HOSTED BY
ELSEVIER
Contents lists available at ScienceDirect
Journal of Acute Disease
journal homepage: www.jadweb.org

Document heading doi: 10.1016/S2221-6189(14)60079-2

The effect of an emergency department clinical "triggers" program based on abnormal vital signs

Jason Imperato[1, 2*], Louisa Canham[1, 3], Tyler Mehegan[2], John D. Patrick[1, 2], Gary S. Setnik[1, 2], Leon D. Sanchez[1, 3]

[1]*Department of Emergency Medicine, Harvard Medical School, Boston, MA, USA*
[2]*Mount Auburn Hospital, Department of Emergency Medicine, Cambridge, MA, USA*
[3]*Beth Israel Deaconess Medical Center, Department of Emergency Medicine, Boston, MA, USA*

ARTICLE INFO

Article history:
Received 15 January 2015
Received in revised form 17 January 2015
Accepted 23 January 2015
Available online 26 January 2015

Keywords:
Clinical triggers
Abnormal vital signs
Rapid response team

ABSTRACT

Objective: To determine the effect of a clinical triggers program in the Emergency Department (ED) setting that utilized predetermined abnormal vital signs to activate a rapid assessment by an emergency physician led multidisciplinary team. **Methods:** A retrospective, separate sample, pre-post intervention study following implementation of an ED triggers program. Abnormal vital sign criteria that warranted a trigger response included: heart rate <40 or >130 beats/min, respiratory rate <8 or >30 respirations/min, systolic blood pressure <90 mm Hg, or oxygen saturation <90% on room air. The primary outcome investigated was time to physician evaluation with secondary outcomes being the time to disposition decision and time to first critical therapeutic intervention. **Results:** The median time to physician evaluation was reduced by 25% from 28 min to 21 min (P<0.05). The median time to disposition decision was decreased by 12% from 154 minutes to 135 minutes (P<0.05). The median time to first intervention was 46 min and 43 min (P=0.33) in the before and after groups, which did not represent a statistically significant difference. **Conclusions:** In our model, the implementation of an ED triggers program resulted in a modest decreased time to physician evaluation and disposition decision but not time to intervention.

1. Introduction

Triage is the initial assessment and sorting of patients, and is used to determine clinical priority and appropriate area for treatment. Over the years, a number of Emergency Department (ED) triage scales have been created, revised, implemented and studied in attempts to ensure the accuracy of triage categorization[1-7]. While vital signs are often included in triage assessments, they are not the main decision point in most triage systems.

Because abnormal vital signs frequently indicate the potential for clinical deterioration, it is logical to make emergency physicians aware of those patients who present with or develop abnormal vital signs as soon as possible. This notification should allow for a rapid patient assessment to determine if immediate actions or interventions are indicated in order to improve patient outcome.

In a study conducted at an academic teaching Emergency Department, a 15-day clinical triggers pilot based on abnormal vital signs successfully demonstrated a reduction in time to provider evaluation, first therapeutic intervention and antibiotics[8]. However, it did not show a reduction in time to disposition decision. Because of the limited time frame and sample size in this prior study we attempted to replicate the system they described[8] in an external validation study with nearly four times the number of patients meeting inclusion criteria.

In our study we evaluated the effect of a clinical triggers program that utilized predetermined abnormal vital signs or marked nursing concern to prompt a physician led multidisciplinary team to converge on the bedside of potentially sick patients. We sought to determine the benefit of the triggers program by evaluating the program's effect on

*Corresponding author: Jason Imperato, M.D., M.B.A., Mount Auburn Hospital, Department of Emergency Medicine, 330 Mount Auburn Street, Cambridge, MA 02138, USA.
Tel: 617-499-5617
Fax: 617-864-0085
E-mail: jimperat@mah.harvard.edu

timeliness of physician evaluation, first critical therapeutic interventions and disposition.

2. Materials and methods

2.1. Study design

We conducted a retrospective, separate sample, pre-post intervention study following implementation of an ED triggers program. We analyzed separate samples of those patients who met the predetermined ED trigger criteria 90 days before and after the program intervention. The hospital institutional review board approved the study design.

The study population was all patients aged 18 and above presenting to the Emergency Department from April 10, 2012 to October 7, 2012. The "trigger patients" where those who met any one of the predetermined ED trigger vital sign parameters: 1. Heart rate of <40 or >130 beats/min; 2. Respiratory rate of <8 or >30 respirations/min; 3. Systolic blood pressure of <90 mm Hg; 4. Oxygen saturation of <90 % on room air.

