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Multicenter Test of an Emergency Department Trigger Tool for Detecting Adverse Events

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Abstract

Objectives—Traditional approaches to safety and quality screening in the emergency department (ED) are porous and low yield for identifying adverse events (AEs). A better approach may be in the use of trigger tool methodology. We recently developed a novel ED Trigger Tool (EDTT) using a multidisciplinary, multicenter approach. We conducted a multicenter test of this tool and assess its performance.

Methods—Design and Participants: We studied the EDTT over a 13-month period at four EDs. All patients 18 and older with Emergency Severity Index (ESI) acuity levels of 1-3 seen by a provider were eligible. Reviewers completed standardized training modules. Each site reviewed 50 randomly selected visits per month. A first-level reviewer screened for presence of pre-defined triggers (findings that increase the probability of an AE). If no trigger is present, the review is deemed complete. When present, a trigger prompts an in-depth review for an AE. Any event identified is assigned a level of harm using the Medication Event Reporting and Prevention (MERP) Index, ranging from a near miss (A) to patient death (I). Events are noted as present on arrival (POA) or in the ED, an act of commission or omission and are assigned one of 4 event categories. A second level physician performs a confirmatory review of all AEs, and independently reviews 10% of cases to estimate the false negative rate. All AEs or potential AEs were reviewed in monthly group calls for consensus on findings. The primary outcome is the proportion of visits in which an AE is identified, overall and by site. Secondary outcomes include categories of events, distribution of harm ratings, and association of AEs with sociodemographic

and clinical factors and triggers. We present sociodemographic data and details about AEs and results of logistic regression for associations of AEs with triggers, sociodemographics, and clinical variables.

Results—We captured 2,594 visits that are representative, within site, of their patient population. Overall, the sample is 64% white, 54% female, with a mean age of 51. Variability is observed between sites for age, race and insurance, but not gender. A total of 240 events were identified in 228 visits (8.8%) of which 53.3% were POA, 19.7% were acts of omission and 44.6% were medication-related, with some variability across sites. A MERP F score (contributing to need for admission, higher level of care or prolonged hospitalization) was the most common severity level (35.4% of events). Overall, 185 /240 events (77.1%) involved patient harm (MERP level E), affecting 175 visits (6.7%). Triggers were present in 951 visits (36.6%). Presence of any trigger was strongly associated with an AE (adjusted OR 4.6; 95%CI: 3.2, 6.6). Ten triggers were individually associated with AEs (adjusted ORs from 2.1 to 7.7). Variability was observed across sites in individual trigger associations, event rates and categories but not in severity ratings of events. The overall false negative rate was 6.1%.

Conclusions—The trigger tool approach was successful in identifying meaningful events. The EDTT appears to be a promising approach for identifying all-cause harm in the ED.

INTRODUCTION

Traditional approaches to safety and quality screening in the ED are porous and low yield for identifying adverse events (AE). Though the true AE rate in the ED is unknown, commonly used screening practices have a yield just under 2% and likely underestimate the number of AEs, reflecting inadequate and inefficient surveillance.¹ A better approach to quality and safety review may be in the use of trigger tool methodology. This process, popularized by the Institute for Healthcare Improvement's (IHI) Global Trigger Tool (GTT) aims for efficiency in identifying more AEs and a broader scope of events, and in multiple studies has resulted in substantially higher yields compared to traditional approaches.²⁻⁶ Trigger tools include a two-tiered review approach, with a first-level (usually a nurse) reviewer screening a random sample of records on regular intervals for the presence of pre-defined triggers. Triggers are findings that may be indicative of an adverse event (e.g. an elevated INR [international normalized ratio] is often used as a trigger to look for an associated hemorrhage). The presence of a trigger prompts an in-depth record review for an adverse event. When an AE is found, the level of harm is estimated, ranging from the need for intervention to a patient death. A second level physician reviewer then evaluates the case summary to confirm the presence of an AE and the level of harm assigned by the first reviewer. When no trigger is present, the review is complete without need for further investigation. The trigger tool approach has the potential to 1) provide a new, more efficient approach to quality and safety review in the ED, broadening the scope of the types of AEs identified; 2) establishing a baseline AE rate at a given facility against which to evaluate performance efforts; 3) provide much-needed data on AE rates across facilities and associations of AEs with sociodemographic and clinical factors; and 4) improve identification of areas at high risk for AEs in order to help direct improvement resources. Trigger tools have been developed for and studied in a number of clinical settings,

⁷⁻¹³ but a trigger tool for use in the ED has been lacking. We recently developed a novel ED Trigger Tool using a multidisciplinary, multicenter approach.¹⁴ In this study, we perform a multicenter test of this tool, to trial this approach and assess performance.

