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Journal
International Journal for Quality in Health Care, 30(5)

ISSN
1353-4505

Authors
Villa, Stephen
Weber, Ellen J
Polevoi, Steven
et al.

Publication Date
2018-06-01

DOI
10.1093/intqhc/mzy056

Peer reviewed

International Journal for Quality in Health Care, 2018, 30(5), 375–381
doi: 10.1093/intqhc/mzy056
Advance Access Publication Date: 25 April 2018
Article

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Decreasing triage time: effects of implementing a step-wise ESI algorithm in an EHR[†]

STEPHEN VILLA[1], ELLEN J. WEBER[1], STEVEN POLEVOI[1], CHRISTOPHER FEE[1], ANDREW MARUOKA[2], and TINA QUON[1]

[1]Department of Emergency Medicine, UCSF, 535 Parnassus Ave, San Francisco, CA 94143, USA, and [2]IT Clinical Applications and Analytics, UCSF, 400 Parnassus Ave, San Francisco, CA 94143, USA

Address reprint requests to: Stephen Villa, Department of Emergency Medicine, UCSF, 535 Parnassus Ave, San Francisco, CA 94143, USA. Tel: +415-206-5752; Fax: +415 353-8499; E-mail: stephen.villa@ucsf.edu
[†]This work was presented at the Society for Academic Emergency Medicine National Annual Meeting in Dallas, Texas on May 2014.

Editorial Decision 4 January 2018; Accepted 20 April 2018

Abstract

Objectives: To determine if adapting a widely-used triage scale into a computerized algorithm in an electronic health record (EHR) shortens emergency department (ED) triage time.
Design: Before-and-after quasi-experimental study.
Setting: Urban, tertiary care hospital ED.
Participants: Consecutive adult patient visits between July 2011 and June 2013.
Intervention: A step-wise algorithm, based on the Emergency Severity Index (ESI-5) was programmed into the triage module of a commercial EHR.
Main Outcome Measures: Duration of triage (triage interval) for all patients and change in percentage of high acuity patients (ESI 1 and 2) completing triage within 15 min, 12 months before-and-after implementation of the algorithm. Multivariable analysis adjusted for confounders; interrupted time series demonstrated effects over time. Secondary outcomes examined quality metrics and patient flow.
Results: About 32 546 patient visits before and 33 032 after the intervention were included. Post-intervention patients were slightly older, census was higher and admission rate slightly increased. Median triage interval was 5.92 min (interquartile ranges, IQR 4.2–8.73) before and 2.8 min (IQR 1.88–4.23) after the intervention ($P < 0.001$). Adjusted mean triage interval decreased 3.4 min (95% CI: −3.6, −3.2). The proportion of high acuity patients completing triage within 15 min increased from 63.9% (95% CI 62.5, 65.2%) to 75.0% (95% CI 73.8, 76.1). Monthly time series demonstrated immediate and sustained improvement following the intervention. Return visits within 72 h and door-to-balloon time were unchanged. Total length of stay was similar.
Conclusion: The computerized triage scale improved speed of triage, allowing more high acuity patients to be seen within recommended timeframes, without notable impact on quality.

Key words: quality improvement, quality management, patient outcomes (health status, quality of life, mortality), measurement of quality, computerized expert-systems, general methodology, design for safety, patient safety, emergency care, setting of care

Introduction

Emergency department (ED) visits are steadily rising worldwide, and as a result, wait times to see a physician are increasing. Data from the USA indicates that these delays disproportionately affect higher acuity patients [1].

Triage prioritizes patients when resources are limited, allowing ED staff to quickly identify those patients who should be seen ahead of other patients who may have arrived before them. However, a prior study at our institution demonstrated that less than half of high acuity ambulatory patients completed triage within the recommended time frame and this performance was worse during peak arrival times [2]. We hypothesized that triage takes too long because nurses are expected to first collect data, and then, after collecting this data, determine an acuity [3]. We believed that the electronic medical record afforded the opportunity to lead the triage nurse through the triage algorithm, focusing nurses on only that information necessary for an acuity assignment and allowing them to end the encounter as soon as a triage level was assigned.

