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Improvement of the Trauma Care Process by Implementation of a Computerized Physician Order Entry-Based Trauma Team Approach

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Abstract

Purpose: The need for the rapid evaluation and treatment of emergency department patients with major trauma is essential. A computerized physician order entry (CPOE) system can improve communication and provide immediate access to information with the goal of reducing ED time delays. The aim of this study was to report on the operation of a trauma CPOE program and demonstrate its usefulness by comparing time intervals from ED arrival to various evaluation steps before and after implementation of the program.

Methods: This was a before-and-after observational study from a single emergency department at an academic center. The CPOE program was implemented for 6 months and compared with the data collected from the pre-CPOE implementation period. The efficacy of the program was assessed by comparing the time difference before and after CPOE implementation based on the following factors: total boarding time in ED, door-to-disposition decision time, door-to-blood-test report time, door-to-X-ray time, door-to-CT time, and door-to-transfusion time.

Results: Over a period of 6 months, the CPOE was activated for a total of 17 patients. Total boarding time was reduced significantly after implementation [median, 641.5 minutes (IQR, 367.3-859.3) versus289.0 minutes (IQR, 140.0-508.0) for pre-CPOE vs. post-CPOE, respectively, $p < 0.05$). Time intervals for all evaluation steps were reduced after implementation of the program. The improvements in the door-to-blood-test and door-to-CT times were both statistically significant.

Conclusion: This study demonstrated that a standard CPOE system can be successfully implemented and can reduce ED time delays in managing trauma patients.

Key words

Emergency department, Computerized physician order entry, Trauma

Ⅰ. Introduction

Trauma is the leading cause of death in those younger than 40 years[1] and is also the fourth leading cause of death in the Western world.[2] A systematic and team approach to the initial management of trauma patients is widely accepted as the best approach to improving trauma care.[3-5] Despite the widespread recognition of the value of trauma teams to reduce mortality, the adoption and implementation of this approach has been variable. In 2007, a report by the United Kingdom National Confidential Enquiry into Patient Outcome and Death found that trauma teams were only available in 20% of hospitals and that a trauma team response was documented for only 59.7% of patients with injury severity scores (ISS) >16.[2] Data from Australia in 2003 show that only 56% of adult trauma hospitals and 75% of tertiary pediatric hospitals which receive trauma patients provided a trauma team reception.[6,7] In Korea, trauma is the third leading cause of death,[8] and according to a report by the Korea Health Industry Development Institute in 2005, the preventable trauma mortality rate was 39.6%.[9] Many hospitals have adopted the concept of a trauma team, but there have been very limited reports on the efficiency of trauma team operations.[10,11] Previous reports have described simple trauma team systems with limited successes. The Korean system currently does not have a traumatologist or trauma surgeon specialty. Therefore, by developing trauma code systems and trauma team activities based on clinical pathways, rapid trauma care may be expedited. Timeliness is an important dimension of quality in trauma care because of its relation to outcomes for trauma patients and because of the need to optimize the flow of patients through busy emergency departments (ED).[12] However, operation of a trauma code system requires many resources, effective communication between staff and faculty members of various departments, and adequate monitoring with feedback to continually improve the system. One promising approach for an effective trauma code system is using a computerized physician order entry (CPOE). CPOE is a process that physicians use to enter medical orders electronically. These medical orders are communicated over a computer network linked to a hospital information system with physicians, nurses, technicians, and other related staff in various departments.[13] In this regard, a CPOE may improve critical care pathways for diverse emergent medical conditions. We developed a trauma code program based on a CPOE system, called Trauma care through Efficient and Accessible Modal (TEAM). This program was based on a predecessor program developed by our stroke team, called Brain salvage through Emergent Stroke Therapy.[14,15] The object of the present study was to report the organization and operation of the TEAM program and demonstrate its usefulness by comparing time intervals from ED arrival to various evaluation steps before and after implementation of the program.

II. Methods

This was a prospective, before-and-after observational study from a single emergency department in an urban, academic tertiary care center with an average of 45,000 annual visits. This hospital is located in a densely populated area of 40 km2 with an estimated population of 570,000 people (14,000/km2). During the study period, there were no closures of hospitals located in this area. In the ED, there are 30 beds (9 monitored beds), 1 triage room, 1 resuscitation room, and 1 room dedicated to procedures. The ED is staffed by 11 emergency physicians (7 residents and 4 specialists) and 29 registered nurses. There are 3 residents, 1 specialist, and 10 nurses per duty shift. In this hospital, an electronic health record (EHR) system, including the CPOE, has been implemented in the C#.NET environment and Windows XP with Microsoft Framework v. 1.1 since 2005.[16] This study was exempted from approval by the hospital Institutional Review Board.