On July 10, 2012 we implemented the ED triggers program. If any patient met the specified vital sign criteria at initial nursing triage a trigger alert occurred. In this process, the nurse placed an overhead page stating "Trigger patient to room X" with the expectation that the ED attending physician, ED resident, ED nurse, and ED technician would report to the specified location immediately. During times of double coverage one ED attending physician was assigned to be the responsible provider for trigger patients based on time of day along with the most senior emergency medicine resident on shift.

To ensure compliance, we modified the nursing portion of our proprietary electronic documentation system so that any vital sign entered that met trigger criteria generated a pop up dialog window notifying the nurse that the patient required a trigger alert. The nurse had to acknowledge the abnormal vital sign as a trigger before they would be able to move on to further electronic documentation.

In the post-intervention time period we also encouraged the nurse to call a trigger alert if they had a "marked nursing concern", defined as a patient who despite not meeting trigger vital sign criteria but appeared sufficiently ill to warrant immediate physician evaluation. These patients were treated with the same response as those who met the abnormal vital sign criteria, but this subset of patients were not included as trigger patients in the data analysis of this study.

All patients were included in the data analysis, even if they skipped the standard triage process, if they had initial vital signs that met the predetermined trigger criteria. Similarly, patients arriving by ambulance were included if they met the predetermined trigger vital sign criteria.

2.2. Study setting

Our facility is a 200-bed community teaching hospital with an ED volume of 37 000 adult and pediatric patients per year. Board-certified emergency medicine physicians and emergency medicine residents from two affiliated residency programs primarily staff our ED. One of the two groups of residents was already familiar with a triggers program since they utilized a similar program at their sponsoring institution. Both physicians and nurses utilize the same proprietary electronic documentation program to document patient encounters. Because there is no computerized physician order entry (CPOE) available, orders for medications are hand written on a physician order sheet. These are dated, timed and signed at time of order writing and similarly dated, timed and signed by the nurse when the medications are administered.

Patients who require admission to the hospital can be admitted to one of several locations depending on the severity of illness. These include: intensive care unit (ICU)-both medical and surgical, ward-telemetry with and without continuous oxygen saturation monitoring capability, medical or surgical wards, or a step down unit (SDU)-an intermediate between the ICU and ward with enhanced nursing capabilities not available on the regular floors.

2.3. Measurements

We performed a structured chart review on all adult patients who presented to the ED in the 90 days before and after the ED triggers intervention. Vital signs for each of these patients were extracted using our proprietary electronic documentation and tracking system. We extracted time data on all patients aged 18 and older who met trigger criteria from time stamps from the electronic tracking system to determine time to provider-defined as the time from patient registration to the first provider entry (attending or resident physician) in the EMR, approximating the actual time at the bedside. We used the same electronic tracking system to record time stamps for time to disposition decision-defined as the time from registration to printing of discharge instructions, transfer orders, or admission orders for patients who were discharged, transferred, or admitted respectively.

If a patient met any of the abnormal vital sign criteria a single trained data abstractor performed a full structured chart review to determine the number and times to intervention. We recorded all interventions performed within or ordered while in the ED. The interventions were defined as any documented, targeted, therapeutic intervention and then categorized into the following subgroups: vasoactive agents, cardiac (including medications or cardioversion), pulmonary (including medications or intubation), antibiotics, analgesics, antiemetics, antipyretics, or mood stabilizer. A categorization of the first and total interventions that

occurred in the Emergency Department is depicted in Table 1. Similar to the prior study[8], we chose not to include interventions or testing that are typical nursing interventions without specific direction such as intravenous access, intravenous fluid administration, oxygen administration, electrocardiogram, and basic laboratory or plain film testing.

Table 1
First and total interventions [*n* (%)].

Categorization	First intervention		Total interventions	
	Pre-trigger (*N*=334)	Post-trigger (*N*=246)	Pre-trigger	Post-trigger
Antibiotic	62 (19)	34 (14)	196 (19)	134 (20)
Analgesic	27 (8)	23 (9)	91 (9)	65 (9)
Antipyretic	25 (7)	18 (7)	73 (7)	51 (7)
Antiemetic	22 (7)	10 (4)	51 (5)	33 (5)
Cardiac	76 (23)	50 (20)	270 (26)	148 (22)
Pulmonary	41 (12)	28 (11)	124 (12)	77 (11)
Mood Stabilizer	9 (3)	10 (4)	32 (3)	27 (4)
Vasopressor	1 (0)	1 (0)	10 (1)	5 (1)
Other	22 (7)	20 (8)	141 (14)	96 (14)
None	49 (15)	52 (21)	49 (5)	52 (8)

Both the time of physician order and time of nursing administration were recorded from the hard copy of physician order sheet of the medical record. We defined the time to intervention as the time from registration to the earliest time entry of either the physician order or documented nursing intervention.