METHODS

Study Setting and Design

We performed a multicenter prospective study of a novel ED trigger tool¹⁴ over a 13-month period (3/1/16 – 3/31/17). IRB approval was obtained at each site using a common protocol.

Study Setting and Participants

Four EDs affiliated with 3 academic medical centers participated. Sites were chosen for an infrastructure that allowed completion the work, and engagement of a physician safety and quality champion. First level reviewers at different sites included emergency nurses, acute care nurse practitioners, emergency medicine residents and attending physicians. All second level reviewers were attending emergency physicians.

Study Population

All ED patients 18 and older with an Emergency Severity Index (ESI) 1-3 were eligible. Patients who left without being seen or before treatment was complete were excluded. Each site reviewed fifty records/month, selected at random from all visits at their site meeting criteria.

Study Protocol

Record reviews followed the two-tiered approach typical of trigger tool methodology. First-level reviewers used a standard data form organized into modules (medical care, laboratories, medications, trauma, procedures) typical of trigger tools to enhance efficiency of review, aid in trigger detection and facilitate abstraction of sociodemographic data. Presence of a trigger prompted a detailed review looking for an AE. If none was present, the review was considered complete. Any AEs detected were scored on severity of harm with the widely-used National Coordinating Council's Medication Error Reporting and Prevention (NCC MERP) Index, modified for our use as was done for the GTT. Reviewers assigned events to one of four categories (medication, procedural, medical care, other); indicated whether the AE was an act of omission or commission; and whether it was present on arrival (POA). Putative AEs were reviewed by second-level reviewers to confirm that an AE occurred and the level of harm. For a number of reasons including concerns about hindsight bias and limitations in the medical record, we did not attempt to determine preventability of events as has been done in some trigger tool studies. As is done with the GTT, multiple events occurring during one visit are only counted as separate events if they are unrelated. Events in which one AE leads to a second are considered "cascading" events and are only counted as a single event.

Reviews were completed monthly for the prior month's data. All cases with AEs, including the uncertain ones, were discussed on the monthly all-site call to facilitate learning and to gain consensus. In order to determine the false negative rate (missed AEs), second-level

reviewers also reviewed a randomly-selected minimum of ~5 records/month, in which triggers were present but no AE was found on the first-level review. We held monthly conference calls during which each site presented AEs or potential AEs they identified. We discussed these for learning purposes and to achieve consensus on how AEs were defined and how MERP levels and other designations (omission/commission; present on arrival; event category) were assigned. Deidentified data were entered directly into a REDCap data form (Vanderbilt University, Nashville, TN) for centralized review and analysis.

Training

All participants completed free online training from the IHI, which includes test cases. Participants completed additional training developed the IHI (used with permission) that included cases modified by two of the authors (RTG, RML) to include events specific to the ED. These were reviewed with one of the authors (LA) who is an expert in trigger tool development. Reviewers participated in a series of web-based conferences prior to the beginning of formal data collection to discuss cases. We performed three months of “dry run” data collection to establish our consensus process and to demonstrate feasibility. A library of trigger definitions was shared with the group via a shared cloud-based file folder to guide interpretation.

Outcome Measures

Our primary outcome measure is the overall event rate (proportion of visits with at least one event), stratified as near miss events (MERP A-D) and those with harm (MERP E-I) and stratified by whether events were present on arrival or occurred in the ED (including events occurring up to 24 hours and attributable to ED care for admitted patients). Secondary outcomes include association of AEs with triggers, sociodemographic and clinical variables. We report on the distribution of triggers and severity scores for AEs across sites and on the categories of AEs identified. We also tracked the proportion of events identified over time to evaluate to what extent learning and sensitivity improved over the study period.

Primary Data Analysis

Sociodemographic data and AE characteristics are summarized as proportions with 95% confidence intervals, overall and within site. Fisher’s exact tests were used for testing pairwise associations; ANOVA with Tukey post-hoc comparisons for comparing age across sites; and univariate and multivariable logistic regression analyses for testing for association of AEs (level E-I) with sociodemographics and clinical data. We report results both unadjusted (trigger by AE) and adjusted results (with age, gender, race and site). Complete observations only are used in the analyses and we did not attempt to impute data in the few instances where data were missing. Significance levels are adjusted for multiple comparisons with the Benjamini-Hochberg procedure, for an approximate experiment-wide false discovery rate of 5%. Analyses were conducted using SAS 9.4 (SAS Institute, Cary, NC).