1. TEAM program

Before the TEAM program, trauma patients were initially managed only by emergency physicians. Surgeons were involved after they had been consulted by the emergency physicians. The system operates so that the initial consultation from the emergency physician is given to the duty resident of that surgical department. The resident then examines the patient, waits for the essential diagnostic findings, and then reports to the on-call faculty. In order to get rapid results from the laboratory and radiology suites and expedite the administrative process, the emergency physician must call the technician and the registration clerk for a priority process. This results in time delays in patient care and disposition from the ED. Providing feedback on the disposition results to the consulting department was not sufficient to change the care process. Given this, faculty from the ED decided to utilize a CPOE system to improve trauma care.

The TEAM program is a CPOE-based trauma team activation/notification system that enables all steps to be carried out efficiently and online: activation, communication, notification, entering of predetermined standing order sets, providing of protocols and guidelines, and deactivation. The CPOE was also used to evaluate the program's efficacy by gathering time data for each evaluation step. The candidates for TEAM activation were identified in the triage area upon ED arrival. Patient screening was based on trauma triage criteria developed by the CPOE team. Criteria included at least one of the following: shock status or unconsciousness with a history of trauma, a significant penetrating wound, multiple injuries to more than two major anatomical areas, amputation or near amputation injury above the knee or elbow with uncontrolled bleeding, or any other injury that the emergency physician decided required immediate care. When a patient met

these criteria, an ED physician activated the TEAM program by clicking a check box on the patient's order entry window and selecting the activation icon. Immediately after TEAM activation, a two tier communication system was activated. An open announcement was made through the central broadcasting system, and then an automatic short message service was sent to the cellular phones of all on-duty surgical teams. Once the program was activated, the patient's name was highlighted in pink on the patient list. By highlighting the name, a TEAM patient could be easily recognized by all medical personnel involved in care. In addition, by entering predetermined order sets through CPOE, personnel could rapidly notify and communicate with appropriate medical staff. Administrative authorizations, which are often required prior to proceeding with tests and treatment and may potentially delay the care process, were waived until the TEAM program was deactivated. Entering medical orders for a computed tomography (CT) scan or blood tests automatically activated an alarm, such as a beeping sound, and a pop-up window on the computer screens of staff members who were responsible for fulfilling physicians' orders. These processes allowed technicians to receive orders at the same time that physicians were entering medical orders. Therefore, technicians could prepare examinations, wait for a patient or blood samples, and perform examinations without delay. The TEAM program was deactivated when the patient's disposition was finalized. On deactivation, the highlighting of the patient's name changed from pink back to the original background color, so that every team member could recognize that the patient was no longer a TEAM patient. The CPOE program team consisted of emergency physicians, general surgeons, neurosurgeons, chest surgeons, orthopedic surgeons, anesthesiologists, pediatricians for pediatric cases, and interventional radiologists. Supporting members of the team were emergency nurses, radiology technicians, clinical laboratory technicians, administrative staff, and quality improvement staff.

2. Implementation

After several meetings amongst the program and supporting team members, the TEAM program was pilot tested for 1 month prior to implementation. The pilot test revealed no technical problems. However, additional methods were required to inform and educate the staff and faculty regarding the new program. Therefore, the CPOE system was also used for the introduction of the protocol and criteria of the TEAM program. Essential portions of the protocol were incorporated into standing orders in the form of messages, and a full manual could be easily referenced at any time through the computer by clicking the guide menu bar. The goal time mark was decided by the program team. The team reviewed the flow time data of the ED from the previous two years. The data showed that disposition was decided within 120 minutes

in approximately half of the consulted patients. Therefore, 120 minutes was chosen as the time goal. However, to allow for unexpected factors, the time limit was extended to 150 minutes. A 200 minute boarding time limit in the ED was also derived from the hospital data registry. The goal of 200 minutes was the maximum boarding time allowed for efficient turnover in the ED.

3. Data analysis

After finalization of the protocol, the program was implemented for 6 months. The results were compared with the data collected from the pre-TEAM implementation period, which is the same 6 months from previous year. The efficacy of the program was assessed by comparing the time difference between before-and-after TEAM implementation for the following factors (Table 1): total boarding time in ED, door-to-disposition decision time, door-to-blood-test report time, door-to-x-ray time, door-to-CT time, and door-to-transfusion time. The data from the pre-TEAM period was collected by reviewing medical records.

