

Narrative Review

## Trends in Measurement and Improvement of Emergency Physician Performance: An Environmental Scan

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### **Abstract**

**Background:** This is a narrative review of emergency medicine quality metrics and associated quality improvement interventions. Most measures of emergency encounters in managed care focus on preventable encounters, but quality of the emergency care delivered during encounters can have long-term impact on outcomes.

**Background:** To summarize the current landscape of guideline-based quality improvement metrics and review interventions targeting performance improvement on those measures.

**Methods:** We conducted an environmental scan of published literature to identify studies of guideline-based performance measures in emergency medicine, recent changes to these measures, and the design and effectiveness of programs aimed at improving performance on the most broadly adopted metrics.

**Results:** Many clinical practice guidelines and recommendations for emergency medicine have not been operationalized into process metrics that can be used to assess individual performance. Metrics that have been widely adopted do not cover the breadth of emergency medicine practice. Both metrics and interventions have focused predominantly on decreasing low-value resource utilization and providing effective clinical care; less attention has been directed towards the role of emergency physicians in other quality priority areas, such as population health and care coordination. Reported interventions to improve performance on these measures have primarily been single-site, non-randomized studies that incorporate one or more components of education, clinical decision support, and audit and feedback. More research on patient impact of unintended consequences of metrics and interventions is needed. Of several promising areas for intervention, opioid stewardship, use of alternatives to opioids, and referrals for substance use disorders are major emerging priorities.

**Conclusion:** Continued development of metrics and evidence-based performance improvement strategies are needed. This process must involve emergency clinicians, and development of validated metrics should match with priority areas in quality. Interventions using education, clinical decision support, and audit and feedback, alone or in combination, have been implemented with varying effectiveness.

**Keywords:** *emergency medicine, quality measurement, performance improvement, clinical decision support tools*

## **Introduction**

The triple aim of improving quality of care, promoting population health, and reducing costs of care has stimulated development of guidelines targeting these goals and strategies for measurement of guideline adherence. Guidelines are based on both the best available evidence and expert judgment [1-4] and measuring adherence to guidelines in process measures can provide early indicators for patient outcomes. An example is reperfusion therapy for acute myocardial infarction (AMI), which has seen continuous improvements in Emergency Department (ED)-related process measures [5,6], contributing to overall reductions in mortality [7-9]. Policy groups and professional societies have endorsed consensus measures for ED performance [2], and to a more limited extent, national reporting and incentive programs have subsequently incorporated these measures [10]. The results of quality improvement and incentive programs targeting these ED measures are beginning to emerge.

Previous studies have highlighted the disjointed history of ED quality measurement [11,12]. The Hospital Quality Alliance laid the early groundwork upon which other organizations subsequently pioneered early quality measures in emergency medicine. Some of these metrics were incorporated into government and institutional programs. In 2009, recognizing the need to standardize quality measurement across disjointed sets of metrics, the National Quality Forum (NQF) established 22 national voluntary consensus standards for emergency care [2,12,13]. Despite this effort, few of these metrics have been incorporated into a payor policy that would promote widespread adoption [12]. This is, in part, because not all of these standards have been endorsed by professional societies, and some have been withdrawn [14].

One area that has benefited from leadership and continuity in measure development is ED operations and throughput [15]. The Emergency Department Benchmarking Alliance (EDBA), a not-for-profit collaborative of performance-minded EDs, has hosted a series of consensus summits since 2006. They have established key definitions and metrics for ED performance and operations to allow for standardization and common language for policies created by regulatory bodies, including the Centers for Medicare and Medicaid Services (CMS) and the Joint Commission [4,16]. However, most of these metrics are not guideline driven in a way that can be used to inform measurement of individual clinicians' performance.

Since the last Emergency Department Benchmarking Alliance (EDBA) summit in 2014, the most recent wave of changes towards value-based payment was codified with the passage of the Medicare Access and Children's Health Insurance Program Reauthorization Act of 2015 (MACRA). The last reporting year for Physician Quality Reporting System (PQRS) ended in 2016, and under MACRA, a number of incentive programs were replaced with the Quality Payment Program (QPP). Moving forward, Medicare will adjust physician fee schedule payments through one of two value-based tracks: The Merit-based Incentive Payment System (MIPS) or the Advanced Alternative Payment Models [17]. In emergency medicine most attention has been placed on MIPS, as initially most emergency physicians will be affected by this change [18].

In the context of this renewed focus on measurement and improvement, our objective is to provide a summary of performance metrics that have been adopted and endorsed by professional societies and federal programs and to review the effectiveness of interventions targeting these measures.

## **Methods**

An emergency physician (SN) searched peer-reviewed publications to identify quality indicators and performance metrics for emergency medicine, in addition to ED-based interventions to improve group or individual performance in quality measures.

We used the following search terms in PubMed and MEDLINE: ("emergency medicine"[Title/Abstract]) AND (quality[Title/Abstract] OR performance[Title/Abstract] OR measure[Title/Abstract] OR intervention[Title/Abstract])

OR improvement[Title/Abstract] OR "Outcome and Process Assessment (Health Care)"[Mesh] OR "Quality Indicators, Health Care"[Mesh] OR "Quality Improvement"[Mesh] OR "Program Evaluation"[Mesh]).

Based upon titles and abstracts, we excluded articles that were not primarily focused on the ED and not related to measurement or performance improvement. Articles written in a non-English language were excluded. Full-text articles were then retrieved to review further candidacy. For each of the relevant articles identified, we screened the references and further reviewed any additional publications that might have been missed in the initial search.

In addition to published literature indexed in MEDLINE, we reviewed websites related to emergency medicine quality measurement and guideline dissemination. Based on this initial review, we included the CMS programs Hospital Outpatient Quality Reporting (OQR), Hospital Inpatient Quality Reporting Program (IQR), PQRS, MIPS; the National Quality Forum (NQF); the American College of Emergency Physicians (ACEP); and Choosing Wisely by the American Board of Internal Medicine (ABIM) Foundation and ACEP.

We excluded studies intended to measure organizational performance with diffuse attribution (e.g. staffing structures for ED throughput; preventable emergency visits; CMS annual patient experience metrics). Studies that assessed only provider knowledge or attitudes after an educational intervention without examining changes in clinical practice were excluded. In our analysis of interventional studies, we did not include interventions targeting structural rather than individual performance factors (e.g. creating multi-disciplinary teams or staffing workflows). Articles were categorized as systematic reviews (including reviews of measurement strategies), measurement and performance trends, and interventional quality improvement studies.

We de-duplicated studies with multiple publications by selecting the earliest peer-review article with hypothesis-testing statistics. The majority of quality improvement literature is opportunistic reporting of positive findings, and a number of negative results will not surface. Therefore, to better understand publication bias, we inspected significance statistics to assess if the distribution skewed toward borderline significance.

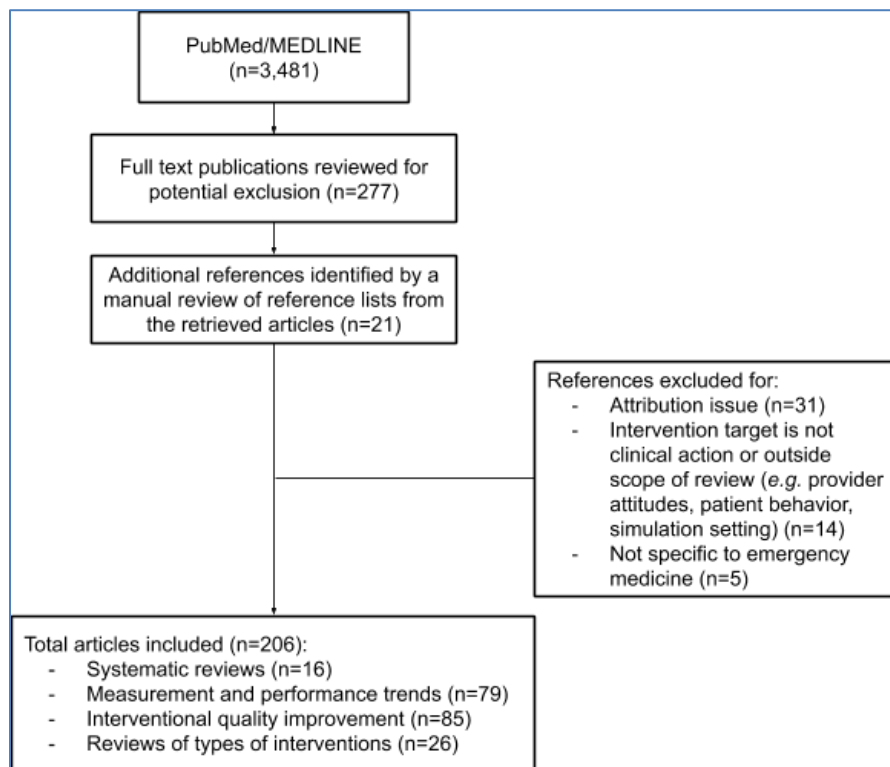


Figure 1. Article selection process

## Results

### Search Results

A total of 3,481 articles were found through the search strategy (Figure 1). Based on initial screening criteria and full text review, 207 relevant articles were identified, including 16 systematic reviews (including reviews of measurement strategies), 79 articles on measurement and performance trends, 85 interventional quality improvement studies, and 26 articles reviewing types of interventions. There were no recent systematic reviews devoted to the topic of emergency care metrics. However, in addition to summary reviews [12,19], there have been systematic reviews on specific areas of quality measurement, such as ED measure appraisal [20], operations [21], clinical practice guidelines [3], and specific conditions [22]. The most recent systematic review on interventions in 2016 focused on implementation research, but was limited to articles published in 2002, 2007, and 2012 [23].

