LOS is arrival-to-exit. Please verify that this is correct as I am suspicious that it is not. Looking at the outcomes reported on p. 8, I’m surprised that 69% would meet this definition of LOS further reinforcing the need to verify this.	We were not able to have a consistent definition, but rather used these definitions to guide our data analysis when multiple data points were available. This text has been updated to reflect this. We also discuss the issue of defining measure in more detail in our limitations section.
p.4 para 1 line 10: Clarify the definition of LWBS. When referring to “all visits” do you mean for the day?	This was not well defined in the studies, but typically reflected the percentage of patients who left before being seen of all patients over the study period. This language has been updated for clarity.
p.7 Figure 1: I suspect that many of these interventions were overlapping in categories. How did you handle overlapping interventions?	This was a conceptual challenge for our team, but in order to have one bubble per study (mutually exclusive, exhaustive categorization), we determined the category of best fit for each study. Our methods have been updated to reflect this.
p.20 Para 1 line 6: Use of the term “improvement” makes interpreting a negative number as somewhat challenging. For example, what is a “-10” improvement? Perhaps, describe this as a “Change from	We agree, this wording has been updated as suggested

baseline"? This obviously flips the y-axis but makes it much easier to interpret. This is similarly a problem in Map 6 (LWBS).	
p.23 Summary and Discussion: Referencing definitions above, please verify that these measures are in fact identical. I am very skeptical that these are in fact identical.	We now describe this issue in the limitations.
Minor Comments P.1 Para 2 Line 19: Should be "LWBS" P.1 Para 2 Line 20: Should have a "." After "excluded". P.2 Para 1 Line 11: The accepted term is "crowding" not "overcrowding" p. 2 Para 2 line 28: There appear to be multiple uses of the term "physician triage" with references to "MD at triage", "physician-in-triage", and "MD Triage." With the additional use of "team triage" the multiple terms may be confusing to the reader. I would choose one and stick with it. p.3 Para 4 line 43: Extra "," after the period. p.9 Tables 1 and 2: I don't understand how these tables are sorted. They do not appear to be alphabetical nor in descending in the number of projects. This order appears to be carried into the evidence maps as well. p.12 Table 3: Perhaps move to an appendix as these represent all of the studies, not just "examples." p.18 Para 1 line 6: What is meant by "average"? Is it mean or median?	We have updated all these revisions in our text. Regarding the multiple versions of the MD triage term, we now use Physician Triage throughout. Regarding the organization of projects, we have now updated to reflect the interventions to be descending in order of number of projects. Regarding Table 3, we have shortened this table and moved the longer text into an appendix.

APPENDIX D. CITATIONS OF INCLUDED PUBLICATIONS

1. Allen B BB, Weeks E, Payton T. An Assessment of Emergency Department Throughput and Provider Satisfaction after the Implementation of a Scribe Program. Advances in Emergency Medicine. 2014;2014(1).

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APPENDIX E. CITATIONS OF FULL TEXT EXCLUDES

Pre-1996 (n=3)

1. Tsai WW, Nash DB, Seamonds B, Weir GJ. Point-of-care versus central laboratory testing: an economic analysis in an academic medical center. *Clin Ther.* 1994;16(5):898-910; discussion 854.

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Not Outcome of Interest (n=22)

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APPENDIX F. UNABRIDGED EXAMPLES OF TEXT COUNTED AS "QUANTIFYING COSTS"