The primary outcome investigated was the time to physician evaluation defined as the time from patient registration to the first recorded physician encounter. Secondary outcomes included the number and time to the first critical therapeutic intervention, and time to disposition decision.

2.4. Data analysis

Median times were compared between the pre-trigger and post-trigger groups (reported in minutes with interquartile range [IQR] 25-75), with the Wilcoxon rank sum test used to determine statistical significance, with *P*-values reported where appropriate with an alpha set at 0.05 as being significant. 95% confidence intervals were calculated for the values obtained. Microsoft Excel (Microsoft Corp., Redmond, WA) and JMP (SAS Institute Inc., NC) were used for data analysis.

3. Results

The study population was all patients' aged 18 or older presenting to the Emergency Department from April 10, 2012 to October 7, 2012. Table 2 reflects the study characteristics of the total patient population. In the 90 days prior to the ED triggers program we evaluated a total of 9486 patients. We excluded the 555 pediatric patients (age <18 years) and the 161 patients who left without being seen during that time period. A total of 8770 eligible patients were therefore included in the pre-intervention study arm. In the 90 days after the ED triggers program we evaluated a total of 9336 patients. After excluding the 495 pediatric patients and the 182 patients that left without being seen we were left with 8659 eligible patients in the post-intervention study arm. Based on the predefined abnormal vital sign trigger criteria, there were 334 patients (3.8%) who met inclusion in the pre-triggers group and 246 patients (2.8%) in the post-triggers group, which did represent a statistically significant difference ($P<0.005$). The mean age of patients in the pre-triggers group was 66 of which 55.4% were female. The mean age of patients in the post-triggers group was 64 of which 48.4% were female.

Table 2
Characteristics of study subjects.

Study subjects	Pre-trigger	Post-trigger	*P*-value
Total patient encounters	9486	9336	
Pediatric patients (age<18)-excluded	555 (5.9)	495 (5.3)	0.108
Left without being seen-excluded	161 (1.7)	182 (1.9)	0.215
Total patients meeting trigger criteria	334 (3.8)	246 (2.8)	0.0005*

Values reported as *n* (%) (unless otherwise specified).
*: Statistically significant ($P<0.05$).

The characteristics of both groups including Emergency Severity Index (ESI) comparison, trigger criteria met and disposition location are shown in Table 3. There was a difference in the proportion of patients who were classified as ESI 2 and ESI 3 between the two groups ($P<0.05$).

Table 3
Patient variables.

Variables	Pre-trigger [% (95% *CI*)]	Post-trigger [% (95% *CI*)]	*P*-value
ESI comparison			
1	2.7 (1.0-4.4)	5.3 (2.5-8.1)	0.125
2	60.2 (55.0-65.5)	73.2 (67.8-78.7)	0.0014*
3	36.8 (31.6-42.0)	20.3 (15.3-25.3)	0.0001*
4	0.3 (0.0-0.9)	1.2 (0.0-2.6)	0.317
5	0.0 (0.0-0.0)	0.0 (0.0-0.0)	1.000
Trigger criteria met			
HR<40	1.6 (0.3-3.0)	2.5 (0.6-4.5)	0.410
HR>130	29.5 (24.6-34.4)	33.8 (27.9-39.7)	0.255
SBP<90	21.6 (17.2-26.0)	24.1 (18.8-29.4)	0.501
RR<8	0.8 (0.0-1.8)	0.0 (0.0-0.0)	0.266
RR>30	20.3 (16.0-24.6)	15.5 (11.0-20.0)	0.120
O_2 Sat<90%	26.3 (21.6-31.0)	24.1 (18.8-29.4)	0.516
Disposition			
ICU	14.1 (10.4-17.8)	17.5 (12.8-22.3)	0.297
SDU	20.4 (16.8-24.7)	24.0 (18.7-29.3)	0.311
Ward	43.7 (38.4-49.0)	40.2 (34.1-46.3)	0.129
Discharge	19.2 (15.0-23.4)	15.9 (11.3-20.5)	0.324
Transfer	2.7 (1.0-4.4)	2.4 (0.5-4.3)	1.000

Patients may have met more than one trigger criteria. HR: Heart rate; SBP: Systolic blood pressure; RR: Respiratory rate; O_2 Sat: Oxygen saturation. *: Statistically significant ($P<0.05$).