### Guideline-Based Physician Performance Metrics

Given the uneven uptake of measures, we focused on recent sets of quality measures most frequently referenced in the literature, organized by National Quality Strategy (NQS) domains (Table 1). Following the Patient Protection and Affordable Care Act, the Department of Health and Human Services established the NQS as a guiding plan for quality improvement in health care to frame federal efforts for high-value care [24,25]. These domains are: (1) Efficiency and cost reduction; (2) Effective clinical care; (3) Community and population health; (4) Effective communication and care coordination; (5) Patient safety; and (6) Person and caregiver-centered experience and outcomes. Measures of effectiveness with thresholds (e.g. “within 30 minutes”) can also be reported as continuous time measurements. In Table 1, continuous measures of elapsed time are distinguished as a separate throughput domain related to either patient experience or effective clinical care. No national metrics for patient experience explicitly devoted to emergency medicine were identified outside of the throughput domain.

**Table 1:** National quality measures for emergency medicine

Measure Title	Federal Programs				Professional Society		Endorsement
	CMS OQR (2018)	CMS IQR (2018)	CMS PQRS (2016)	CMS MIPS (2017)	ACEP (2018)	ABIM/ACEP Choosing Wisely	NQF (2018)
<b>Efficiency and cost reduction</b>							
CT for minor blunt head trauma (Age ≥ 18 years, Age 2-17 years)	-	-	PQRS 415, 416	MIPS 415, 416	ACEP 19, 20	2013	*
Appropriate use of CT for pulmonary embolism	-	-	-	-	ACEP 22	2014	*
Appropriate use of imaging for recurrent renal colic	-	-	-	-	ACEP QI02	2014	-
Appropriate use of imaging for low back pain	OP-8	-	PQRS 312	MIPS 312**	-	2014	*
Appropriate use of head CT for low risk syncope	-	-	-	-	-	2014	-
Overuse of neuroimaging for patients with primary headache and normal neurologic exam	*	-	PQRS 419	MIPS 419**	-	-	-
Coagulation studies in patients with chest pain and no coagulopathy or bleeding	-	-	-	-	ACEP 21	-	-

Pharyngitis - Appropriate testing	-	-	PQRS 66	MIPS 66	-	-	*
Acute otitis externa - Avoid inappropriate use of systemic antimicrobial therapy	-	-	PQRS 93	MIPS 93	-	-	NQF 0654
Acute bronchitis - Avoidance of antibiotic treatment	-	-	PQRS 116	MIPS 116	-	-	NQF 0058
Adult sinusitis - Overuse of antibiotic prescribed for acute sinusitis	-	-	PQRS 331	MIPS 331**	-	2014	-
Adult sinusitis - Appropriate choice of antibiotic: amoxicillin with or without clavulanate prescribed for patients with acute bacterial sinusitis	-	-	PQRS 332	MIPS 332**	-	-	-
Adult sinusitis - Overuse of CT for acute sinusitis	-	-	PQRS 333	MIPS 333**	-	-	-
Uncomplicated skin and soft tissue abscesses - Avoid antibiotics and wound cultures after successful incision and drainage	-	-	-	-	-	2013	-
Pediatric dehydration - Avoid intravenous fluids before trial of oral rehydration therapy	-	-	-	-	-	2013	-
<b>Effective clinical care</b>							
STEMI - Fibrinolytic therapy within 30 minutes of ED arrival	OP-2	-	-	-	-	-	*
STEMI - Primary PCI within 90 minutes of hospital arrival	-	AMI-8a	-	-	-	-	*
AMI - Aspirin at arrival	OP-4	-	-	-	-	-	*
12-Lead ECG for non-traumatic chest pain	-	-	PQRS 54	-	-	-	*
Anticoagulation for atrial fibrillation / flutter	-	STK-03	PQRS 326	MIPS 326**	-	-	NQF 1525
Acute CVA (Cerebrovascular accident) - thrombolytic therapy (tPA)	-	STK-04	PQRS 187	MIPS 187**	-	-	NQF 0437
Acute CVA - Head CT or MRI (Magnetic Resonance Imaging) scan interpretation within 45 minutes of ED arrival	OP-23	-	-	-	-	-	NQF 0661
Sepsis management (lactate level, blood cultures, antibiotics, intravenous fluids (IV) fluids, repeat lactate, lactate clearance $\geq 10\%$ )	-	37135	-	-	ACEP 26-30, 48, Q101	-	NQF 0500
Ultrasound determination of pregnancy location for pregnant patients with abdominal pain	-	-	PQRS 254	MIPS 254	-	-	*
Rh immunoglobulin (Rhogam) for Rh-negative pregnant women at risk for fetal blood exposure	-	-	PQRS 255	MIPS 255	-	-	*
Acute otitis externa - Topical therapy	-	-	PQRS 91	MIPS 91	-	-	NQF 0653

Mental health - Adult major depressive disorder suicide risk assessment	-	-	PQRS 107	MIPS 107**	-	-	NQF 0104e
Mental health - pediatric psychosis screening for drugs of abuse	-	-	-	-	-	-	NQF 2806
Early involvement of palliative and hospice care services	-	-	-	-	-	2013	-
<b>Community and population health</b>							
High blood pressure screening and follow-up documented	-	-	PQRS 317	MIPS 317	-	-	*
Tobacco screening and cessation intervention	-	-	PQRS 226, 402	MIPS 226, 402	ACEP 25	-	NQF 0028
Unhealthy alcohol use: screening and brief counseling	-	-	PQRS 431	MIPS 431	-	-	NQF 2152
<b>Effective communication and care coordination</b>							
Initiation and engagement of alcohol and other drug abuse or dependence treatment	-	-	PQRS 305	MIPS 305	-	-	NQF 0004
<b>Patient safety</b>							
Pregnancy test for female abdominal pain patients	-	-	-	-	ACEP 24	-	*
Appropriate foley catheter use	-	-	-	-	ACEP 31	2013	-
Prevention of catheter-related bloodstream infections (crbsi): central venous catheter insertion protocol	-	-	PQRS 76	MIPS 76**	-	-	NQF 2726
Wrong-patient retract-and-reorder measure	-	-	PQRS 2723	-	-	-	NQF 2723
Care Plan - patents age ≥ 65 years with advanced care plan or surrogate decision maker documented	-	-	PQRS 47	MIPS 47	-	-	NQF 0326
Documentation of current medications in the medical record	-	-	PQRS 130	MIPS 130	-	-	NQF 0419ee
Closing the referral loops: receipt of specialist report	-	-	PQRS 374	MIPS 374	-	-	-
Left without being seen	OP-22	-	-	-	-	-	*
<b>Throughput (Time): Person and caregiver-centered experience and outcomes</b>							
Median time from ED arrival to ED departure for admitted ED patients	-	ED-1	-	-	-	-	NQF 0495
Admit decision Time to ED departure time for admitted patients	-	ED-2	-	-	-	-	NQF 0497
Median time from ED arrival to ED departure for discharged ED patients	OP-18	-	-	-	ACEP 32-47	-	NQF 0496
Door to diagnostic evaluation by a qualified medical professional	OP-20	-	-	-	-	-	*
<b>Throughput (Time): Effective clinical care</b>							
STEMI - median time to fibrinolysis	OP-1	-	-	-	-	-	*
STEMI - median time to transfer to another facility for acute coronary intervention	OP-3	-	-	-	-	-	NQF 0290