Objectives

We sought to determine the impact of a computerized, step-by-step triage algorithm focused solely on information pertinent to assigning an acuity level (and priority for being seen) on throughput time at triage. We hypothesized that by shortening the triage time for all patients with this algorithm, more high acuity patients could complete triage in the recommended time from arrival. We also investigated whether this focused triage would have negative consequences.

Methods

Study Design and Setting

This was a retrospective before-and-after quasi-experimental study of adult patients presenting to an ED at an urban, academic tertiary care hospital in the USA between June 2011 and May 2013. The annual ED census is ~40 000 patients; 15% are pediatric. The Emergency Severity Index (ESI-5), the most commonly used triage scale in the US EDs, has been in use since September 2007 and only triage-trained nurses perform triage [4]. Using the ESI-5, nurses assign an acuity level from 1 to 5, with level 1 the most urgent. This study was approved by the institutional review board at the University of California, San Francisco.

Participants

All adult patients presenting to the ED between 1 June 2011 and 31 May 2013 were included. Visits for patients under 18 years old were excluded due to the development of a pediatric ED during this time. Patients without a designated acuity, or missing triage start or end times were also excluded.

Intervention

Between 2006 and 2012, the ED used a stand-alone, locally developed EHR, with a typical triage data collection form requiring documentation of chief complaint, vital signs, medical problems, medications and allergies. There were also fields (not mandatory) for last tetanus, last menstrual period and name of the primary doctor. After completing the form, nurses would then assign a triage acuity to the patient the ESI-5 guidelines were posted on the wall and had been taught in triage classes. In June 2012, the hospital adopted a commercial EHR (Epic™), which provided an opportunity to change the triage method. Prior to launching the commercial EHR, we re-configured its triage module into a stepwise algorithm for assigning the appropriate ESI triage level (Fig. 1). The algorithm walks the nurse through the ESI criteria, from highest to lowest acuity. When criterion for a particular level is met, the acuity assignment is made and triage ends. Allergies are then solicited but other past medical history and medications are recorded later at the bedside. Advanced triage protocols and providers at triage were not used during the study period.

Data Sources

Prior to the intervention, demographics, registration time and intervals of care were abstracted from the ED's locally developed EHR documentation system (based on Filemaker Pro™), and a registration system from General Electric (GE) Centricity™. The post-implementation data source was the hospital-wide EHR system (Epic™). Quality data in both phases were obtained from databases kept by the medical center quality improvement department.

Measurements

For each patient, we collected age, sex, race, ethnicity, arrival method, time and date entering ED, arrival time, triage start time, triage completion time, time of acuity assignment, time and date leaving ED, triage acuity level, triage nurse, ED disposition and census at time of arrival. Triage completion time was the time the nurse marked the note complete (Fig. 2). In cases where the triage complete button was never pressed, but an acuity selected, the time of acuity assignment was used as the triage end time. The triage interval was defined as the time between triage start time and triage complete. Arrival to triage complete was defined as the time between arrival and the triage complete timestamp or in those cases where triage complete was never checked, time of acuity assignment.

Database entries were checked for accuracy (Stephen Villa) by reviewing charts of patients who had missing timestamps, unusually long intervals and negative time intervals. Because triage may occur before registration is completed, patients whose triage times were within 1 h of arrival (before or after) were retained; longer intervals were considered erroneous and those patients excluded from the analysis.

Outcomes

The primary outcomes were the difference in triage interval and percentage of high acuity patients (levels 1 and 2) completing triage within 15 min of arrival before-and-after the intervention. While the ESI does not recommend specific timeframes for triage, the US National Hospital Ambulatory Medical Care Survey (NHAMCS) recommends the following for time from arrival to provider: 'immediate', 'emergent' (<15 min), 'urgent' (15 min–1 h), 'semi-urgent' (1–2 h) and 'non-urgent' (2–24 h). Based on description of acuities in ESI, we defined 'immediate' as Level 1 and 'emergent' as ESI 2 [1].