RESULTS

We captured data for a total of 2,594 visits (Table 1). There is variability across sites in age ($p < 0.0001$), race ($p < 0.0001$), type of insurance coverage ($p < 0.0001$), but not in gender ($p = 0.21$). The visits are representative, and these differences reflect differences in the patient populations served by the four centers. Site 2, for example, is primarily characterized by an older population with Medicare/Private insurance coverage.

Adverse event rates

A total of 240 events (irrespective of severity) were found in 228 of the 2594 records reviewed (8.8%; 95% CI: 7.8%, 9.9%; Table 2). Multiple events were identified in 11 records (0.4%). We observed differences in event frequency across sites ($p < 0.0001$), from a low of 3.9% (95% CI: 2.5%, 5.6%) to a high of 14.0% (95% CI: 11.5%, 16.8%).

Approximately half of the 240 identified events were present on arrival to the ED (POA, 53.3%, 95% CI: 47.0%, 59.6%), with no evidence of heterogeneity across sites ($p = 0.37$). By site, the highest proportion of POA cases was 65.4% (95%CI 44.3%, 82.8%) and the lowest was 48.4% (38.0%-58.9%). Acts of omission accounted for 19.7% of events (95%CI 14.8% - 25.2%), with variation across sites ($p < 0.0001$): incidence was higher at Site 4 (44.0%, 95%CI 24.4% - 65.1%) than at the other three sites, where the frequencies were virtually identical, from 14.71% (95%CI 7.3% - 25.4%) to 17.9% (95%CI 10.8% - 27.1%). Finally, medication-related events were the most common category of events (44.6% overall, 95% CI 38.1% to 51.1%), though variability was noted across sites ($P = 0.0002$, Table 2).

Among the 240 identified events, 185 (77.1%, 95% CI: 71.2%, 82.2%) resulted in patient harm (MERP E-I), a percentage that is high at all sites, albeit with some variation ($p = 0.02$): from a low of 69.1% (95% CI: 56.7%-79.7%) to a high of 92.2% (81.1%-97.8%). Events that were POA were more likely to be associated with harm (88.3%; 95%CI 81.4% - 93.3%) than those occurring in the ED (64.3%; 95%CI 55.7% - 73.1%; $P < 0.0001$). This finding is consistent across all sites. Using multiple logistic regression, we found significant differences in AE rates by site ($P < 0.0001$), and no association with race (coded as White, Black and Other, $P = 0.83$) nor with gender ($P = 0.39$). Higher age was strongly associated with an increased rate of AEs ($P < 0.0001$; per year, OR: 1.03, 95%CI: 1.02 - 1.03). There is insufficient data (given the limited number of AEs) to perform a more detailed analysis of the interplay of site, age, gender and ethnicity.

Distribution of Severity Scores

A MERP score of F (contributing to need for admission, higher level of care or prolonged hospitalization) was the most common overall (35.4% of events, Figure 1). The proportion of events with harm (MERP E or above) was marginally higher at one site 92.2% (95%CI: 81.1% to 97.8%) and comparable for the other sites: 69.1% (56.7% to 79.8%), 73.7%; (95% CI 63.4% to 82.2%), and 80.8% (95%CI: 60.1%-93.4%).

False Negative Rate

Second level reviewers collectively conducted an independent review of 399 records (15.4% of total) to estimate the false negative rate (FNR). These were randomly selected from those where the first level reviewer had not reported an AE. The estimated FNR is 6.08% (95% CI 3.9% to 8.9%). There were significant differences in FNR between sites ($P < 0.0001$), with Site 3 having the highest rate (12.9%) compared to the other three sites (<1%, 5.2% and 1.7%).

Distribution of Triggers

The cumulative prevalence of triggers was significant, with at least one trigger identified in 37% of records (951/2594). Individually, over half of the 47 tested triggers proved rare, 27 out of 46 having a frequency less than 1% (Supplementary Table). One trigger (C11 - Delivery in the ED) was never reported. Fourteen triggers had frequencies that differed significantly across sites.

Trigger Associations with Adverse Events (MERP E-I)

After adjusting for site, age, gender, and race, the presence of any trigger was strongly associated with the presence of an event (adjusted OR: 4.1; 95% CI: 2.9 – 5.5), regardless of severity; as well as with the occurrence of an AE (adjusted OR=4.6 95% CI: 3.2-6.6; Table 3 and Supplementary Table). Individually, 10 of 47 triggers tested were associated with presence of an AE (adjusted ORs ranging from 2.1 to 7.7, Table 3). Adjusted and unadjusted results agree in the majority of cases, suggesting that trigger definition is generally robust to patient population characteristics. Three triggers (C2 Patient fall; C13 Blood product administration; M3 Heparin administration) were significant in the unadjusted analysis but not after adjusting for other covariates. Frequencies for seven of the triggers associated with AEs varied by site. However, we found no evidence for differences for the effect of triggers on AE risk between sites (Breslow-Day test of homogeneity of odds-ratios, all p -values > 0.20), while acknowledging that the present study may be underpowered for assessing effect modification.