AMI - median time to ECG	OP-5	-	-	-	-	-	*
Acute Stroke - time to intravenous thrombolytic therapy	-	-	-	-	-	-	NQF 1952
Median time to pain management for long bone fracture	OP-21	-	-	-	-	-	*
<p>ABIM: American Board of Internal Medicine Foundation; ACEP: American College of Emergency Physicians; AMI: Acute Myocardial Infarction; CMS: Centers for Medicare and Medicaid Services; CT: Computed Tomography; ECG: Electrocardiogram; IQR: Hospital Inpatient Quality Reporting Program; MIPS: Merit-based Incentive Payment System; NQF: National Quality Forum; NQS: National Quality Strategy; OQR: Outpatient Quality Reporting Program; PCI: Percutaneous Coronary Intervention; PQRS: Physician Quality Reporting System; STEMI: ST-Elevation Myocardial Infarction</p> <p>* = Endorsement retired, ** = Not included in the MIPS Emergency Medicine Specialty Measures Set</p>							

Of these broadly adopted metrics, the majority fall into the categories of Efficiency and Cost Reduction and Effective Clinical Care. Measures of Person and Caregiver-Centered Experience are largely limited to ED throughput measures related to elements of length of stay. There are relatively few existing ED measures for Community/Population Health and Effective Communication and Care Coordination. The majority of the Efficiency and Cost Reduction metrics are targets for decreasing low-value resource utilization, such as unnecessary advanced imaging and inappropriate antibiotics. No metrics are tied to specific costs of care in the ED setting, such as the costs of a defined episode of care.

**Federal Programs:** The most widely adopted measures are those that are part of federal programs such as OQR/IQR and PQRS/MIPS. Notably, of the eleven OQR measures, only four are currently endorsed by NQF, while the other seven lost their endorsement between 2012 and 2017. Of the five IQR measures, four are currently endorsed by NQF, and one had its endorsement removed in 2016 [26,27].

Of the twenty-six PQRS measures, all but two were retained in the transition to MIPS (exceptions were performing a 12-lead electrocardiogram for non-traumatic chest pain and placing clinical orders on the incorrect patient). Nine of the MIPS measures listed in Table 1 are not included in the Emergency Medicine Specialty Measures Set, but are still listed here for their relevance to clinical practice in the ED.

**National Quality Forum Quality Positioning System:** The NQF database catalogues eighteen endorsed measures as applicable to the ED care setting. The majority were not specifically attributable to performance of emergency physicians and did not meet our inclusion criteria. Table 1 includes NQF measures relevant to quality of emergency medical care, including several that are not listed under the ED care setting. Six measures are “time to event” measures, while eighteen measures had NQF endorsement revoked between 2012 and 2017, but nonetheless remain included in OQR/IQR, MIPS, and/or ACEP [26].

**American College of Emergency Physicians:** In 2016, ACEP launched the first specialty-wide clinical registry, the Clinical Emergency Department Registry (CEDR) as a CMS Qualified Clinical Data Registry [28]. Among its advantages is the flexibility to directly develop and test emergency medicine metrics in parallel to the process of obtaining NQF endorsement. Further, the CEDR can include non-Medicare patients in its reporting [29]. Many CEDR metrics are time and throughput-related. Other measures are distributed among reducing inappropriate use, providing effective clinical care, and improving patient safety.

**Choosing Wisely:** Over 2013 and 2014, ACEP joined other specialties and published a set of ten recommendations as part of the Choosing Wisely Campaign, an ABIM initiative devoted to reducing unnecessary care. Half of these address inappropriate use of advanced imaging. The campaign does not include measurement or reporting of guideline adherence, although some aims reflect existing measures. Choosing Wisely recommendations from other specialties and professional societies are also applicable in emergency settings. For example, the American College of Surgeons’ Choosing Wisely recommendations include avoidance of “whole-body” diagnostic computed tomography

(CT) scanning in patients with minor or single system trauma or use of CT for the evaluation of suspected appendicitis in children until after ultrasound has been considered as an option [30]. However, recommendations from other specialties have not necessarily been endorsed by ACEP [31].

### Interventions for Physician Performance Improvement

**Results of Literature Scan:** There were 42 interventional studies excluded—31 interventions included organizational components not easily attributable to individual physicians, and 11 of the remaining 85 interventional studies did not report statistics that could be abstracted. Eleven studies demonstrated negative outcomes, defined as no improvement (or paradoxical worsening) in performance on the target measure. Among the remaining positive outcome studies, 4 included p values of 0.04 or higher. The distribution of results suggests there may be some publication or submission bias [32].

Our analysis of interventional studies targeting physician performance also revealed gaps. The literature on evidence-based ED interventions targeted at programmatically recognized performance measures is limited (Table 2). There were very few randomized controlled trials, and the majority of papers used a pre-post design to evaluate trends in the metric before and after implementing a guideline or pathway without an external comparator cohort. Similar to prior reports [23], studies provided little detail on the content and intensity of the intervention.

**Table 2:** Emergency department performance interventions for national quality measures

Performance Metric	Measure Set	Number of Sites	RCT	Education	Clinical Decision Support and EHR User Experience	Audit and Feedback	Reference
<b>Efficiency &amp; Cost Reduction</b>							
Imaging of head in trauma	PQRS, MIPS, ACEP, CW	13		●	●		[33]
		1			●		[34]
		5			●		[35]
		1		●	●	●	[36]
Imaging of cervical spine in trauma	None*	1		●			[37] (-)
		1		●			[38]
		1		●			[39]
		1		●	●		[40]
		12	+	●	●		[41]
		5			●		[35]
Imaging for pulmonary embolism	ACEP, CW	1		●	●	●	[42]
		1			●		[43]
		1			●		[44]
		5			●		[35]
		4	+		●		[45]
		1	+			●	[46]
Imaging of head in syncope	CW	1			●		[47] (-)
Imaging for recurrent renal colic	ACEP, CW	2		●			[48]
Imaging for low back pain	OQR, PQRS, MIPS, CW	1		●			[49] (-)
		1		●	●		[50]
		1			●		[51]
Avoiding antibiotics for acute bronchitis	PQRS, MIPS, NQF	16		●		●	[52]



Avoiding IV before trial of oral rehydration in pediatric dehydration	CW	2				●	[53]
		1				●	[54]
<b>Effective Clinical Care</b>							
STEMI - Fibrinolytic therapy within 30 minutes of ED arrival	OQR	28	+			●	[55]
		6	+	●		●	[56] (-)
		1				●	[57]
		1				●	[58]
STEMI - Primary PCI within 90 minutes of hospital arrival	IQR	1				●	[59]
Sepsis	IQR, NQF, ACEP	1		●		●	[60]
		1			●		[61]
		1			●		[62] (-)
		1				●	[63]
Suicide risk assessment	PQRS, MIPS, NQF	1		●			[64]
Early palliative & hospice care services	CW	1		●			[65]
<b>Community and population health</b>							
Tobacco screening & cessation intervention	PQRS, MIPS, NQF, ACEP	2		●		●	[66]
<b>Patient safety</b>							
Reducing opioid prescriptions	None*	1		●			[67]
		2			●		[68]
		7				●	[69]
<b>Throughput (Time): Person and caregiver-centered experience and outcomes</b>							
ED length of stay	OQR, IQR, NQF, ACEP	1				●	[70]
		2				●	[71]
ACEP: American College of Emergency Physicians; CT: Computed Tomography; CW: ABIM/ACEP Choosing Wisely ; ECG: Electrocardiogram; ED: Emergency Department; EHR: Electronic Health Record; IQR: Hospital Inpatient Quality Reporting Program; MIPS: Merit-based Incentive Payment System; NQF: National Quality Forum; OQR: Outpatient Quality Reporting Program; PCI: Percutaneous Coronary Intervention; PQRS: Physician Quality Reporting System ; RCT: Randomized Control Trial; STEMI: ST-Elevation Myocardial Infarction * = <b>Not currently a national measure but a demonstrated or emerging area of high interest</b> (-) = <b>Negative outcome study</b>							

**Interventions Targeting National Quality Measures:** Of the nearly 50 metrics commonly adopted and reported on a national level, only 14 metrics have been studied in published quality improvement interventions. Only five studies were randomized controlled trials (RCTs) [45,46,52,55,56]. A sixth RCT looked at cervical spine imaging [41], which is not included among the national sets of measures.

**Interventions for Other Quality Measures:** Beyond the common national measures, studies have evaluated interventions in a range of other ED quality areas. In addition to cervical spine imaging in trauma [72], other process areas include: clinical care for specific conditions, such as diabetic ketoacidosis [73], sickle cell anemia [74], transient ischemic attack [75], acute pain management [76,77], pediatric asthma [78,79], and migraines [80]; resource utilization, such as aggregate rates of CT and/or MRI use [81,82], laboratory studies [83], or appropriate antibiotic prescribing [84]; patient safety indicators [85,86]; and patient experience reports [87].