Secondary outcomes explored potential negative impacts on quality of care. We compared the monthly percentage of 72-h returns with the ED, defined as the total number of visits by the same person within 72 h of their index visit, divided by the number of all ED encounters that month. We also compared median time to electrocardiogram (ECG) acquisition and the door-to-balloon time for ST-elevation myocardial infarction (STEMI) patients before and after the intervention.

To determine if the use of a new EHR itself could have explained any improvement in triage flow, we measured total length of stay

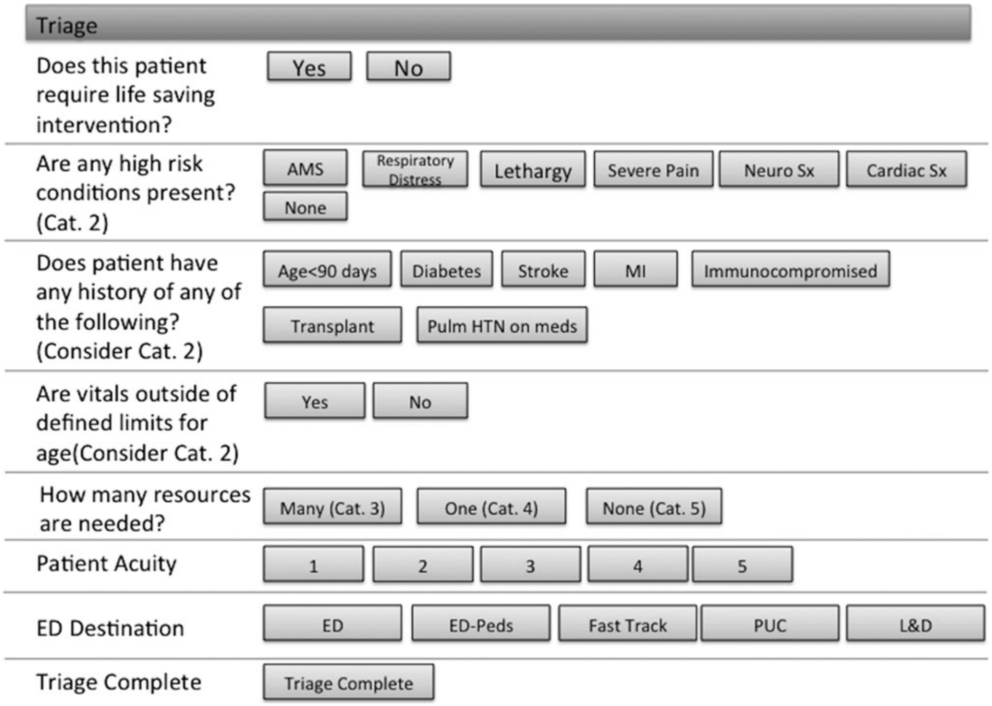

Figure 1 Triage Algorithm in HER. © 2015 Epic Systems Corporation. Used with permission.

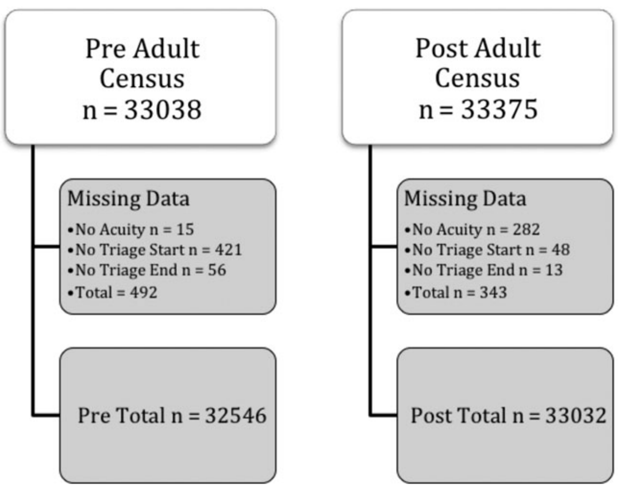

Figure 2 Flow diagram of Included patients.