Analysis of detection over time

There appears to have been a steady increase in AE discovery with time. This was confirmed via logistic regression of AE detection on log-month (OR= 1.3, 95% CI: 1.07 to 1.61, $P= 0.0086$), after adjusting for site, age, gender and ethnicity. The AE detection rate steadily increased from a low of 5.5% in month 1 of the study (95% CI: 3.0% - 9.3%) to 10.3% in month 13 (95% CI: 6.7%-15.0%).

LIMITATIONS

Our study had a number of limitations. Though we included sites from different geographic locations and included a community site in addition to academic sites, the study was not designed to be representative of EDs in the US. The sites used a different mix of first level reviewers including nurses, acute care nurse practitioners, residents and attending physicians. This real-world approach offers some interesting preliminary observations (a higher FNR among the resident reviewing group; lower yield in the site with an attending

first level reviewer) and overall demonstrates feasibility using different approaches. Though we attempted to provide some assessment of sensitivity with independent oversampling of cases, without a gold standard review in which all records are sent in to a central location for over-review, it is impossible to know to what degree variability in first level reviewers may have impacted the observed AE rates. For reasons including feasibility and privacy and risk management concerns, a centralized approach was not possible for this study. Future considerations to assess sensitivity and interrater reliability might include site visits to audit reviews and the embedding of records known to contain AEs of various MERP levels. Because in prior testing we determined that inclusion of patients with ESI scores was low yield, we limited our cases to patients with ESI 1-3 acuity scores. This approach has precedent both in inpatient trigger tool studies and in ED-based studies of adverse events.^{15,16}

DISCUSSION

Our study represents the first iteration of the ED Trigger Tool and is the first trial we are aware of using a trigger tool in the ED.^{17,18} The primary goal of trigger tools is to identify all-cause harm, and this is the approach we emulated, with the additional aim to identify non-harm, near-miss events (MERP A-D), which is recognized as important for safety and quality evaluation and improvement in EM.¹⁸⁻²¹ We used the IHI's definition of harm as an "unintended physical injury resulting from or contributed to by medical care that requires additional monitoring, treatment or hospitalization, or that results in death."²² It is important to recognize that AEs (harm) are not necessarily due to errors and that errors usually do not lead to patient harm. It is also important to take the patient's perspective in considering whether harm occurred. What might qualify as an AE is not always intuitive to providers who may be inured to what are common occurrences in the ED setting. Examples include a rash or pruritis caused by medication administration requiring treatment with diphenhydramine (MERP E), hypoventilation and hypoxia during procedural sedation requiring ventilatory assistance (H), iatrogenic pneumothorax during central line placement requiring admission (F), and a fall in a patient on anticoagulants resulting in an intracranial hemorrhage with permanent injury (G) or death (I). Studying methods for measuring quality and safety measurement is an area that has not enjoyed an abundance of attention in emergency medicine research. Accordingly, for years, overall approaches to surveillance have remained fairly static, focusing on periodic reviews of specific case types: returns with admission, deaths, upgrades in care, etc., with a low yield for identifying AEs.^{1,23} Referrals from other physicians, administrators, or departments is the only category that we have consistently found to be high-yield.^{1,24}

Trigger tool studies have demonstrated a 10-fold increase in AE detection compared to traditional methods,² with AE rates of up to 27-33% of hospital or skilled nursing facilities admissions respectively,^{3,4} and estimates of deaths from AEs 2-4 times higher than previously thought.⁶ Because ED encounters are significantly shorter than inpatient stays, with limited "exposure time" to the system, we (fortunately) do not expect to see these same AE rates. Though single-site studies have reported AE rates as high as 27.8% of visits,^{16,19,20,25-27} a recent systematic review estimated a more reliable AE rate in the ED to be in the range of 0.16% - 6%,²⁸ which is consistent with our findings. Some prior studies

have focused on errors rather than AEs or on specific AE types (e.g. drug events) or specific sub-populations (e.g. asthma, boarding patients), rather than general ED patients.^{19,20,26,29} Though our study was not designed to compare the yield of the EDTT to traditional methods used for AE detection, we did observe an equivalent or higher yield at the three sites for which we had baseline data, (albeit for a different 1-year period).¹

That approximately half of identified events were POA, provides some insight as to the volume of visits to the ED that are related to AEs in the health care system. This proportion is consistent with at least one prior study that captured similar information in the ED setting.²¹ These AEs also tended to have higher severity scores, which is not entirely surprising. It is likely the case that this was the reason these patients were sent in or self-referred to the ED in the first place. Though we do not report data on the details of AEs beyond the event categories assigned, the scope of events identified with the ED trigger tool was felt by participants to be broader than that using traditional methods.