**Types of Interventions:** ED-based interventions largely fall into one of three categories: provider education, electronic health record (EHR) based clinical decision support (CDS) and user experience, and audit and feedback. Education most frequently involved formal endorsement of practice guidelines by a department, as well as other

methods, such as teaching sessions [36,41,42,52,88], letters/emails [36,42], pocket cards [41], workplace signage [36,41], and online learning modules [33]. CDS has primarily focused on radiology ordering guidelines. Given the discrete criteria that comprise many clinical decision rules, such as the Canadian Head CT rule, the Canadian/NEXUS cervical spine rules, and the PERC/Wells criteria for pulmonary embolism, CDS studies have focused on facilitating customized user prompts to curtail overutilization [89]. Other EHR-based interventions involve thoughtful choice architecture through redesigns of the ordering interface, such as by removing certain orders, repositioning certain options relative to another, or changing default settings [68,88]. Audit and feedback studies have utilized group- and individual-level feedback, as well as private [36,46,53,54,82] and public [69,71,88] reporting.

## **Discussion**

Efforts to measure ED quality continue to evolve from its early stages, which focused on a small set of conditions and timeliness measures, such as waiting times and length-of-stay. Perhaps owing to both the wide variety of quality metrics and the lack of standardized integration with efforts in clinical guideline development and policy implementation, we did not identify any systematic reviews. Given the heterogeneity of metrics, we focused on the most highly adopted national guidelines, which come from CMS, NQF, and Choosing Wisely (Table 1). Adherence to these guidelines is variable, as there is frequent discordance between actual and recommended physician practice [90-97].

This study is not intended to be a systematic review or meta-analysis; rather it provides an early look into emerging evidence on programmatic performance measurement and improvement strategies. We do not review the predictive validity of measures with outcomes or the quality of underlying evidence. While the NQF process of measure maintenance has resulted in withdrawal of endorsement for some measures based on poor association with outcomes or specificity concerns, measures with limitations may still be included in programs. We intentionally excluded metrics that characterize organizational or community-level factors that are unlikely to reform in short periods of time. We focus on metrics that can be primarily attributed to physician performance. As such, several important measures and interventions are not included.

Our review reveals four fundamental gaps that challenge the future of improving quality of emergency care.

### **Poor processes of measure validation threaten provider trust in measurement**

The evolution of ED metrics has not been without growing pains, as not all adopted measures have proved equally successful. A small number of measures have been removed because of high guideline concordance as a result of national quality improvement and decreasing marginal gains compared to cost for continued measurement. An example is giving aspirin on arrival for patients with AMI [25]. However, these instances have been overshadowed by failed measures and some are subject to documentation variations that may not improve outcomes.

A commonly noted example is Pneumonia PN-5b, an NQF-endorsed CMS measure to prompt the administration of antibiotics within four hours of hospital arrival for patients admitted with pneumonia. Following the voices of resistance among ED providers who were skeptical of the evidence, the measure proved its unintended consequences of “overtriage” for potential pneumonia in patients who then received antibiotics that were ultimately not appropriate [29,98,99]. Another example is OP-15, a CMS utilization measure intended to reduce CT imaging for atraumatic headache. In independent, peer-reviewed evaluation, such a claims-based measure did not prove reliable, valid, or accurate, as the administrative coding in claims did not capture documented exclusion criteria for patients with clear indications for imaging [29,98,100].

Ultimately, both measures were retired. PN-5b showed poor process-outcome relationships and suffered from expert committee judgment outweighing inconsistent evidence [101]. Meanwhile, OP-15 demonstrated the consequences of foregoing measure reliability testing before implementation and of missing important exclusion

criteria. Both have been criticized for a development and implementation process that occurred without broad input from the emergency medicine community [29]. More recently, the creation of CMS SEP-1 measures for sepsis care has stirred similar debate. Practitioners have raised concerns with the ambiguous definition and often heterogeneous presentation of sepsis, prescriptive fluid volume requirements and their potential for unintended patient harm, and burden of data collection from the complex abstraction logic required for chart review [102-104]. NQF endorsement nominally requires that measures meet standards of feasibility, predictive validity, scientific validity, and importance. More extensive multi-site testing of metrics for both feasibility and predictive validity with outcomes will be necessary to ensure acceptance.

### **Capturing the complexity of emergency medicine is difficult**

Beyond specific data source issues such as with the claims-based OP-15, the accurate measurement of quality and individual provider performance faces complexities that are magnified in emergency medicine. First, the majority of ED care is based on diagnosing and treating a patient's symptoms, rather than the longitudinal treatment of a specific disease. There are few measures based on the most common complaints of ED patients, and there has been little research into the accuracy of those that do exist [105,106]. This major hurdle helps to explain why we do not have better strategies for improving efficiency of diagnostic testing and why we have no measures that reflect national patient-centered priorities, such as misdiagnosis [12].

Second, national bodies initially adopted process measures that reflect adherence to guidelines. Outcome measures, such as readmission, mortality, and patient satisfaction, are stated priorities. However, timely outcome data are difficult to obtain in the US's non-integrated health and health information systems. Furthermore, methods of risk adjustment are imperfect, and attributing a patient's outcome to a specific encounter is challenging. Additionally, due to the nature of ED care being team-based and involving numerous providers spanning prehospital, ED, and inpatient settings, it can be difficult to determine the appropriate unit of attribution [12,13,107].

### **Existing metrics are limited in consistency, aim, and scope**

Reflective of the continuously changing landscape of defining metrics, measure endorsement lacks consistency across national entities. Few measures are included entirely across national programs. For example, it is notable that none of the ten Choosing Wisely recommendations currently have corresponding measures with NQF endorsement (three were previously removed). Only three Choosing Wisely recommendations have corresponding MIPS measures, and four are not found among any of the other measure sets (Table 1). ACEP may be beginning to address alignment, with CEDR's goal of mirroring metrics required by MACRA.

Perhaps even more strikingly, the national measures do not squarely hit the stated priority areas in the NQS. A metric may be well-designed and thoughtfully implemented, but a lack of alignment with priority areas is problematic. Our results show that Efficiency and Cost Reduction may see advancements, but other areas such as the role of the emergency physician in Community and Population Health and Effective Communication and Care Coordination may continue to be neglected. This may be indicative of measure feasibility issues; a tendency to 'look for keys under the lamppost' of administrative data that is already routinely collected rather than addressing costs associated with data collection or coordination.

Fundamentally, we must ask if we are directing our focus to the right areas. A recent study suggested that only 37% of the 86 MIPS/QPP measures relevant to ambulatory general internal medicine are valid [108]. This finding holds face validity in emergency medicine.

Furthermore, the metrics that are publicly reported and rewarded do not cover the scope of emergency medicine practice. Many clinical practice guidelines and consensus recommendations to improve care have not yet been translated into metrics. Examples include geriatric care [109], patient safety through improving provider

communication and standardizing care handoffs [25,110], and other elements of emergency care. Several studies have demonstrated disparities and the possible role of implicit bias in the quality of emergency care [111-115], yet few programs monitor this systematically. We are not assessing critical aspects of access to care, diagnosis, and treatment. Others have made an argument that performance measures for high value ED care should be aligned with the needs of the community, including timely access, emergency preparedness, and cost [12,18].

### **Few high-quality intervention studies exist to guide performance improvement**

For the metrics that have been prioritized for measurement and payment, the limited number of studies meeting Grade A standards of evidence prevent conclusions about how best to improve performance [116]. In our scan, we found studies evaluating physician-level interventions for only 14 of the nearly 50 national measures. Part of this limitation may stem from a large proportion of improvement efforts falling into local, unpublished ED quality improvement initiatives. Most studies are single-center designs, and randomized controlled studies are infrequent.

Many interventions relied primarily on provider education, but practice guidelines alone have limited effect on changing physician behaviour [117]. Some studies did attempt to identify barriers to guideline adherence in designing interventions, but rarely was the intervention explicitly based on theories in decision science or behavioral change, such as the Theory of Planned Behavior, which has been proposed as a good model to understand physician behaviour [118]. However, observational studies and quasi-experimental designs demonstrate promising possibilities [68]. This leaves open the possibility for developing a research program that can systematically evaluate quality improvement strategies that take these complexities into account.