(LOS) in the two periods. ED-LOS was defined as the difference between 'Arrival' time and 'ED Departure' time. LOS was determined for all patients and for those who were discharged directly from the ED, as LOS for admissions is subject to bed availability in the hospital.

Statistical Methods

For triage interval, we compared median and interquartile ranges (IQR) for patients in the two time periods using the Mann–Whitney U method. These comparisons were also stratified by high vs low acuity (1–2 vs 3–5), mode of arrival and whether patients arrived when one or two nurses were scheduled at triage.

A generalized estimating equation (GEE) was used to assess the relationship between the triage interval, a normally distributed outcome and the intervention, while accounting for multiple encounters among patients and patients who were seen by the same nurse. A time-series GEE model examined the relationship of the new algorithm with triage interval immediately after implementation. The GEE models controlled for potential confounders: age linearly, sex, race, ethnicity, arrival method, number of nurses present at triage and nursing triage experience. Nurses were considered more experienced if they had more than 50 triage encounters during the entire study period. Comparisons were made for the periods before and after the intervention, and an interrupted time series using monthly data was plotted.

We created a histogram of arrival to triage times, using 5 min intervals, showing the number of high acuity patients completing triage within 15 min of arrival in each time period.

For secondary outcomes, a chi-square test was used to compare differences in 72-h returns. Time to ECG acquisition for STEMI patients was treated as a continuous variable and compared using Mann–Whitney U test. Median ED-LOS was compared using the Mann–Whitney *U* method.

Sample size was determined by the number of visits. We chose a full year in each period to account for seasonal variation and the learning curve for implementation of the new EHR. Due to the large sample size, many comparisons are statistically, but not clinically significant. Statistical analyses used SAS version 9.3 (SAS Institute, Cary, NC). All statistical tests provided two-sided *P*-values (*P*); values <0.05 were considered statistically significant.

Sensitivity Analysis

We set a priori limits on what were reasonable triage timestamps; for instances where it was clear that the time was impossible (e.g. if arrival,

Table 1 System and subject characteristics

	Pre-intervention	Post-intervention
Study population	32 546	33 032
Age (mean ± SD)[a]	49.3 (±20.06)	50.45 (±20)
Female (%)	53.4	52.7
Race		
White (%)	48.8	48.8
Black (%)	16.1	15.4
Asian (%)	17.8	18.7
Other (%)	15.0	15.2
Unknown (%)	2.3	1.9
Ethnicity		
Hispanic (%)	10.1	10.7
Non-Hispanic (%)	86.4	86.5
Unknown (%)	3.5	2.7
Arrival method		
Ambulatory (%)	75.7	75.2
Ambulance (%)	20.6	23.9
Unknown (%)	3.7	0.9
ED-LOS[b]		
All patients		
Median (IQR), min*	309 (195–451)	317 (198–469)
95% Percentile, min	756	796
Discharged patients only**		
Median (IQR), min*	265 (172–381)	259 (168–379)
95% Percentile, min	596	588
Percentage admitted to hospital (%)	25.6	27.5
ESI acuity distribution		
High acuity* (ESI 1–2), %	14.4	16.7
Low acuity* (ESI 3–5), %	85.6	83.3

[a]Excluded patients without recorded age. Pre-intervention: 72 encounter post-intervention: 15 encounters.

[b]Excluded patients without either arrival or disposition time. Pre-intervention: 1138 encounter post-intervention: 0 encounters.