We did not find increased risks of AEs related to sociodemographic variables other than increasing age. Prior inpatient studies have also demonstrated age as a risk factor for AEs and prolonged ED length of stay as a risk factor for elderly ED patients.^{2,15,20,25,27,28,30} Among the 10 individual triggers we identified as being associated with adverse events, two were related to vital sign findings (hypotension and hypoxia), five were related to medications or to blood product administration, two were diagnoses or events (fall, delirium), and one was an operational metric. The medication triggers included reversal agents, treatment for allergic reactions and anticoagulants known to be associated with adverse events. These are all fairly straightforward triggers that could be captured, reproduced and potentially automated. Because in prior studies, including our own, 72-hour returns have been identified as low yield for detecting AEs,^{18,23,31} we were surprised to see that this was a significant trigger.

Variability from month to month is typical of the random sampling approach used with trigger tools. Longer timeframes result in more stable estimates of the baseline AE rate. Variability in AE rates observed across sites is likely multifactorial. Sites differ in patient populations and this may have import for AE rates. EDs also differ in terms of which triggers are more relevant in identifying their specific “trouble spots.” For example, sites with lower burdens of hospital crowding and ED boarding may have fewer visits with triggers such as length of stay >6 hours, while another ED may have more triggers for medication events. Yield is also likely to be operator dependent, especially impacted by the sensitivity of the 1st level reviewer. This variability has been discussed in prior studies.^{32–35} Though a range of AE rates across sites is expected, one site had a low number of AEs identified in the ED, with relatively more events identified that were present on arrival. We suspect this may have been due to a focus on detecting more serious events with a resultant decrease in overall sensitivity. This was also a site where the first and second level reviewers were attending physicians, which raises the question as to who is best suited to be a first level reviewer. In most trigger tools studies, nurses perform this role, and it makes sense that nurses may be more adept at combing through nursing notes in a record to identify AEs that might go undetected by physicians. Conversely, nurses are likely less attuned to acts of omission on the part of a provider. Nurse practitioners might be the ideal first level reviewers

as they are in the unique position of having worked in the role of a nurse and a provider. Our monthly calls included both first and second level reviewers, greater participation by second level reviewers may have focused calls more upon agreement with AE determinations and severity designations than upon sensitivity in the first level review.

Though improved detection is one of the goals of trigger tools, equally important is consistency in application of the methods, which allows for this approach to serve as a yardstick against which improvements can be measured. To this end, we recently created a document outlining our consensus approach to commonly encountered scenarios and the thought processes behind the designations made.³⁶ Our false negative rate of 6% is consistent with prior reported levels,⁴ demonstrating a reasonable level of internal consistency. In this study, it is not surprising that yield would increase over time, with increased experience and learning by reviewers. This has also been reported in use of the Global Trigger Tool.³⁷ We observed that reporting of AEs nearly doubled from the first month to the last. Importantly, the goal of trigger tools is not to find all AEs but to identify a majority of these.

By including acts of omission as well as acts of commission, our approach differed from many trigger tool studies. While it is critical to be judicious in identifying acts of omission, we felt these were nevertheless important to include. Timely and life-saving interventions are the hallmark of care in the ED, and failure to provide an important evidence-based intervention (e.g. aspirin in ST elevation MI, antibiotics in septic shock) is highly relevant from a quality and safety perspective. We limited inclusion of acts of omission to those in which there was complete consensus among the group.

In this study, the presence of any trigger increased the likelihood of an AE and the prevalence of triggers was fairly high. A number of triggers were rarely present and may be low yield for inclusion when using a manual approach to detect trigger presence. Current work is underway to refine, automate and test an expanded ED Trigger Tool. We anticipate that by 1) identifying and including only those triggers that are high-yield for identifying AEs, 2) automating the first step in the first level review – the search for triggers – with a computerized query, and 3) limiting the pool for random sampling of records to those that include at least 1 trigger, we will realize significantly improved detection of AEs and further simplify this review process. This study demonstrates the feasibility of the trigger tool approach, and provides some preliminary data about the utility of specific triggers in the detection of AEs and about the nature of AEs in the ED, and reveals some useful lessons for improvement in future work.