### **Emerging research areas in ED-based performance interventions**

One new area of interest is the use of interventions to reduce the quantity of opioid prescriptions from the ED and strengthen referrals for substance use disorders and alternative pain management. Delgado et al. took advantage of EHR order system changes to study the effect of choice architecture on prescription quantities [68]. Burton et al. used individual audit and feedback with sharing of peer prescribing rates to demonstrate reductions in opioid prescribing variability and overall frequency and quantity [69]. New guidelines and metrics for opioid stewardship [119], management of overdose and substance use disorder [120,121], and alternative pain management therapies focused on the ED setting [122] are available. The effects of such interventions on patient outcomes are yet to be studied at length. In our sample of studies and others', most successful interventions appear to combine strategies, incorporating elements of education, CDS, and feedback, as well as other deliberate efforts such as clinical leadership endorsement to facilitate a change in culture [33,46,88,123,124].

### **Future Areas of Study**

There is a need for rigorous investigations of quality improvement strategies. Intervention designs should incorporate or be assessed for consistency with theoretical principles of decision science and adhere to study pre-registration guidelines. Numerous commentaries have pointed to the ED setting as an opportunity to study cognitive factors [125,126], however few studies test these theories.

Reproducible phenomena, such as cognitive load and decision fatigue [127,128], may serve as occasions to intervene with preventative as well as persuasive strategies to improve care. Well-framed feedback may help nudge emergency physicians default decisions to be more consistent with best practices. Meanwhile, large-scale natural experiments may be occurring as a result of policies intended to limit unnecessary utilization. Resourceful use of diagnostics can conserve more than the time and costs associated with testing.

Avoiding the cognitive load of result anticipation and interpretation may help conserve cognitive resources for critical prognostic and diagnostic judgements. Interventions that optimize performance of individuals and teams may

take these considerations into account. As an increasing number of pay-for-performance contracts based on quality metrics are developed, these occasions for rigorous evaluation can help inform what strategies are effective in a complex discipline.

In this context, the CEDR may offer a number of opportunities. First, it represents a platform to coordinate more systematic evaluations of performance metrics that will help improve their validity and utility. CEDR may also help provide contemporaneous benchmarking for studies that strengthen single-site or small trials with pre-post designs. Additionally, CEDR may improve the feasibility of pragmatic multisite interventional studies, in particular studies of interventions that incorporate feedback.

### **Limitations**

The focused nature of this review limits the metrics to those that have been endorsed and are part of existing programs in the US. By narrowing the intervention search, we did not include performance improvement studies targeting metrics beyond the scope of our review.

### **Conclusions**

The current state of performance measurement and improvement in the ED setting offers many prospects for contributions. Measurement strategy would benefit from refinement and re-alignment with NQS goals. This applies to (a) how priority guideline and outcome concepts are selected for measurement, (b) how national programs and initiatives are coordinated, and (c) how individual measures, once selected, are specified, operationalized, and tested to ensure that they are relevant, feasible, and valid indicators. There are a limited number of studies of approaches to improve performance on programmatic measures in the ED setting. Imaging metrics comprise more than half of the peer-reviewed studies, most involving one or more elements of education, CDS, and feedback.

Interventions, particularly those aimed at curbing utilization, must guard against unintended consequences such as accountability shuffling, missed diagnoses, and undertreatment. Measurement fatigue and resource consumption are real concerns [129] and must be balanced with a thoughtful approach to supporting frontline ED practitioners in improving the quality of outcomes.

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### **References**

1. Schuur JD, Carney DP, Lyn ET, Raja AS, Michael JA, et al. (2014) A top-five list for emergency medicine: a pilot project to improve the value of emergency care. *JAMA Intern Med* 174: 509-515.
2. National Quality Forum (2009) National voluntary consensus standards for emergency care: a consensus report [Internet]. Washington, D.C.: National Quality Forum. Available at: [http://www.qualityforum.org/Publications/2009/09/National\\_Voluntary\\_Consensus\\_Standards\\_for\\_Emergency\\_Care.aspx](http://www.qualityforum.org/Publications/2009/09/National_Voluntary_Consensus_Standards_for_Emergency_Care.aspx)
3. Venkatesh AK, Savage D, Sandefur B, Bernard KR, Rothenberg C, et al. (2017) Systematic review of emergency medicine clinical practice guidelines: Implications for research and policy. *PLoS One* 12: e0178456.
4. Wiler JL, Welch S, Pines J, Schuur J, Jouriles N, et al. (2015) Emergency Department Performance Measures Updates: Proceedings of the 2014 Emergency Department Benchmarking Alliance Consensus Summit. *Acad Emerg Med* 22: 542-553.

5. Gibson CM, Pride YB, Frederick PD, Pollack CV Jr, Canto JG, et al. (2008) Trends in reperfusion strategies, door-to-needle and door-to-balloon times, and in-hospital mortality among patients with ST-segment elevation myocardial infarction enrolled in the National Registry of Myocardial Infarction from 1990 to 2006. *Am Heart J* 156: 1035-1044.
6. Flynn A, Moscucci M, Share D, Smith D, LaLonde T, et al. (2010) Trends in door-to-balloon time and mortality in patients with ST-elevation myocardial infarction undergoing primary percutaneous coronary intervention. *Arch Intern Med* 170: 1842-1849.
7. Ford ES, Ajani UA, Croft JB, Critchley JA, Labarthe DR, et al. (2007) Explaining the decrease in U.S. deaths from coronary disease, 1980-2000. *N Engl J Med* 356: 2388-2398.
8. Bradley EH, Herrin J, Elbel B, McNamara RL, Magid DJ, et al. (2006) Hospital quality for acute myocardial infarction: correlation among process measures and relationship with short-term mortality. *JAMA* 296: 72-78.
9. Krumholz HM, Wang Y, Chen J, Drye EE, Spertus JA, et al. (2009) Reduction in acute myocardial infarction mortality in the United States: risk-standardized mortality rates from 1995-2006. *JAMA* 302: 767-773.
10. Wiler J, Granovsky M, Cantrill S, Newell R, Venkatesh A, et al. (2016) Physician Quality Reporting System Program Updates and the Impact on Emergency Medicine Practice. *West J Emerg Med* 17: 229-237.
11. Schull MJ, Guttman A, Leaver CA, Vermeulen M, Hatcher CM, et al. (2011) Prioritizing performance measurement for emergency department care: consensus on evidence-based quality of care indicators. *CJEM* 13: 300-309.
12. Schuur JD, Hsia RY, Burstin H, Schull MJ, Pines JM (2013) Quality measurement in the emergency department: past and future. *Health Aff (Millwood)* 32: 2129-2138.
13. Pines JM, Fee C, Fermann GJ, Ferroggiaro AA, Irvin CB, et al. (2010) The Role of the Society for Academic Emergency Medicine in the Development of Guidelines and Performance Measures. *Acad Emerg Med* 17: e130-e140.
14. de Vries EF, Struijs JN, Heijink R, Hendriks RJ, Baan CA, et al. (2016) Are low-value care measures up to the task? A systematic review of the literature. *BMC Health Serv Res* 16: 405.
15. Yiadom MYAB, Ward MJ, Chang AM, Pines JM, Jouriles N, et al. (2015) Consensus Statement on Advancing Research in Emergency Department Operations and Its Impact on Patient Care. *Acad Emerg Med* 22: 757-764.
16. Yiadom MYAB, Scheulen J, McWade CM, Augustine JJ (2016) Implementing Data Definition Consistency for Emergency Department Operations Benchmarking and Research. *Acad Emerg Med* 23: 796-802.
17. Centers for Medicare & Medicaid Services (2018) Enhancing Patient Care: Transitioning from the Physician Quality Reporting System (PQRS) to the Merit-based Incentive Payment System (MIPS) [Internet]. Available at: [https://www.cms.gov/Medicare/Quality-Initiatives-Patient-Assessment-Instruments/PQRS/Downloads/TransitionResources\\_Landscape.pdf](https://www.cms.gov/Medicare/Quality-Initiatives-Patient-Assessment-Instruments/PQRS/Downloads/TransitionResources_Landscape.pdf)
18. Medford-Davis L, Marcozzi D, Agrawal S, Carr BG, Carrier E (2017) Value-Based Approaches for Emergency Care in a New Era. *Ann Emerg Med* 69: 675-683.
19. Graff L, Stevens C, Spaite D, Foody J (2002) Measuring and Improving Quality in Emergency Medicine. *Acad Emerg Med* 9: 1091-1107.
20. Madsen M, Kiuru S, Castrè M, Kurland L (2015) The level of evidence for emergency department performance indicators: systematic review. *Eur J Emerg Med* 22: 298-305.
21. Wylie K, Crilly J, Toloo GS, FitzGerald G, Burke J, et al. (2015) Emergency department models of care in the context of care quality and cost: A systematic review. *Emerg Med Australas* 27: 95-101.