The admission rate for trigger patients was 78.8% in the pre-intervention group and 81.7% in the post-intervention group, while the total admission rate for all patients during the same time periods was 27.5% and 26.5% respectively. The rate of admission to a unit (ICU or SDU) for trigger

patients was 34.5% in the pre-intervention group and 41.5% in the post-intervention group. During the same time periods the overall admission rate to a unit for all patients was 3.8% and 3.7% respectively.

The measured outcomes are shown in Table 4. For patients who met trigger criteria the median time to physician evaluation was reduced by 25% from 28 min (IQR=11-50 min) in the pre-triggers group to 21 min (IQR=10-40 min) in the post-triggers group (P<0.05). The median time to physician evaluation for all patients was reduced by 16% from 61 min (IQR=29-80 min) to 51 min (IQR=28-84 min) in the same groups (P=0.48). For patients who met trigger criteria the median time to disposition decision was decreased by 12% from 154 min (IQR=107-225 min) in the pre-triggers group to 135 min (IQR=91-219 min) in the post-triggers group (P<0.05). The median time to disposition decision for all patients increased by 3% from 155 min (IQR=98-241 min) to 160 min (IQR=104-243) in the same groups (P=0.096). The median time to first intervention was 46 min and 43 min in the same groups, which did not represent a statistically significant difference (P=0.33).

Table 4
Median times pre-trigger versus post-trigger (min).

Time	Pre-trigger	Post-trigger	% Change	P-value
Physician evaluation -trigger patients	28 (11-50)	21 (10-40)	-25%	0.0066*
Physician evaluation -all patients	61 (29-80)	51 (28-84)	-16%	0.480
First intervention - trigger patients	46 (19-102)	43 (17-92)	-7%	0.330
Disposition decision -trigger patients	154 (107-225)	135 (91-219)	-12%	0.044*
Disposition decision -all patients	155 (98-241)	160 (104-243)	+3%	0.096

*: Statistically significant (P< 0.05).

4. Discussion

Because abnormal vital signs frequently indicate the potential for clinical deterioration, it is logical to make emergency physicians aware of those patients who present with or develop abnormal vital signs as soon as possible. McGillicuddy *et al.*[8] showed a reduction in time to physician evaluation, first intervention and first antibiotic but no change in time to disposition decision utilizing an adopted clinical triggers model based on abnormal vital signs.

We attempted to replicate the system described in this investigation[8] in an external validation study with nearly four times the number of patients meeting inclusion criteria. Like the prior study, we demonstrated that the implementation of a clinical triggers system, coupled with an overhead alert, followed by the expectation of immediate provider team evaluation, decreased the time to physician evaluation by 25%. We also observed a reduction in time to physician evaluation for all patients during the same time period.

Unlike the prior study, however, we were able to reduce the time to disposition decision by 12% facilitating an earlier transition of care from the ED to the inpatient services. This was despite a slight increase in time to disposition decision for all patients.

However, although a slight reduction was observed, we were unable to show a statistically significant reduction in the time to first critical intervention-46 min to 43 min. This difference could be the result of the fact that the time stamps used for time to physician evaluation and time to disposition decision were recorded using electronic time stamps while times to intervention were extracted from hand written physician order sheets.

Emergency Departments around the country struggle to meet time expectations for time to physician evaluation and length of stay particularly on patients with the highest acuity levels[9]. Alerting physicians of potentially unwell patients based on abnormal vital signs at the earliest possible time should improve not only time to physician evaluation and perhaps patient outcome-an area that requires further investigation.

This study is subject to the limitations associated with any retrospective design including incomplete data and inability to control for confounders. Because we reviewed data for all patients who presented during the study time period and did an intensive chart review on all patients who met abnormal vital sign criteria we believe we included all patients that were eligible for inclusion.

This type of study does not have the ability to control for the Hawthorne effect. However, our providers were only aware that the triggers program was a quality improvement project and was not a research study. Therefore, we don't believe this had a major impact on the study results.

We included patients who met trigger vital sign criteria both before and after the intervention. It is possible that patients met abnormal vital sign criteria and the nurse did not activate the trigger response. We attempted to limit this effect by having an automatic notification to the nurse in the computerized charting system when an abnormal vital sign was present. In order to ensure compliance, the nurse had to acknowledge the abnormal vital sign as a trigger before they could complete further electronic documentation on that patient. We did not, however, has a mechanism to track whether a trigger was actually called by the nurse.