CONCLUSIONS

In this multicenter test of the EDTT, 8.8% visits had one or more events (any severity) and 6.7% of visits had an AE. Overall, 240 events were identified, 53.3% of which were present on arrival, and 77.1% associated with patient harm (77.1%). The presence of any trigger significantly increased the probability of an AE and 10 triggers were individually associated with an adverse event. Increasing age was associated with an increased frequency of AEs. Reviewers improved in detection of AEs over time with experience using the tool. Further

work is needed to standardize the review process, to refine the use of triggers, provide more granularity for a taxonomy of events and to test these associations on a larger scale. This study provides preliminary data suggesting that the ED trigger tool has promise as a novel approach for ED safety and quality review.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

References

1. Griffey RT, Schneider RM, Sharp BR, et al. Description and Yield of Current Quality and Safety Review in Selected US Academic Emergency Departments. *Journal of Patient Safety*. 2017
2. Classen DC, Resar R, Griffin F, et al. 'Global trigger tool' shows that adverse events in hospitals may be ten times greater than previously measured. *Health Aff (Millwood)*. 2011; 30 :581–9. [PubMed: 21471476]
3. Landrigan CP, Parry GJ, Bones CB, Hackbarth AD, Goldmann DA, Sharek PJ. Temporal trends in rates of patient harm resulting from medical care. *The New England journal of medicine*. 2010; 363 :2124–34. [PubMed: 21105794]
4. Office of the Inspector General. Adverse Events in Skilled Nursing Facilities: National Incidence Among Medicare Beneficiaries. Washington D.C.: Department of Health & Human Services. Office of the Inspector General; 2014.
5. Office of the Inspector General. Adverse Events in Hospitals: Methods for Identifying Events. Services DoHaH; 2010.
6. James JT. A new, evidence-based estimate of patient harms associated with hospital care. *J Patient Saf*. 2013; 9 :122–8. [PubMed: 23860193]
7. Suarez C, Menendez MD, Alonso J, Castano N, Alonso M, Vazquez F. Detection of adverse events in an acute geriatric hospital over a 6-year period using the Global Trigger Tool. *Journal of the American Geriatrics Society*. 2014; 62 :896–900. [PubMed: 24697662]
8. Sharek PJ, Horbar JD, Mason W, et al. Adverse events in the neonatal intensive care unit: Development, testing, and findings of an NICU-focused trigger tool to identify harm in North American NICUs. *Pediatrics*. 2006; 118 :1332–40. [PubMed: 17015521]
9. Resar RK, Rozich JD, Simmonds T, Haraden CR. A trigger tool to identify adverse events in the intensive care unit. *Joint Commission journal on quality and patient safety / Joint Commission Resources*. 2006; 32 :585–90.
10. Kalenderian E, Walji MF, Tavares A, Ramoni RB. An adverse event trigger tool in dentistry: a new methodology for measuring harm in the dental office. *Journal of the American Dental Association*. 2013; 144 :808–14. [PubMed: 23813262]
11. Griffin FA, Classen DC. Detection of adverse events in surgical patients using the Trigger Tool approach. *Quality & safety in health care*. 2008; 17 :253–8. [PubMed: 18678721]
12. Carnevali L, Krug B, Amant F, et al. Performance of the adverse drug event trigger tool and the global trigger tool for identifying adverse drug events: experience in a Belgian hospital. *The Annals of pharmacotherapy*. 2013; 47 :1414–9. [PubMed: 24285758]
13. Stockwell DC, Bisarya H, Classen DC, et al. Development of an Electronic Pediatric All-Cause Harm Measurement Tool Using a Modified Delphi Method. *J Patient Saf*. 2016; 12 :180–9. [PubMed: 25162206]
14. Griffey RT, Schneider RM, Adler LM, et al. Development of an Emergency Department Trigger Tool Using a Systematic Search and Modified Delphi Process. *J Patient Saf*. 2016
15. Kennerly DA, Saldana M, Kudyakov R, da Graca B, Nicewander D, Compton J. Description and Evaluation of Adaptations to the Global Trigger Tool to Enhance Value to Adverse Event Reduction Efforts. *Journal of Patient Safety*. 2013; 9 :87–95. [PubMed: 23334632]