Statistical analyses were performed with the Statistical Package for Social Sciences (PASW Statistics 17.0; IBM Corp., Armonk, NY, USA). Continuous variables were analyzed with the Mann-Whitney test, and categorical variables were analyzed with a χ 2-test. Continuous variables were expressed as median and inter-quartile range (IQR), while categorical variables were expressed as numbers and percentages. A value of $p < 0.05$ was considered statistically significant.

Table 1. Time interval factors

Time interval	Definition
Total boarding time	Time from ED* entry to exit (ED entry time is when the registration clerk clicks on the CPOE† for registration; ED exit time is when the charge nurse clicks on the CPOE after handover to the admitting department)
Door-to-disposition time	Time from ED entry to disposition decision (Disposition decision time is when the admitting faculty clicks on the CPOE after the decision to admit the patient)
Door-to-blood-test	Time from ED entry to blood test results for hemoglobin/hematocrit (Blood test result time is when the laboratory technician enters the results into the CPOE)
Door-to-portable-X-ray	Time from ED entry to portable X-ray for chest and pelvis (X-ray result time is when the radiology technician initiates the x-ray)

Door-to-CT[†]	Time from ED entry to whole-body CT (Whole-body CT includes the head, neck, chest, and abdomen with options for the facial and pelvic bones; CT result time is when the CT scan is initiated by the technician)
Door-to-transfusion	Time from ED entry to universal blood transfusion (Universal blood refers to O-type Rh^- blood; Transfusion time is when the nurse initiates transfusion)

[*]ED: emergency department
[†]CPOE: computerized physician order entry
[‡]CT: computed tomography

Ⅲ. Results

Over a period of 6 months, TEAM was activated for a total of 17 patients. The average age was 33.7 years old. Pedestrian injury was the most common mechanism of injury. Results for disposition of the patients were variable for the post-TEAM group, while most of the pre-TEAM group patients were admitted to the intensive care unit (Table 2).

Table 2. Patient characteristics

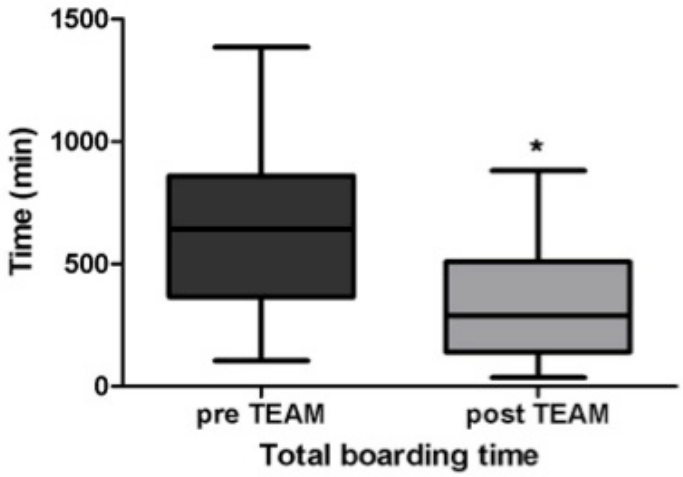
	Pre-TEAM[*] implementation, N=22	Post-TEAM implementation, N=17	*P*
Age (years)	44±14	35±22	0.098
Male sex	16 (72.7)	11 (64.7)	0.730
Type of injury			0.922
Pedestrian injury	10 (45.5)	7 (41.2)	
Passenger injury	7 (31.8)	4 (23.5)	
Fall injury	3 (13.6)	6 (35.3)	
Stab injury	1 (4.5)	–	
Slip injury	1 (4.5)	–	
Disposition			0.005
General Ward	5 (22.7)	4 (23.5)	
Intensive Care Unit	11 (50.0)	2 (11.8)	
Operating Room	6 (27.3)	2 (11.8)	
Transfer	–	4 (23.5)	
Death	–	4 (23.5)	
Discharge	–	1 (5.9)	

Notes: Data are expressed as the mean (standard deviation) or n (%).
[*]TEAM: Trauma care through Efficient and Accessible Modal.
$p<0.05$

Total boarding time was significantly reduced after TEAM implementation. The median times for pre-TEAM and post-TEAM were 641.5 (IQR 367.3-859.3) minutes and 289.0 (IQR 140.0-508.0) minutes, respectively (Figure 1). Time intervals for all evaluation steps were reduced after program initiation. The time improvement for door-to-blood-test was reduced from 56.0 (IQR 38.0-72.5) minutes to 26.5 (IQR 21.5-49.8) minutes. Door-to-CT time was reduced from 88.0 (IQR 57.5-134.5) minutes to 42.5 (IQR 36.0-51.3) minutes. These results were both statistically significant. Although the median time was improved after TEAM implementation for door-to-portable-X-ray [16.0 (IQR 5.8-34.3) minutes versus 12.0 (IQR 7.0-22.0) minutes], door-to-transfusion [68.0 (IQR 43.0- 91.0) minutes versus 31.5 (IQR 15.8-62.0) minutes], and door-to-disposition [353.5 (IQR 201.0-535.5) minutes versus 216.0 (IQR 176.3-347.8) minutes], these differences were not statistically significant (p =0.61, 0.10, and 0.26, respectively; Figure 2).