22. Sauser K, Burke JF, Reeves MJ, Barsan WG, Levine DA (2014) A Systematic Review and Critical Appraisal of Quality Measures for the Emergency Care of Acute Ischemic Stroke. *Ann Emerg Med* 64: 235-244.
23. Tavender EJ, Bosch M, Fiander M, Knott JC, Gruen RL, et al. (2016) Implementation research in emergency medicine: a systematic scoping review. *Emerg Med J* 33: 652-659.
24. 2011 Report to Congress: National Strategy for Quality Improvement in Health Care. U.S. Department of Health and Human Services; 2011 Mar.
25. Venkatesh AK, Goodrich K (2015) Emergency care and the national quality strategy: highlights from the Centers for Medicare & Medicaid Services. *Ann Emerg Med* 65: 396-399.
26. NQF: Quality Positioning System [Internet]. Available at: <http://www.qualityforum.org/QPS/>
27. NQF: Musculoskeletal Off-Cycle Measure Review 2017 [Internet]. [cited 2018 Mar 12]. Available at: [http://www.qualityforum.org/Publications/2017/07/Musculoskeletal\\_Off-Cycle\\_Measure\\_Review\\_2017.aspx](http://www.qualityforum.org/Publications/2017/07/Musculoskeletal_Off-Cycle_Measure_Review_2017.aspx)
28. Medicare Program; Merit-Based Incentive Payment System (MIPS) and Alternative Payment Model (APM) Incentive Under the Physician Fee Schedule, and Criteria for Physician-Focused Payment Models [Internet]. Centers for Medicare & Medicaid Services; 2016 Nov. Available at: <https://www.federalregister.gov/d/2016-25240>
29. Pines J, Venkatesh A, Silverman M (2015) Taking Control of Quality Measurements - Emergency Physicians Monthly [Internet]. *Emergency Physicians Monthly*. [cited 2018 Apr 3]. Available at: <http://epmonthly.com/article/taking-control-of-quality-measurements/>
30. American College of Surgeons (2015) Five Things Physicians and Patients Should Question [Internet]. Choosing Wisely: An Initiative of the ABIM Foundation; Available at: <http://www.choosingwisely.org/wp-content/uploads/2015/02/ACS-Choosing-Wisely-List.pdf>
31. Maughan BC, Rabin E, Cantrill SV (2017) 272 A Broader View of Quality: Identifying Other Specialties' Choosing Wisely Recommendations with High Relevance to Emergency Care. *Ann Emerg Med* 70: S107-S108.
32. Simonsohn U, Nelson LD, Simmons JP (2014) P-curve: a key to the file-drawer. *J Exp Psychol Gen* 143: 534-547.
33. Sharp AL, Huang BZ, Tang T, Shen E, Melnick ER, et al. (2018) Implementation of the Canadian CT Head Rule and Its Association With Use of Computed Tomography Among Patients With Head Injury. *Ann Emerg Med* 71: 54-63.
34. Ip IK, Raja AS, Gupta A, Andruchow J, Sodickson A, et al. (2015) Impact of clinical decision support on head computed tomography use in patients with mild traumatic brain injury in the ED. *Am J Emerg Med* 33: 320-325.
35. Bookman K, West D, Ginde A, Wiler J, McIntyre R, et al. (2017) Embedded Clinical Decision Support in Electronic Health Record Decreases Use of High-cost Imaging in the Emergency Department: EmbED study. *Acad Emerg Med* 24: 839-845.
36. Nigrovic LE, Stack AM, Mannix RC, Lyons TW, Samnaliev M, et al. (2015) Quality Improvement Effort to Reduce Cranial CTs for Children With Minor Blunt Head Trauma. *Pediatrics* 136: e227-e133.
37. Dearden C, Hughes D (2005) Does the National Emergency X-ray Utilization Study make a difference? *Eur J Emerg Med* 12: 278-281.
38. Kerr D, Bradshaw L, Kelly AM (2005) Implementation of the Canadian C-spine rule reduces cervical spine x-ray rate for alert patients with potential neck injury. *J Emerg Med* 28: 127-131.
39. Maurice S, Brown S, Robertson C, Beggs I (1996) The effect of introducing guidelines for cervical spine radiographs in the accident and emergency department. *J Accid Emerg Med* 13: 38-40.
40. Goergen SK, Fong C, Dalziel K, Fennessy G (2006) Can an evidence-based guideline reduce unnecessary imaging of road trauma patients with cervical spine injury in the emergency department? *Australas Radiol*. 50: 563-569.

41. Stiell IG, Clement CM, Grimshaw J, Brison RJ, Rowe BH, et al. (2009) Implementation of the Canadian C-Spine Rule: prospective 12 centre cluster randomised trial. *BMJ* 339: b4146.
42. Drescher MJ, Fried J, Brass R, Medoro A, Murphy T, et al. (2017) Knowledge Translation of the PERC Rule for Suspected Pulmonary Embolism: A Blueprint for Reducing the Number of CT Pulmonary Angiograms. *West J Emerg Med* 18: 1091-1097.
43. Drescher FS, Chandrika S, Weir ID, Weintraub JT, Berman L, et al. (2011) Effectiveness and acceptability of a computerized decision support system using modified Wells criteria for evaluation of suspected pulmonary embolism. *Ann Emerg Med* 57: 613-621.
44. Raja AS, Ip IK, Prevedello LM, Sodickson AD, Farkas C, et al. (2012) Effect of computerized clinical decision support on the use and yield of CT pulmonary angiography in the emergency department. *Radiology* 262: 468-474.
45. Kline JA, Jones AE, Shapiro NI, Hernandez J, Hogg MM, et al. (2014) Multicenter, randomized trial of quantitative pretest probability to reduce unnecessary medical radiation exposure in emergency department patients with chest pain and dyspnea. *Circ Cardiovasc Imaging* 7: 66-73.
46. Raja AS, Ip IK, Dunne RM, Schuur JD, Mills AM, et al. (2015) Effects of Performance Feedback Reports on Adherence to Evidence-Based Guidelines in Use of CT for Evaluation of Pulmonary Embolism in the Emergency Department: A Randomized Trial. *AJR Am J Roentgenol* 205: 936-940.
47. Melnick ER, Genes NG, Chawla NK, Akerman M, Baumlin KM, et al. (2010) Knowledge translation of the American College of Emergency Physicians' clinical policy on syncope using computerized clinical decision support. *Int J Emerg Med* 3: 97-104.
48. Blecher G, Meek R, Egerton-Warburton D, McCahy P (2017) Introduction of a new imaging guideline for suspected renal colic in the ED reduces CT urography utilisation. *Emerg Med J* 34: 749-754.
49. Chandra K, Atkinson PR, Fraser J, Chatur H, Adams C (2017) MP31: The contrarian effect: how does a Choosing Wisely focused knowledge translation initiative affect emergency physician practice in a high awareness-low investigation environment? *Canadian J Emerg Med* 19: S75-S76.
50. Tracey NG, Martin JB, McKinstry CS, Mathew BM (1994) Guidelines for lumbar spine radiography in acute low back pain: effect of implementation in an accident and emergency department. *Ulster Med J* 63: 12-17.
51. Min A, Chan VWY, Aristizabal R, Peramaki ER, Agulnik DB, et al. (2017) Clinical Decision Support Decreases Volume of Imaging for Low Back Pain in an Urban Emergency Department. *J Am Coll Radiol* 14: 889-899.
52. Metlay JP, Camargo CA, MacKenzie T, McCulloch C, Maselli J, et al. (2007) Cluster-Randomized Trial to Improve Antibiotic Use for Adults With Acute Respiratory Infections Treated in Emergency Departments. *Ann Emerg Med* 50: 221-230.
53. Jain S, Frank G, McCormick K, Wu B, Johnson BA (2015) Impact of Physician Scorecards on Emergency Department Resource Use, Quality, and Efficiency. *Pediatrics* 136: e670-e679.
54. Tavarez MM, Ayers B, Jeong JH, Coombs CM, Thompson A, et al. (2017) Practice Variation and Effects of E-mail-only Performance Feedback on Resource Use in the Emergency Department. *Acad Emerg Med* 24: 948-956.
55. Selker HP, Beshansky JR, Griffith JL (2002) Use of the Electrocardiograph-Based Thrombolytic Predictive Instrument To Assist Thrombolytic and Reperfusion Therapy for Acute Myocardial Infarction: A Multicenter, Randomized, Controlled, Clinical Effectiveness Trial. *Ann Intern Med* 137: 87-95.
56. Kinsman LD, Rotter T, Willis J, Snow PC, Buykx P, et al. (2012) Do clinical pathways enhance access to evidence-based acute myocardial infarction treatment in rural emergency departments? *Aust J Rural Health* 20: 59-66.
57. Krall SP, Reese CL 4th, Donahue L (1995) Effect of continuous quality improvement methods on reducing triage to thrombolytic interval for acute myocardial infarction. *Acad Emerg Med* 2: 603-609.