16. Calder LA, Forster A, Nelson M, et al. Adverse events among patients registered in high-acuity areas of the emergency department: a prospective cohort study. *Cjem*. 2010; 12 :421–30. [PubMed: 20880432]
17. Howard IL, Bowen JM, Al Shaikh LAH, Mate KS, Owen RC, Williams DM. Development of a trigger tool to identify adverse events and harm in Emergency Medical Services. *Emerg Med J*. 2017; 34 :391–7. [PubMed: 28153866]
18. Calder L, Pozgay A, Riff S, et al. Adverse events in patients with return emergency department visits. *BMJ Qual Saf*. 2015; 24 :142–8.
19. Camargo CA Jr, Tsai CL, Sullivan AF, et al. Safety climate and medical errors in 62 US emergency departments. *Ann Emerg Med*. 2012; 60 :555–63e20. [PubMed: 23089089]
20. Liu SW, Thomas SH, Gordon JA, Hamedani AG, Weissman JS. A Pilot Study Examining Undesirable Events Among Emergency Department-Boarded Patients Awaiting Inpatient Beds. *Annals of Emergency Medicine*. 2009; 54 :381–5. [PubMed: 19303168]
21. Hendrie J, Sammartino L, Silvapulle MJ, Braitberg G. Experience in adverse events detection in an emergency department: incidence and outcome of events. *Emerg Med Australas*. 2007; 19 :16–24. [PubMed: 17305656]
22. Griffin, FA, Resar, RK. IHI Global Trigger Tool for Measuring Adverse Events. Second. Cambridge, Massachusetts: Institute for Healthcare Improvement; 2009.
23. Pham JC, Kirsch TD, Hill PM, DeRuggerio K, Hoffmann B. Seventy-two-hour returns may not be a good indicator of safety in the emergency department: a national study. *Academic emergency medicine : official journal of the Society for Academic Emergency Medicine*. 2011; 18 :390–7. [PubMed: 21496142]
24. Griffey RT, Bohan JS. Healthcare provider complaints to the emergency department: a preliminary report on a new quality improvement instrument. *Quality & safety in health care*. 2006; 15 :344–6. [PubMed: 17074871]
25. Fordyce J, Blank FS, Pekow P, et al. Errors in a busy emergency department. *Ann Emerg Med*. 2003; 42 :324–33. [PubMed: 12944883]
26. Hafner JW Jr, Belknap SM, Squillante MD, Bucheit KA. Adverse drug events in emergency department patients. *Ann Emerg Med*. 2002; 39 :258–67. [PubMed: 11867978]
27. Forster AJ, Rose NG, van Walraven C, Stiell I. Adverse events following an emergency department visit. *Quality & safety in health care*. 2007; 16 :17–22. [PubMed: 17301197]
28. Stang AS, Wingert AS, Hartling L, Plint AC. Adverse events related to emergency department care: a systematic review. *PloS one*. 2013; 8 :e74214. [PubMed: 24069281]
29. Stiell IG, Clement CM, Aaron SD, et al. Clinical characteristics associated with adverse events in patients with exacerbation of chronic obstructive pulmonary disease: a prospective cohort study. *CMAJ : Canadian Medical Association journal = journal de l'Association medicale canadienne*. 2014; 186 :E193–204.
30. Ackroyd-Stolarz S, Read Guernsey J, Mackinnon NJ, Kovacs G. The association between a prolonged stay in the emergency department and adverse events in older patients admitted to hospital: a retrospective cohort study. *BMJ Qual Saf*. 2011; 20 :564–9.
31. Rising KL, Victor TW, Hollander JE, Carr BG. Patient Returns to the Emergency Department: The Time-to-return Curve. *Academic emergency medicine : official journal of the Society for Academic Emergency Medicine*. 2014; 21 :864–71. [PubMed: 25154879]
32. Schildmeijer KG, Nilsson L, Arestedt K, Perk J. The assessment of adverse events in medical care; lack of consistency between experienced teams using the Global Trigger Tool'. *BMJ Qual Saf*. 2013; 22 :271–2.
33. Schildmeijer K, Nilsson L, Arestedt K, Perk J. Assessment of adverse events in medical care: lack of consistency between experienced teams using the global trigger tool. *BMJ Qual Saf*. 2012; 21 :307–14.
34. Mattsson TO, Knudsen JL, Lauritsen J, Brixen K, Herrstedt J. Assessment of the global trigger tool to measure, monitor and evaluate patient safety in cancer patients: reliability concerns are raised. *BMJ Qual Saf*. 2013; 22 :571–9.
35. Deilkas ET. Imprecision concerning the Global Trigger Tool. *BMJ Qual Saf*. 2013; 22 :271.

36. Griffey RT, Schneider RM, Sharp BR, Vrablik MC, Adler L. Practical Considerations in Use of Trigger Tool Methodology in the Emergency Department. *Journal of Patient Safety*. 2018
37. Adler L, Denham CR, McKeever M, et al. Global Trigger Tool: Implementation Basics. *Journal of Patient Safety*. 2008; 4 :245–9.