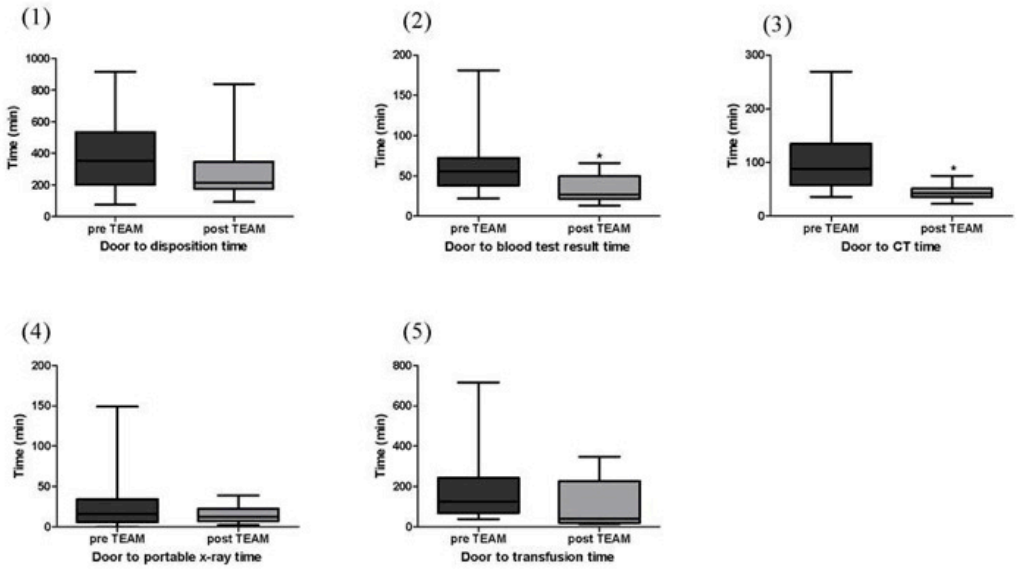
Results for the target time for disposition of the patients were not statistically significant (p=0.536). The number of patients included within the target time zone of 150 minutes were 5 (22.7%) and 1 (12.5%) for the pre-TEAM and post-TEAM groups, respectively. However, the results for a target time of 200 minutes for boarding time in the ED were statistically significant (p=0.044). The numbers of patients included within the target time zone of 200 minutes for boarding time in the ED were 2 (9.1%) and 6 (35.3%) for the pre-TEAM and post-TEAM groups, respectively (Table 3).

Figure 1. Total boarding time between groups. Total boarding time was significantly reduced after protocol implementation. Pre-TEAM: before-protocol implementation group; Post-TEAM: after-protocol implementation group.



* $p < 0.05$ compared with pre-protocol implementation.

Figure 2. Time intervals from emergency department arrival to evaluation processes. Time interval from arrival to blood test results time, and CT (computed tomography) time were significantly reduced after protocol implementation. Pre-TEAM: before-protocol implementation group; Post-TEAM: after-protocol implementation group



* $p < 0.05$ compared with pre-protocol application group.

Table 3. Results of target time for disposition and boarding in the emergency department (ED) between the two groups.

	TEAM* Implementation		*P*
	Before	After	
Disposition decision within 150 minutes from arrival to ED	22 (100)	8 (100)	0.536
Before 150 minutes	5 (22.7)	1 (12.5)	
After 150 minutes	17 (77.3)	7 (87.5)	
Total boarding time in ED less than 200 minutes from disposition decision	22 (100)	17 (100)	0.044
Less than 200 minutes	2 (9.1)	6 (35.3)	
More than 200 minutes	20 (90.9)	11 (64.7)	

Notes: Data are expressed as n (%).
*TEAM: Trauma care through Efficient and Accessible Modal.
$p<0.05$