**P*-value <0.001 when comparing two groups; **pre-intervention: 21 374 encounters post-intervention: 22 645 encounters.

triage start, or triage end was after the ED departure time or if the patient had triage start >1 h before they arrived) we set that time to unknown. We then analyzed the triage intervals using different assumptions: (1) questionable triage intervals set to zero, (2) questionable triage intervals set to unknown (therefore excluded) or (3) questionable interval set to a clinically appropriate number: e.g. where patient was immediately roomed (before triage was complete), setting the triage interval to the time between triage start and room time. As results were minimally changed by the different assumptions (maximum discrepancy of 0.25 min for triage interval in either study group), we chose to report results with the assumption that led to the most conservative (null) impact of the intervention (analyses available on request).

Results

There were 33 038 adult encounters prior to, and 33 375 after the invention. About 492 subjects from the pre-intervention phase were excluded: 15 had no acuity assigned, 421 had no triage start timestamp and 56 had no triage end (or acuity) timestamp or an inaccurate timestamp (Fig. 2). In the post-intervention phase, 343 patients were excluded: 282 did not have acuity assigned, 48 had no triage start and 13 had no acuity or triage end timestamp. This left 32 546 encounters before the intervention and 33 032 encounters after the intervention for analysis.

Sex, race, ethnicity and mode of arrival were similar between the study periods, although there were more encounters with 'unknown' mode of arrival before the intervention (Table 1). The post-intervention population was slightly older. Total ED census and the percentage of patients admitted was similar in the two periods.

Primary outcomes

Median triage interval for all patients was 5.9 min (IQR 4.2–8.73) before and 2.8 min (IQR 1.88–4.23) after the intervention (Table 2). Adjusting for confounders, the mean triage interval was 5.9 min (95% CI 4.1, 7.8) before and 2.5 min (95% CI 0.7, 4.4) after the intervention; adjusted mean difference −3.4 min (95% CI −3.6, −3.2). Higher acuity patients benefited more than the population as a whole with a decrease of −4.3 min (95% CI −4.9, −3.7). The improvement in triage interval was greater for periods when only one nurse was present at triage and for patients arriving by ambulance.

The time series demonstrates the intervention caused an immediate, large and significant decrease in the triage interval of 1.3 min (95% CI 0.9–1.7) (Fig. 3). The triage interval declined a further 0.6 min between the first and last 6 months of the post-implementation period.

The percentage of high acuity patients completing triage within the recommended time frame increased from 63.9% (95% CI 62.5, 65.2) to 75% (95% CI 73.8, 76.1) (Fig. 4).

Secondary outcomes

Impact on Quality

Unscheduled returns within 72 h made up 5.4% (95% CI 5.1, 5.6) of all visits before the intervention and 4.9% (95% CI 4.7, 5.2) after the intervention. Over the 2-year study period, 53 patients had an angiographically proven STEMI, 27 before the intervention and 26 after. Median time to ECG for STEMI patients was 2 min before the intervention and 4.5 min after the intervention (P = 0.06). All STEMI patients after the intervention had door-to-balloon times <90 min.

Compared with the pre-intervention period, post-intervention ED-LOS for all patients was slightly longer, but post-intervention LOS was slightly shorter for patients discharged from the ED (Table 1).

Limitations

The study was conducted in a single institution. As a before-and-after study design, results could be confounded by other changes that occurred in the ED simultaneously. We controlled for confounders we could measure and found very little difference between adjusted and unadjusted rates.

The most obvious difference between the two periods is the use of a new EHR, which in itself could have contributed to any improvements (or poorer performance) seen. Because the introduction of a new EHR requires major adjustments in workflow and new training, however, it was the ideal time to introduce this change in triage. We did not anticipate that a shorter triage interval would have much impact on the entire ED-LOS but analyzed this outcome to see if the new EHR had led to clinically important improvements in flow. Prior studies have generally found a new EHR lengthens time in the ED [5, 6]. In our case, we found LOS was affected by <10 min. The ED was familiar with electronic charting and tracking, thus a new hospital-wide EHR was unlikely to have a large effect at