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Figure 1.
Distribution of severity scores across sites

Table 1

Sociodemographic data by site

	Site				
	ALL N=2594	1 N=650	2 N=654	3 N=643	4 N=647
Annual ED Volume		95,000	11,000	28,758	59,639
Average EDLOS for admitted patients (min)		381	384	443	289
Mean age	51.1	49.2	54.8	49.0	51.4
% female	54.4%	53.5%	58.0%	53.5%	52.7%
White	63.9%	36.9%	62.2%	72.5%	84.9%
Black	29.1%	59.4%	34.9%	10.4%	11.0%
Asian	3.7%	1.1%	1.1%	9.6%	3.2%
Hispanic	<1%	<1%	<1%	1.1%	<1%
Other	3.0%	2.6%	1.8%	6.4%	<1%
Private	40.5%	25.2%	49.0%	39.5%	48.5%
Self Pay	11.0%	25.5%	12.5%	2.1%	3.4%
Medicaid	15.7%	22.3%	3.8%	24.3%	12.5%
Medicare	13.3%	8.0%	5.8%	6.9%	33.3%
Medicare + Medicaid	6.1%	11.2%	4.6%	8.4%	<1%
Medicare + Private	13.4%	7.7%	24.3%	18.9%	2.3%

EDLOS – ED Length of Stay

Table 2

Distribution of Adverse Events and Non-Harm Events across sites, occurring in and Prior to Arrival to the ED, with Event Category Distributions

Site	Visits ^J	All		POA		ED		Medical Care	Medication	Procedural	Other
		A-D	E-I	A-D	E-I	A-D	E-I				
All	2594	55	185	15	113	40	72	32.9%	44.6%	16.3%	6.3%
1	650	25	70	4	42	21	28	43.2%	47.4%	6.3%	3.2%
2	654	4	47	0	30	4	17	23.5%	54.9%	17.7%	3.9%
3	643	21	47	7	28	14	19	22.1%	38.2%	30.9%	8.8%
4	647	5	21	4	13	1	8	42.3%	30.8%	11.5%	15.4%

^JNote: 11 visits had multiple events/AEs: One event and one AE (N=2 visits); 2 AEs (N=8 visits); 3 AEs (N=1).

A-D - Modified Medication Error Reporting and Prevention Index level A-D (non-harm events)

E-I - Modified Medication Error Reporting and Prevention Index level E-I (adverse events)

POA – present on arrival

ED – Emergency Department

Table 3Significant Triggers associations with Adverse Events¹

Trigger	p-value ²		Odds Ratio (95% CI)	
	Unadj. ³	Adj. ⁴	Unadjusted ³	Adjusted ⁴
Any trigger present	<.0001	<.0001	5.23 (3.71 - 7.39)	4.60 (3.22 - 6.59)
C2 Patient fall	<.0001	NS	3.92 (2.21 - 6.95)	2.11 (1.15 - 3.87)
C8 Systolic BP < 90 on ≥2 readings at least 15 minutes apart	<.0001	<.0001	5.47 (3.12 - 9.60)	4.76 (2.64 - 8.59)
C13 Blood product administration	0.0276	NS	3.51 (1.67 - 7.40)	2.57 (1.18 - 5.60)
C14 Diagnosis of delirium or altered mental status	<.0001	<.0001	4.18 (2.51 - 6.95)	3.66 (2.13 - 6.29)
C15 Oxygen saturation < 90% on 2 readings	<.0001	0.0001	4.59 (2.68 - 7.85)	3.89 (2.19 - 6.91)
C16 Return visit to ED within 72hrs resulting in hospital admission	<.0001	<.0001	5.38 (3.15 - 9.19)	6.06 (3.45 - 10.63)
M1 Reversal agent (Naloxone, Flumazenil) administration	0.0176	0.0323	6.48 (2.23 - 18.87)	6.41 (2.12 - 19.40)
M3 Heparin admin. (incl: Enoxaparin, Fondaparinux, Bivalirudin)	0.0786	NS	3.09 (1.48 - 6.45)	2.25 (1.06 - 4.82)
M4 Benadryl administration	0.0208	0.0008	2.69 (1.52 - 4.77)	3.66 (2.00 - 6.69)
M6 Vitamin K administration	<.0001	0.0069	12.64 (4.53 - 35.28)	7.70 (2.61 - 22.73)

¹ Complete Table in Supplemental Materials.² p-values are corrected for multiple comparisons with the Benjamini-Hochberg procedure; threshold at 0.05³ Unadjusted: bivariate analysis of AE and trigger.⁴ Adjusted: From a logistic regression of AE on trigger, adjusting for age, sex, ethnicity and site