58. Guidry UA, Paul SD, Vega J, Harris C, Chaturvedi R, et al. (1998) Impact of a Simple Inexpensive Quality Assurance Effort on Physician's Choice of Thrombolytic Agents and Door-to-Needle Time: Implication for Costs of Management. *J Thromb Thrombolysis* 5: 151-157.
59. Lai CL, Fan CM, Liao PC, Tsai KC, Yang CY, et al. (2009) Impact of an audit program and other factors on door-to-balloon times in acute ST-elevation myocardial infarction patients destined for primary coronary intervention. *Acad Emerg Med* 16: 333-342.
60. Plambech MZ, Lurie AI, Ipsen HL (2012) Initial, successful implementation of sepsis guidelines in an emergency department. *Dan Med J* 59: A4545.
61. Bond CM, Djogovic D, Villa-Roel C, Bullard MJ, Meurer DP, et al. (2013) Pilot Study Comparing Sepsis Management with and without Electronic Clinical Practice Guidelines in an Academic Emergency Department. *J Emerg Med* 44: 698-708.
62. Kuttub HI, Sterk E, Rech MA, Nghiem T, Bahar B, et al. (2018) Early Recognition and Treatment of Sepsis After the Addition of Lactate to the Laboratory's Critical Result Call List. *J Intensive Care Med* 33: 111-115.
63. Nguyen HB, Corbett SW, Steele R, Banta J, Clark RT, et al. (2007) Implementation of a bundle of quality indicators for the early management of severe sepsis and septic shock is associated with decreased mortality. *Crit Care Med* 35: 1105-1112.
64. Reshetukha TR, Alavi N, Prost E, Kirkpatrick RH, Sajid S, et al. (2018) Improving suicide risk assessment in the emergency department through physician education and a suicide risk assessment prompt. *Gen Hosp Psychiatry* 52: 34-40.
65. Weng TC, Yang YC, Chen PJ, Kuo WF, Wang WL, et al. (2017) Implementing a novel model for hospice and palliative care in the emergency department. *Medicine* 96: e6943.
66. Kimmel S, Smith SL, Sabino JN, Gertner E, Dostal J, et al. (2009) Tobacco Screening Multicomponent Quality Improvement Network Program: Beyond Education. *Acad Emerg Med* 16: 1186-1192.
67. Pace C, Shah S, Zhang AX, Zosel AE (2017) Impact of a chronic pain management pathway on opioid administration and prescribing in an Emergency Department. *Clin Toxicol* 23: 1-7.
68. Delgado MK, Shofer FS, Patel MS, Halpern S, Edwards C, et al. (2018) Association between Electronic Medical Record Implementation of Default Opioid Prescription Quantities and Prescribing Behavior in Two Emergency Departments. *J Gen Intern Med* 33: 409-411.
69. Burton JH, Hoppe JA, Echternach JM, Rodgers JM, Donato M (2016) Quality Improvement Initiative to Decrease Variability of Emergency Physician Opioid Analgesic Prescribing. *West J Emerg Med* 17: 258-263.
70. Wu KH, Cheng FJ, Li CJ, Cheng HH, Lee WH, et al. (2013) Evaluation of the effectiveness of peer pressure to change disposition decisions and patient throughput by emergency physician. *Am J Emerg Med* 31: 535-539.
71. Song H, Tucker AL, Murrell KL, Vinson DR (2017) Closing the Productivity Gap: Improving Worker Productivity Through Public Relative Performance Feedback and Validation of Best Practices. *Manage Sci* 64.
72. Desai S, Liu C, Kirkland SW, Krebs LD, Keto-Lambert D, et al. (2017) Effectiveness of implementing evidence based interventions to reduce c-spine image ordering in the emergency department: a systematic review. *Acad Emerg Med* 25: 672-683.
73. Kempegowda P, Coombs B, Nightingale P, Chandan JS, Al-Sheikhli J, et al. (2017) Regular and frequent feedback of specific clinical criteria delivers a sustained improvement in the management of diabetic ketoacidosis. *Clin Med (Lond)* 17: 389-394.

74. Tanabe P, Freiermuth CE, Cline DM, Silva S (2017) A Prospective Emergency Department Quality Improvement Project to Improve the Treatment of Vaso-Occlusive Crisis in Sickle Cell Disease: Lessons Learned. *Jt Comm J Qual Patient Saf* 43: 116-126.
75. Wydall S, Gordon A, Sims M (2014) Management of transient ischaemic attacks in the emergency department: a quality improvement project. *BMJ Qual Improv Rep* 3: u205496.
76. Platts-Mills TF, Hollowell AG, Burke GF, Zimmerman S, Dayaa JA, et al. (2018) Randomized controlled pilot study of an educational video plus telecare for the early outpatient management of musculoskeletal pain among older emergency department patients. *Trials* 19: 10.
77. Van Woerden G, Van Den Brand CL, Den Hartog CF, Idenburg FJ, Grootendorst DC, et al. (2016) Increased analgesia administration in emergency medicine after implementation of revised guidelines. *Int J Emerg Med* 9: 4.
78. Dexheimer JW, Abramo TJ, Arnold DH, Johnson K, Shyr Y, et al. (2014) Implementation and evaluation of an integrated computerized asthma management system in a pediatric emergency department: A randomized clinical trial. *Int J Med Inform* 83: 805-813.
79. Bekmezian A, Fee C, Weber E (2015) Clinical pathway improves pediatrics asthma management in the emergency department and reduces admissions. *J Asthma* 52: 806-814.
80. Kaar CRJ, Gerard JM, Nakanishi AK (2016) The Use of a Pediatric Migraine Practice Guideline in an Emergency Department Setting. *Pediatr Emerg Care* 32: 435-439.
81. Carnevale TJ, Meng D, Wang JJ, Littlewood M (2015) Impact of an emergency medicine decision support and risk education system on computed tomography and magnetic resonance imaging use. *J Emerg Med* 48: 53-57.
82. Ehrlichman R, Dezman Z, Klein J, Jeudy J, Lemkin D (2017) Quarterly Reporting of Computed Tomography Ordering History Reduces the Use of Imaging in an Emergency Department. *J Emerg Med* 52: 684-689.
83. Scorgie R, Nicholls GM, Jones P (2014) Association between an educational intervention and a reduction in inappropriate troponin testing in patients presenting to an adult emergency department. *Intern Med J* 44: 1100-1118.
84. Borde JP, Kern WV, Hug M, Steib-Bauert M, de With K, et al. (2015) Implementation of an intensified antibiotic stewardship programme targeting third-generation cephalosporin and fluoroquinolone use in an emergency medicine department. *Emerg Med J* 32: 509-515.
85. Graber ML, Sorensen AV, Biswas J, Modi V, Wackett A, et al. (2014) Developing checklists to prevent diagnostic error in Emergency Room settings. *Acta Radiol Diagn* 1: 223-231.
86. Pevnick JM, Li X, Grein J, Bell DS, Silka P (2013) A retrospective analysis of interruptive versus non-interruptive clinical decision support for identification of patients needing contact isolation. *Appl Clin Inform* 4: 569-582.
87. Newgard CD, Fu R, Heilman J, Tanski M, Ma OJ, et al. (2017) Using Press Ganey Provider Feedback to Improve Patient Satisfaction: A Pilot Randomized Controlled Trial. *Acad Emerg Med* 24: 1051-1059.
88. Venkatesh AK, Hajdasz D, Rothenberg C, Dashevsky M, Parwani V, et al. (2018) Reducing Unnecessary Blood Chemistry Testing in the Emergency Department: Implementation of Choosing Wisely. *Am J Med Qual* 33: 81-85.
89. Durand DJ, Lewin JS, Berkowitz SA (2015) Medical-Imaging Stewardship in the Accountable Care Era. *N Engl J Med* 373: 1691-1693.
90. DeAngelis J, Lou V, Li T, Tran H, Bremjit P, et al. (2017) Head CT for Minor Head Injury Presenting to the Emergency Department in the Era of Choosing Wisely. *West J Emerg Med* 18: 821-829.
91. Lin MP, Nguyen T, Probst MA, Richardson LD, Schuur JD (2017) Emergency Physician Knowledge, Attitudes, and Behavior Regarding ACEP's Choosing Wisely Recommendations: A Survey Study. *Acad Emerg Med* 24: 668-675.