Table 2 Triage Interval: unadjusted

	Pre-intervention	Post-intervention	*P*-value
	All patients (*n* = 3 2546)	All patients (*n* = 3 3033)	
Median (IQR), min	5.9 (4.2–8.7)	2.8 (1.9–4.2)	<0.001
95th percentile, min	20.6	8.4	
	High acuity (*n* = 4700)	High acuity (*n* = 5522)	
Median (IQR), min	6.8 (4.78–10.16)	2.9 (1.9–4.6)	<0.001
95th percentile, min	22.0	10.3	
	Low acuity (*n* = 27 846)	Low acuity (*n* = 27 511)	
Median (IQR), min	5.8 (4.1–8.5)	2.7 (1.9–4.1)	<0.001
95th percentile, min	20.2	8.2	
	Ambulatory (*n* = 2 4630)	Ambulatory (*n* = 2 4842)	
Median (IQR), min	6.0 (4.2–8.9)	3 (2.0–4.5)	<0.001
95th percentile, min	20.7	8.8	
	Ambulance (*n* = 6712)	Ambulance (*n* = 7890)	
Median (IQR), min	5.9 (4.3–8.5)	2.3 (1.6–3.3)	<0.001
95th percentile, min	20.8	6.8	
	Unknown (*n* = 1204)	Unknown (*n* = 300)	
Median (IQR), min	5.0 (3.5–7.4)	2.5 (1.6–3.9)	<0.001
95th percentile, min	17.4	7.0	
	Two nurses present[a] (*n* = 22 471)	Two nurses present (*n* = 22 500)	
Median (IQR), min	6.0 (4.2–8.9)	2.9 (1.9–4.4)	<0.001
95th percentile, min	21.0	9.0	
	One nurse present (*n* = 10 075)	One nurse present (*n* = 10 532)	
Median (IQR), min	5.8 (4.2–8.5)	2.6 (1.8–3.9)	<0.001
95th percentile, min	20.0	7.4	

[a]Defined as the time when two nurses were present at triage 11AM–11PM.

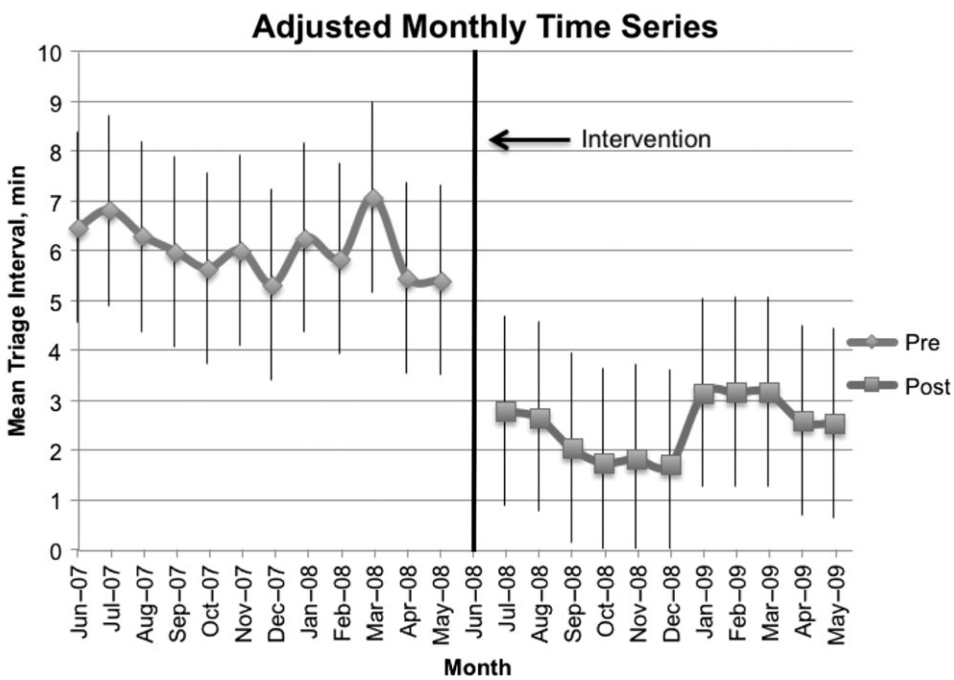

Figure 3 Adjusted monthly time series. Error bars are 95% confidence intervals.

triage. This is further illustrated by our time series, which did not demonstrate the learning curve typically seen in implementations of an EHR or other new procedures [7, 8].