Another potential limitation of this study is that the documented times may not accurately reflect the actual timing of a given interaction or intervention. For example,

we recorded the time that a physician signed into the patient chart as the surrogate for time to physician evaluation. In the setting of an identified potentially ill patient, it seems logical that most physicians would first evaluate the patient and initiate treatment and then start documenting afterwards. Therefore the time to physician evaluation recorded likely reflects a longer time than actually occurred in the clinical setting. However, this practice was unlikely to change before and after the intervention and because we utilized time stamps from our electronic documentation and tracking system for both arms of the study the differences in the times studied most likely reflect an accurate assessment of improvement after the triggers program was started. Our EMR does permit editing of this parameter and our providers are encouraged in these circumstances to estimate their actual time at the bedside.

Similarly, there are likely to be differences between the documentation of a critical intervention and the time it was actually performed in practice. Because we assume no change in practice habits of the nurses before and after the trigger intervention it is likely that the differences in time to intervention accurately reflect actual change.

There was a notable difference between the patient populations in the pre-intervention group versus the post-intervention group. Trigger activation was less frequent in the post-intervention group (2.8%) as compared to the pre-intervention group (3.8%). There was also a higher rate of admission to the hospital (78.8% versus 81.7%) as well as admission frequency to an intensive care unit (34.5% versus 41.5%) in the post-intervention group. This correlates with a higher percentage of patients categorized as either ESI 1 or 2 in the post-intervention group (62.9% versus 78.5%). The trend towards a higher ESI level may simply reflect a higher overall acuity in the post-intervention group. However, this could also reflect nursing triaging at a higher level when prompted to recognize the abnormal trigger vital signs. The trigger may have improved physician's recognition of potentially ill patients as well, which may reflect the higher rate of overall admissions and intensive care admissions. However, this also may reflect a trend towards overutilization of intensive care services.

Another possible limitation of the study is we did not allow for a break-in period for implementing the new system nor did we control for confounding due to other processes in the department. During this time period, there were not other significant operational changes that occurred and the staffing levels of providers remained the same before and after the intervention. However, we did observe a trend towards decreased time to physician evaluation for all patients in the post-trigger time period.

In summary, implementation of an Emergency Department triggers program based on abnormal vital sign criteria was modestly effective in reducing time to physician evaluation and time to disposition decision. However, it was ineffective in reducing the time to first critical intervention. The system does not require a significant increase in resources and makes intuitive sense in an attempt to identify and treat patients in a timelier manner. However, the results remain mixed and as a consequence require further study, including potential effects on clinical outcomes, before recommending as a worthy intervention.

Conflict of interest statement

The authors report no conflict of interest.

References

[1] Wuerz RC, Milne LW, Eitel DR, Travers D, Gilboy N. Reliability and validity of a new five-level triage instrument. *Acad Emerg Med* 2000; **7**(3): 236-242.

[2] Eitel DR, Travers DA, Rosenau AM, Gilboy N, Wuerz RC. The emergency severity index triage algorithm version 2 is reliable and valid. *Acad Emerg Med* 2003; **10**(10): 1070-1080.

[3] Tanabe P, Gimbel R, Yarnold PR, Kyriacou DN, Adams JG. Reliability and validity of scores on the emergency severity index version 3. *Acad Emerg Med* 2004; **11**(1): 59-65.

[4] Fernandes CM, Tanabe P, Gilboy N, Johnson LA, McNair RS, et al. Five-level triage: a report from the ACEP/ENA Five-Level Triage Task Force. *J Emerg Nurs* 2005; **31**(1): 39-50.

[5] Murray M, Bullard M, Grafstein E; CTAS National Working Group; CEDIS National Working Group. Revisions to the Canadian Emergency Department Triage and Acuity Scale implementation guidelines. *CJEM* 2004; **6**(6): 421-427.

[6] Bullard MJ, Unger B, Spence J, Grafstein E; CTAS National Working Group. Revisions to the Canadian Emergency Department Triage and Acuity Scale (CTAS) adult guidelines. *CJEM* 2008; **10**(2): 136-151.

[7] Farrohknia N, Castren M, Ehrenberg A, Lind L, Oredsson S, Jonsson H, et al. Emergency department triage scales and their components: a systematic review of the scientific evidence. *Scand J Trauma Resusc Emerg Med* 2011; **19**: 42-55.

[8] McGillicuddy DC, O'Connell FJ, Shapiro NJ, Calder SA, Mottley LJ, Roberts JC, et al. Emergency department abnormal vital sign "triggers" program improves time to therapy. *Acad Emerg Med* 2011; **18**(5): 483-487.

[9] Horwitz LI, Green J, Bradley EH. US emergency department performance on wait time and length of visit. *Ann Emerg Med* 2010; **55**: 133-141.