Ⅳ. Discussion

This present study demonstrated that implementation of a CPOE-based trauma code system can reduce time intervals from patient ED arrival to the evaluation process and decision. A CPOE system provides user satisfaction and ease of use in healthcare systems.[17] There is accumulating evidence that a CPOE can have a beneficial role in critical and emergency care settings by improving ambiguous workflows, improving compliance with practice guidelines, and improving decision support.[18,19] The CPOE system was a core element in the TEAM program and was beneficial for rapid and efficient communication between team members. Activation of the trauma code system by the user clicking an icon on the computer and the use of a uniform pink color to designate a patient in the list reduces the burden of notification and communication between diverse medical personnel and allows physicians and nurses to spend more time at the patient's bedside. Simultaneous notification of related team members, in addition to simplified initiation of standing order sets, contributed to a further reduction in time delays. There is accumulating evidence that decision support, practice guidelines, and disease-specific order sets can be integrated into a CPOE, resulting in a reduction of medical errors and improvements in the general efficiency of care.[17] The TEAM program may facilitate the implementation and maintenance of standardized trauma care by incorporating predetermined standing order sets, evidence-based protocols, and manuals into the system. Time logs for quality control can be automatically obtained from a computer server. These features of CPOE-based programs may be useful for reducing in-hospital time delays and improving the quality of care with ongoing up-to-date education, monitoring, and feedback.

Implementation of the TEAM program significantly reduced the time for blood tests and CT scans, as well as total boarding time in the ED. During the CPOE implementation, our department was using a centrally operated automatic delivery system to deliver blood tests. This meant that the tests had to travel through a central common pathway along with all inpatient and outpatient blood tests. But with the TEAM CPOE implementation, the laboratory technician was able to recognize and prioritize TEAM patient blood tests. Moving patients to the CT scanner was another significant issue. In our hospital, the CT scanner is located on a separate floor from the ED. Before CPOE implementation, the physician had to contact the appropriate technician and explain the urgency of the case and wait until the radiology suite was ready to receive the patient, which was a very time consuming process. After initiation of the CPOE program, we were able to transport the patient to the CT scanner immediately following resuscitation and stabilization without further delay. After an analysis of the blood test and CT scan process, the hospital elected to

construct a dedicated automatic delivery system between the ED and the laboratory department, which will improve the delivery and the turn-around time for blood tests in the ED. The hospital also made plans for the placement of a CT scanner in the ED. This plan was to be executed the following year. The median time interval for door-to-portable-X-ray and door-to-transfusion was reduced in our study, but this reduction was not statistically significant. The results of the door-to-portable-X-ray timing were not surprising. The X-ray suite is immediately next to the resuscitation room, and the technicians already give priority to unstable patients in critical states. Utilization of the CPOE program is unlikely to have influenced this time factor to the same extent as others. The door-to-transfusion time was improved; however, there were two cases at the beginning of the TEAM implementation in which a nurse was unfamiliar with the universal blood transfusion protocol, causing a delay in the process. This issue was fixed immediately through individual feedback.

The total boarding time was significantly reduced. Unfortunately, we were not able to reach the target time mark of 150 minutes for the disposition time or 200 minutes for the ED boarding time. This was likely due to several factors. First, only a small number of patients were included for evaluation of the post-TEAM group. This is because area hospitals do not receive a large number of major trauma patients, and it is therefore not possible to study larger samples at individual institutions. Gathering data over longer time periods or from a multi-institution sample may provide superior data for evaluation. Second, team training was lacking prior to protocol implementation. Although the protocol and guidelines were embedded in the CPOE for reference, we believe adherence was not sufficient. In a full trauma code alert case, there can be more than 10 people in a single resuscitation room. We are in the process of developing a curriculum for training trauma teams in teamwork during a crisis.

1. Limitations

One limitation of the current study is that the results were from a single institution and thus based on a relatively small number of cases. Therefore, the results cannot be generalized to other institutions, especially if a CPOE system is not utilized. In addition, this study was not designed to investigate whether a CPOE program could improve the clinical outcomes of major trauma victims in an ED. This study attempted to evaluate the time interval for various processes for major trauma patients arriving in the ED. In the future, the outcomes of trauma patients after implementation of a CPOE system will be analyzed in a multi-institutional study.

2. Conclusion

This study demonstrated that a standard CPOE program for trauma patients can be successfully

implemented and can reduce ED time delays in managing trauma patients. However, there is still room for further improvement in reducing time intervals for trauma care. A CPOE has the potential to reduce unnecessary delays in care, therefore improving outcomes and the quality of care for trauma patients, and has the additional benefit of educating faculty and staff on patient safety and quality improvement for patients in complex and chaotic environments such as EDs.

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