We were also limited in the type of data we could collect to assess changes in quality of care. Events that are tracked for quality reporting purposes, such as ST-elevation MI's, are infrequent. We had planned to compare adverse medication reactions, but these were rarely reported in either phase.

Some data were missing and other data seemed erroneous. The types of missing data differed between systems due to differences in

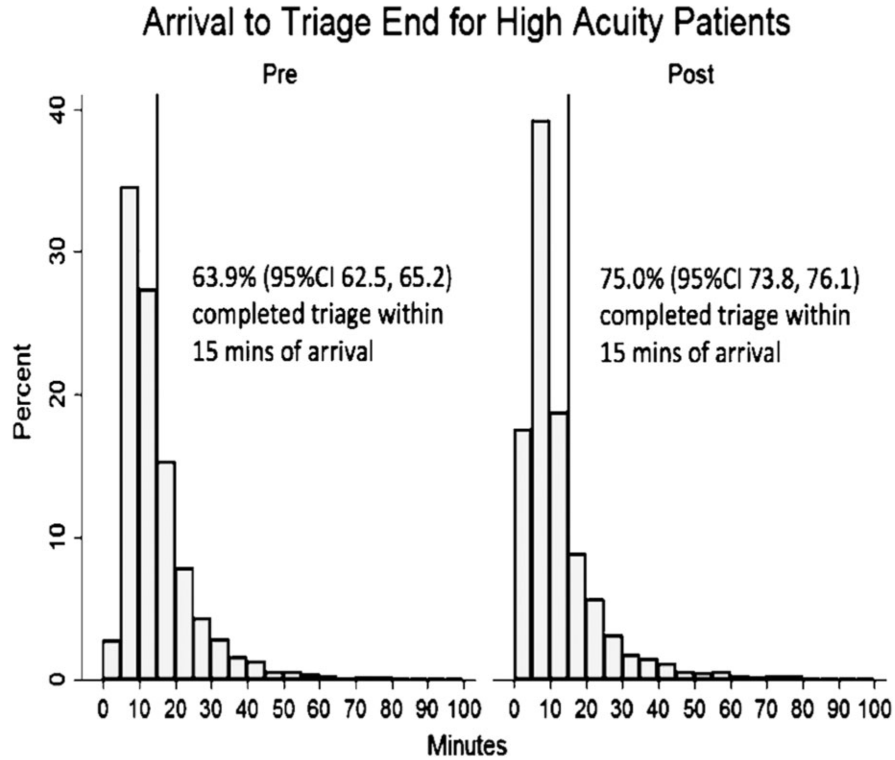

Figure 4 Percentage of patients completing triage within 15 min.

their capabilities. The local EHR required the triage nurse to click a button to start triage (so many of these timestamps were missing) but the triage nurse could complete triage documentation after the patient was moved to a room (hence more acuities recorded). For the new EHR, nurses in the rooms were expected to add the acuity and end triage. Relative to our sample sizes, the amount of missing data was quite small and conducted sensitivity analyses with varying assumptions, reporting results that most bias the study toward the null.

Finally, we cannot rule out a Hawthorne effect as a result of a greater emphasis on quick triage. However, given that the improvement was sustained for a long period of time, we believe the tool itself was the major contributor to the outcome.

Discussion

A computerized version of the ESI algorithm decreased the time for triage an average of 3.4 min and created an 11% absolute improvement in the percentage of high acuity patients triaged within 15 min at our ED. Based on the number of high acuity patients in the pre-intervention period, an additional 520 patients would have been triaged within the recommended time frame had the intervention been in place. Because our intervention was embedded in an enterprise-wide EHR, the observed differences were enduring and should be maintained moving forward.