Fernandez, 1996[11]	"The ED is staffed 24 hours per day by full-time, certified emergency physicians (EPs). Senior medical students, interns, and residents also are in attendance. There are eight to nine staff nurses per 12-hour shift, including one triage nurse. All patients are seen by the triage nurse and classified according to acuity of complaint. Patients then see an admitting clerk to provide demographic information. Patients are sent to one of two areas: FT or acute care. **Prior to the present study, no nurse was assigned solely to the FT area."** " Nine solutions were identified: **1) addition of an extra admitting clerk**; 2) a streamlined FT process; 3) expansion of the FT area; 4) a new triage classification; **5) addition of an FT nurse**; 6) a defined triage nurse role; 7) addition of a unit coordinator; 8) an ED switchboard; and 9) addition of floor color codes/ signs with a more accessible information desk. In Phase I, we added the extra admitting clerk and streamlined the FT process. In Phase II, **we expanded our FT area to include more rooms and stretchers,** implemented a stricter, more detailed triage classification (Table l), and dedicated a nurse to the FT area whose previous responsibilities had been poorly defined. " "During the post-Phase II period, the staffing of the FT area, other than **having a full-time FT nurse**, was identical to that of the control period and the two other post-Phase I study periods."
Partovi, 2001[12]	"We compared the effect of adding a faculty member to ED triage on patients' LOS versus patients' LOS when existing nursing triage practices were used....On eight of the Mondays, triage was conducted as usual with the ED staff of two nursing personnel and one EMT. On the remaining eight Mondays an ED faculty member was added to the regular staff of the triage area for the period under study." "**The cost of additional faculty coverage was estimated to be $11.98/patient seen in ED.** This was simply calculated by dividing triage faculty cost [(number of hours in triage)(hourly wage)] into total number of patients seen in the ED during the study hours. **If this is to be implemented on a fulltime basis, the cost per patient would rise to $19.35. The annual cost will be more than a million dollars for full-time faculty triage.** We did not study changes in physician charges resulting from FT. We conclude that FT offers an increase in efficiency but with relatively high cost."
Ardagh, 2002[13]	"For ten weeks… **an additional nurse and an additional ED registrar were rostered** a 0900 to 1700hr shift Monday to Friday. On the odd weeks, these two staff ran a RAC and on even weeks, they did not run a RAC, but simply joined the other medical and nursing staff, managing patients in the traditional way"
Richardson, 2004[14]	"It was decided that MDT would run only when there were two consultants in the ED, one at triage and one to continue in the traditional consulting role on the floor. It was also decided to target evening shifts as these were the busiest and associated with the most bed and cubicle access block. Hence, **it was necessary to increase the evening consultant cover from one to two consultants**. This was achieved by roster changes, and restricting the coverage to Monday to Friday... **Staff were educated** prior to the introduction of MDT... **There was also extensive education for junior medical staff to ensure that the triage assessment did not prevent the appropriate provisional diagnosis being made 'downstream'. The physical design of the department was modified to include a desktop working area for the MDT doctor and a mini assessment/treatment cubicle behind the triage desk.** Patients were assessed in a reclining chair with a curtain screen for privacy. An

	IV insertion, venepuncture, dressing pack and bandages trolley were supplied. **A diagnostic set and X-ray viewing box was installed on the wall.**"
Terris, 2004[15]	"Medical staffing includes five consultant emergency physicians, 10 specialist registrars, and 25 junior SHOs. Primary care providers are rostered up to 50 hours cover per week. There are 124 WTE nursing staff, including eight emergency nurse practitioners. **Funding was allocated for senior clinicians (medical and nursing) to staff the triage area for 16 hours per week for three months. An emergency medicine consultant and a senior ED nurse (G or F grade) were chosen as the preferred team**."... "In our study the effect of the additional resources was not directly measured, we acknowledge that increasing the overall staffing complement by a consultant plus a senior nurse would be expected to give some improvement in the parameters measured whether IMPACT was occurring or not. Although our staffing levels are generally high in comparison with national standards, current resources within our department are inadequate for IMPACT to operate on a full time basis, but where staffing levels permit, we feel it to be a useful tool for managing flow at times of peak attendance. Clearly in departments without our overall level of staffing it would be difficult to provide an IMPACT type service, let alone sustain it for any period of time. Even with the extra staff only 23 of the intended number of 48 IMPACT sessions could be completed because of staffing shortages on some days, and although our intention was that the IMPACT team should have no other duties during that time, this did not always happen. The direct and indirect costs of such a service would be considerable and this pilot project was not designed to provide a formal cost effectiveness analysis. It may well be that while IMPACT can provide us with the tangible benefits shown in this study the money required to even partially fund such a service could produce even greater benefits elsewhere within the ED, we have not measured such opportunity costs in this paper."
Rodi, 2006[16]	"The PAs were already on staff and had been previously seeing patients (identified as low acuity by the Canadian Emergency Department Triage and Acuity Scale [CTAS]) in the main ED. **The only new cost of the intervention was hiring a dedicated technician to support the PA**."
Levsky, 2008[17]	"If a patient meets EC3 criteria and no beds are available in the main ED, they are seen as soon as possible by a "TNT team," consisting of **an emergency physician or physician's assistant, a registered nurse, and a medic or civilian emergency medical technician.**" "During the intervention, **the TNT team was used 4 days a week: Monday, Tuesday, Thursday, and Sunday from 10:00 a.m. to 6:00 p.m.**" " Specifically, during PI, **five new registered nurses were hired, as were three new medical support assistants (clerks)**, which increased nurse and clerk coverage by approximately 7% and 15%, respectively. No ED operations or staffing changes occurred between P2 and P3, other than the addition of TNT."
Ieraci, 2008[18]	"To accommodate the change, the ED was remodelled to provide a suitable area containing three examination trolleys, four reclining treatment chairs, a treatment room and a staff station. The net result of the remodelling was a reduction in the total number of treatment spaces (beds plus chairs) from 25 to 24." "Separate clinical **resources were provided to staff the FT area with two nurses round the clock, and one senior doctor (career medical officer, CMO) for 16 h/day**. The CMO were specifically recruited to work only in FT, and had the experience and ability to work rapidly and relatively independently. The seniority of the staffing was considered crucial to the intended function, and junior doctors were not rostered to the area (although they saw FT patients during the night shift). The nursing staff rotated from the general ED pool, but also included two nurse practitioners (NP) who worked solely in the FT area.