92. Maughan BC, Baren JM, Shea JA, Merchant RM (2015) Choosing Wisely in Emergency Medicine: A National Survey of Emergency Medicine Academic Chairs and Division Chiefs. *Acad Emerg Med* 22: 1506-1510.
93. Rosenberg A, Agiro A, Gottlieb M, Barron J, Brady P, et al. (2015) Early Trends Among Seven Recommendations From the Choosing Wisely Campaign. *JAMA Intern Med* 175: 1913-1920.
94. Schuur JD, Tibbetts SA, Pines JM (2010) Pregnancy Testing in Women of Reproductive Age in US Emergency Departments, 2002 to 2006: Assessment of a National Quality Measure. *Ann Emerg Med* 55: 449-457.
95. Venkatesh AK, Kline JA, Courtney DM, Camargo CA, Plewa MC, et al. (2012) Evaluation of pulmonary embolism in the emergency department and consistency with a national quality measure: quantifying the opportunity for improvement. *Arch Intern Med* 172: 1028-1032.
96. Mathews SC, Kelen GD, Pronovost PJ, Pham JC (2010) A National Study Examining Emergency Medicine Specialty Training and Quality Measures in the Emergency Department. *Am J Med Qual* 25: 429-435.
97. Seymann GB, Di Francesco L, Sharpe B, Rohde J, Fedullo P, et al. (2009) The HCAP Gap: Differences between Self-Reported Practice Patterns and Published Guidelines for Health Care–Associated Pneumonia. *Clin Infect Dis* 49: 1868-1874.
98. Berdahl C, Schuur JD, Fisher NL, Burstin H, Pines JM (2015) Policy Measures and Reimbursement for Emergency Medical Imaging in the Era of Payment Reform: Proceedings From a Panel Discussion of the 2015 Academic Emergency Medicine Consensus Conference. *Acad Emerg Med* 22: 1393-1399.
99. Pines JM, Hollander JE, Lee H, Everett WW, Uscher-Pines L, et al. (2007) Emergency department operational changes in response to pay-for-performance and antibiotic timing in pneumonia. *Acad Emerg Med* 14: 545-548.
100. Schuur JD, Brown MD, Cheung DS, Graff L, Griffey RT, et al. (2012) Assessment of Medicare’s Imaging Efficiency Measure for Emergency Department Patients With Atraumatic Headache. *Ann Emerg Med* 60: 280-290.
101. Pines JM, Isserman JA, Hinfey PB (2009) The Measurement of Time to First Antibiotic Dose for Pneumonia in the Emergency Department: A White Paper and Position Statement Prepared for the American Academy of Emergency Medicine. *J Emerg Med* 37: 335-340.
102. Venkatesh AK, Slesinger T, Whittle J, Osborn T, Aaronson E, et al. () Preliminary Performance on the New CMS Sepsis-1 National Quality Measure: Early Insights From the Emergency Quality Network (E-QUAL). *Ann Emerg Med* 71: 10-15.
103. Aaronson EL, Filbin MR, Brown DFM, Tobin K, et al. (2017) New Mandated Centers for Medicare and Medicaid Services Requirements for Sepsis Reporting: Caution from the Field. *J Emerg Med* 52: 109-116.
104. Faust JS, Weingart SD (2017) The Past, Present, and Future of the Centers for Medicare and Medicaid Services Quality Measure SEP-1: The Early Management Bundle for Severe Sepsis/Septic Shock. *Emerg Med Clin North Am* 35: 219-231.
105. Griffey RT, Pines JM, Farley HL, Phelan MP, Beach C, et al. (2015) Chief complaint-based performance measures: a new focus for acute care quality measurement. *Ann Emerg Med* 65: 387-395.
106. Wiler JL, Beck D, Asplin BR, Granovsky M, Moorhead J, et al. (2012) Episodes of care: is emergency medicine ready? *Ann Emerg Med* 59: 351-357.
107. Baker WE. Evaluation of Physician Competency and Clinical Performance in Emergency Medicine. *Emerg Med Clin North Am* 27: 615-626.
108. MacLean CH, Kerr EA, Qaseem A (2018) Time Out — Charting a Path for Improving Performance Measurement. *N Engl J Med* 378: 1757-1761.
109. Terrell KM, Hustey FM, Hwang U, Gerson LW, Wenger NS, et al. (2009) Quality indicators for geriatric emergency care. *Acad Emerg Med* 16: 441-449.

110. Pham JC, Alblaihed L, Cheung DS, Levy F, Hill PM, et al. (2014) Measuring Patient Safety in the Emergency Department. *Am J Med Qual* 29: 99-104.
111. Pezzin LE, Keyl PM, Green GB (2007) Disparities in the Emergency Department Evaluation of Chest Pain Patients. *Acad Emerg Med* 14: 149-156.
112. Choi K, Shofer FS, Mills AM (2016) Sex differences in STEMI activation for patients presenting to the ED 1939. *Am J Emerg Med* 34: 1939-1943.
113. Goyal MK, Kuppermann N, Cleary SD, Teach SJ, Chamberlain JM (2015) Racial Disparities in Pain Management of Children With Appendicitis in Emergency Departments. *JAMA Pediatr* 169: 996-1002.
114. Richardson LD, Irvin CB, Tamayo-Sarver JH (2003) Racial and Ethnic Disparities in the Clinical Practice of Emergency Medicine. *Acad Emerg Med* 10: 1184-1188.
115. Dehon E, Weiss N, Jones J, Faulconer W, Hinton E, et al. (2017) A Systematic Review of the Impact of Physician Implicit Racial Bias on Clinical Decision Making. *Acad Emerg Med* 24: 895-904.
116. Oxford Centre for Evidence-Based Medicine Website. [cited 2019 Oct 30]. Available at: Oxford Centre for Evidence-Based Medicine. Levels of evidence. <http://www.cebm.net/index.aspx?o=1025>. [Accessed December 15, 2010].
117. Cabana MD, Rand CS, Powe NR, Wu AW, Wilson MH, et al. (1999) Why Don't Physicians Follow Clinical Practice Guidelines? *JAMA* 282: 1458-1465.
118. Godin G, Bélanger-Gravel A, Eccles M, Grimshaw J (2008) Healthcare professionals' intentions and behaviours: A systematic review of studies based on social cognitive theories. *Implement Sci* 3: 36.
119. Dowell D, Haegerich TM, Chou R (2016) CDC Guideline for Prescribing Opioids for Chronic Pain - United States, 2016. *MMWR Recomm Rep* 65: 1-49.
120. Williams AR, Nunes EV, Bisaga A, Pincus HA, Johnson KA, et al. (2018) Developing an opioid use disorder treatment cascade: A review of quality measures. *J Subst Abuse Treat* 91: 57-68.
121. Schmidt EM, Gupta S, Bowe T, Ellerbe LS, Phelps TE, et al. (2017) Predictive validity of a quality measure for intensive substance use disorder treatment. *Subst Abuse* 38: 317-323.
122. Todd KH (2017) A Review of Current and Emerging Approaches to Pain Management in the Emergency Department. *Pain Ther* 6: 193-202.
123. Yadav K, Meeker D, Mistry RD, Doctor JN, Fleming-Dutra KE, et al. (2019) A Multifaceted Intervention Improves Prescribing for Acute Respiratory Infection for Adults and Children in Emergency Department and Urgent Care Settings. *Acad Emerg Med* 26: 719-731.
124. Vinson DR, Mark DG, Chettipally UK, Huang J, Rauchwerger AS, et al. (2018) Increasing Safe Outpatient Management of Emergency Department Patients With Pulmonary Embolism: A Controlled Pragmatic Trial. *Ann Intern Med* 169: 855-865.
125. Croskerry P (2002) Achieving quality in clinical decision making: cognitive strategies and detection of bias. *Acad Emerg Med* 9: 1184-1204.
126. Croskerry P (2009) Clinical cognition and diagnostic error: applications of a dual process model of reasoning. *Adv Health Sci Educ Theory Pract Suppl* 1:27-35.
127. Linder JA, Doctor JN, Friedberg MW, Reyes Nieva H, Birks C, et al. (2014) Time of day and the decision to prescribe antibiotics. *JAMA Intern Med* 174: 2029-2031.
128. Johnson TJ, Hickey RW, Switzer GE, Miller E, et al. (2016) The Impact of Cognitive Stressors in the Emergency Department on Physician Implicit Racial Bias. *Acad Emerg Med* 23: 297-305.
129. Berwick DM (2016) Era 3 for Medicine and Health Care. *JAMA* 315: 1329-1330.