Weber *et al.* [2] previously demonstrated a need for improving the speed of triage in high acuity (ESI 1–2) patients presenting to this same institution in 2009. We found that only 63% of patients met guidelines two years later. The prior study only looked at high acuity ambulatory patients, but we collected data on all patients as the intervention could potentially benefit higher acuity patients, but negatively impact lower acuity patients. The decrease in triage time was seen for all acuities and arrival methods.

We found no evidence of poorer quality of care as shown by the lack of any increase in 72 h returns. Median time for ECG's for STEMI patients went up, although door-to-balloon time remained excellent. Nurses do many of our ECG's at triage, but its possible that with faster recognition, they moved patients more quickly to a resuscitation room and the ECG was done there, adding some time, but still within the 10 min guideline.

Traditionally, triage is done by collecting a basic set of data from the patient, then picking a triage category based on knowledge of the triage system in use. This is inefficient, in that more information may be gathered than is necessary to make an acuity decision. By focusing the EHR's triage module solely on the priority for treatment, data collected, and thus time to treatment, can be reduced. We believe the triage interval decreased primarily because the intervention focused nurses only on the questions asked by the ESI, and allowed them to stop triage when the appropriate acuity was reached.

Additionally, the use of an algorithm can prevent the use of triage to capture items for administrative or health maintenance purposes. Castner conducted a survey of triage nurses and found that they estimated triage took on average 9 min to complete [9]. In addition to recording vital signs, allergies, pain score, medical history, most nurses were expected to record last menstrual period, surgical history, medication history, immunization status and maltreatment screen, none of which are needed for the ESI. Given that there are many periods of waiting once a patient is in the ED, it is not necessary to collect this information at triage.

In addition to improving throughput, the use of computer systems can improve inter-rater reliability when compared with memory based triage methods [10]. This is particularly important for developing countries that are developing emergency medicine programs and facing a lack of skilled health care professionals and limited training opportunities. An algorithm-based triage system would be easier to adopt with greater consistency in performance [11].

In the USA, the percentage of patients seen by a provider within the recommended time has decreased each year from 1997 to 2006, and by 2006, less than half of emergent patients were seen within the recommended time [1]. Our triage system resulted in 75% of the highest acuity patients being seen in the appropriate time frame. However, 25% of high acuity patients were not triaged soon enough. It is possible, that with increasing age and complexity of patients, EDs will need to consider a form of triage that will quickly identify the highest acuity patients, while all others are seen in order of arrival, as has been done in the UK [12].

Collecting less information at triage may risk missing important information if it is not collected later. However, delaying evaluation of high acuity patients due to lengthy triage of other patients is also risky. The correct balance will need to be assessed further with multi-center studies that can provide more information on safety. The EHR at our site is used at many hospitals nationally, allowing for future opportunities to study the impact of this digital version of the ESI on a larger scale.

Acknowledgements

The authors would like to thank Craig San Luis, UCSF, the CTSI Unit at UCSF, and the Quality Improvement department at UCSF for assistance with obtaining data, and Dr Ann Lazar for statistical assistance.

Funding

Presentation of this work was made possible by R25MD006832 from the National Institute on Minority Health and Health Disparities. The views expressed do not necessarily reflect the official policies of the DHHS.

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Conflicts of interests statement

The authors have no financial conflict of interests to report. The vendor of the EHR was not involved in the planning, execution, analysis or write up of the study. However, they granted permission for use of the screenshot in Fig. 1.

Author's contribution

S.V. contributed to conceptualization of the study; performed data collection, data cleaning, data analysis and data interpretation; wrote first draft of manuscript and participated in revision and editing. S.P. was involved in data interpretation, editing of manuscript, study supervision. C.F. was involved with data interpretation, editing of manuscript, study supervision. A.M. Designed and programmed the algorithm. T.Q. trained nurses on new triage algorithm, assisted with algorithm design E.J.W. conceived study, study supervisor, data analysis, data interpretation, revision and editing of manuscript. S.V. takes responsibility for the paper as a whole.

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