	These staff and space were quarantined for FT patients – there was strong pressure not to re-allocate these resources to other areas of the ED."
Singer, 2008[19]	"The third phase involved **hiring seven personnel, at a laboratory technologist level**, so that a new workstation could be covered 24 hours per day in the central laboratory, 7 days per week. It also involved the **purchase of new analyzers, at a cost of about $46,000, and installation of a dedicated pneumatic tube, at a cost of about $150,000."**
Gerton, 2009[20]	"The PIT provided additional coverage that replaced a triage nurse, but **did not change the physician staffing of the ED."** "During PIT hrs, **11.5 RVUs more were billed on average than without PIT** (384 vs. 373; 95% CI +/-41). **With RVU estimated at $38.08, charges increased by $438 / 8hr shift. If PIT were 5 d/wk for 1 yr, increased billing would be $118,000. This would not offset the cost of a physician."**
Arya, 2010[21]	"The scribe training program is 60 hours in length." " The RVU/hr increased by 0.18 (95% confidence interval [CI] = 0.04 to 0.32, p = 0.0067) units when the percentage of a shift for which a scribe was utilized increases by 10%" "If a physician in our department changed from 0% to 100% of the patients seen with a scribe, 0.8 additional patients per hour can be evaluated in a 10-hour shift, and 24 (2.4/hr) additional RVUs would be generated." "Based on the 2008 Medicare RVU reimbursement rate of $38 for one RVU, **a scribe being utilized to full capacity, resulting in an additional 2.4 RVUs/hr generated, could result in an additional 91 billed dollars per hour. Scribes at our institution are salaried at approximately $16–$19 per hour,** so unless an institution collects less than 30% of their billed revenue, scribes may be expected to improve the financial ‘‘bottom line. A complete cost analysis should of course take into consideration the fixed costs of training, as well as the variable costs of salary and nonsalary benefits."
Han, 2010[10]	Physician triage was initiated on July 11, 2005, 7 days a week from 1:00 p.m. to 9:00 p.m. A dedicated board certified or board-eligible emergency physician initiated diagnostic evaluation and treatment of patients in the waiting room after the triage nurse performed his or her initial evaluation. **The triage physician was an additional physician to the existing staffing model.**
Fry, 2011[22]	"The TENP role, in July 2006, commenced with the employment of 3 full time equivalent positions, which provided a TENP on duty for 15 h a day Monday—Sunday (eight o’clock am to eleven o’clock pm)." (TENP = Transitional Emergency Nurse Practitioner)
Imperato, 2012[23]	Implementation of the PIT protocol **required the addition of two full-time equivalent attending physicians, at a total cost of $490,000 in additional salary costs per year plus fringe benefits**. The nurse and technician assigned to the PIT were reallocated from another part of the ED, so no additional nursing staffing cost was incurred. A portion of the cost may have been recouped by incremental revenue captured by reducing the LWBS rate, but this effect is likely to be modest given the already-low LWBS rate before the PIT implementation. An additional source of cost recuperation may have been from a reduction of diversion time.
Soremekun, 2012[9,24]	"Three components of the financial impact of the physician triage were considered: revenue, operational costs, and capital expenditure. Two main revenue sources were identified from the physician triage system in our study. The first was an increase in ED functional capacity that allowed for the care of additional medium acuity patients. Before implementation of physician screening, the ED was at full capacity and unable to care for additional medium acuity patients without a decrease in the quality of care provided or an increase in percentage of patients who LWBS. Therefore, the accelerated disposition of

	patients performed under the ED physician screening program allowed for care of additional medium acuity patients (low-acuity patients were excluded from the study), effectively increasing ED bed capacity to provide care for additional patients. The second revenue source was an increase in percent billable because of the decrease in the LWBS rate. Given that actual unit charges and reimbursement rates for ED visits and inpatient admissions are considered to be proprietary at our institution and also unique to our institution given the health care market in our state, we used revenue assumptions that are more representative of the national averages and performed sensitivity analysis around these assumptions to demonstrate the range in value of this intervention. The following revenue assumptions were made to determine the revenue impact of discharged patients: (1) average charges of $1390 per patient, based on medical expenditure panel survey, and (2) 35% collection rate, based on rates used in other financial studies and medical expenditure panel survey. The direct costs of ED care for discharged patients, as a percentage of revenue, were assumed to be 35%. This level of direct cost is based on prior published reports. Given the low rates of admissions in the LWBS population, we assumed no margin contribution from the hospitalization of these patients. The admission rate of the other medium acuity patients was based on the observed rate at the study site. The financial contribution margin of these patients' total hospital stay was based on published margin contribution of $1000 per admission via the ED. Annual ED volume growth was assumed to be 3%. Incremental operational costs associated with physician screening include employee and marginal costs of providing care to patients. During operation, physician triage in our center requires an additional nurse practitioner (NP) who is responsible for following up on test results, ordering subsequent treatments, discharge planning, and arranging for the transition of care to appropriate inpatient teams. In addition to the NP, our system requires an additional 4 registered nurses and 1 clinical assistant. Fully loaded fulltime employee rates including benefits were assumed to be physician, $120 per hour; NP, $60 per hour; registered nurses, $40 per hour; and clinical assistant, $20 per hour. Rates were based on national averages from the bureau of labor statistics. Full-time employee salary growth rate was assumed to be 3%. Our center's screening program required construction of dedicated clinical examination spaces adjacent to the triage area to permit the screening physician to obtain a medical history in private and to perform an appropriate physical examination. These 4 clinical spaces are integral to the safe acceleration of disposition decisions for selected patients in our program. The required capital expenditure to create 4 screening rooms, 2 workspaces (one in screening and one in postscreening area), a postscreening internal waiting area, and the associated infrastructure required to monitor and deliver care was $1 200 000 and based on national average hospital construction cost of $188 per square footage. At the study site, there was no increase in the total square footage of the ED but rather remodeling of the waiting area. The 2 workspaces are 500 ft2 each and contained 5 workstations.The screening rooms are 100 ft2 each and contain a stretcher,vital sign machine, otoscope and ophthalmoscope, and adjacent sink. The number of rooms was determined based on modeling a LOS in each screening room for each screened patient occupying the room for 20 minutes. The postscreening area (internal waiting room for patients who have been screened by the MD) consists of a 4875 ft2 waiting room with space for 5 stretchers and 16 chairs. The postscreening area allows the emergency physician to safely accommodate patients in the ED who can wait in an observed internal waiting room, better preserving the monitored bed spaces for those who truly need them. The postscreening area has equipment that allows for reassessment of vital signs, phlebotomy, and medication administration with a dedicatedmedication dispensing medicine for the nurses. Thedepreciation period was assumed to be

	5 years. Time to set up physician screening was 12 months. In our financial model: cash flow (CF) = ED revenue −ED direct costs − operational costs of screening + inpatient margin contribution of admitted patients − capital expenditure. Return on investment (ROI) was calculated based on net present value (NPV) of a 5-year CF stream with no terminal value and a discount rate of 5%. The internal rate of return and years to break even were also calculated. Because multiple assumptions were made to estimate revenue and expenses, a detailed sensitivity analysis was performed to determine the impact of these assumptions on the ROI.".... **"The incremental revenue and operational expense projection generated from physician screening using aforementioned assumptions are depicted in Table 4. In year 1, the estimated ED contribution margin from discharged patients is $1 324 338 (growth in medium acuity patients, $1 137 234; LWBS patients, $187 104) and the estimated contribution margin from admitted patients is $1 384 718. The estimated operational expense associated with the physician screening system at year 1 is $1 864 104 ($1 624 104 in salary costs; $240 000 in depreciation costs). The total earnings and CF projection at year 1 are $844 952 and $1 084 952, respectively. Based on the CF projections and a discount rate of 5%, the NPV of physician screening was $2 816 263 and the internal rate of return is 85%, with time to break even of 13 months."**
Soremekun, 2014[25]	"A dedicated midtrack area was fully implemented in January 2012 after the pilot period in December 2011. The area included three dedicated examination rooms and three hallway spaces. The fast-track area previously used this space, thus the implementation of the midtrack area reduced the dedicated fast-track area with no change in the overall number of treatment spaces in the study center. An attending physician who was reassigned from the main ED staffed the midtrack area so the total number of attending hours per day was also unchanged. **The midtrack area, however, was staffed with two additional registered nurses (RNs) for an additional 16 hours or a 3.4% increase in total nursing clinical hours per day**."
Inokuchi, 2015[26]	"We built the EMR system with a focus on clinical documentation using FileMaker. If a personal computer and wireless environment are available for the FileMaker server, the overall costs are low. Even including several iPads, printers, and scanners, **the system can be built for less than 5000 US dollars**, and it can easily be connected to the readymade EMR with a cable. In addition, emergency medical care varies depending on the hospital, thus EMR needs will also vary."