JAMA Surgery | Original Investigation

Association Between Real-time Electronic Injury Surveillance Applications and Clinical Documentation and Data Acquisition in a South African Trauma Center

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IMPORTANCE Collection and analysis of up-to-date and accurate injury surveillance data are a key step in the maturation of trauma systems. Trauma registries have proven to be difficult to establish in low- and middle-income countries owing to the burden of trauma volume, cost, and complexity.

OBJECTIVE To determine whether an electronic trauma health record (eTHR) used by physicians can serve as simultaneous clinical documentation and data acquisition tools.

DESIGN, SETTING, AND PARTICIPANTS This 2-part quality improvement study included (1) preimplementation and postimplementation eTHR study with assessments of satisfaction by 41 trauma physicians, time to completion, and quality of data collected comparing paper and electronic charting; and (2) prospective ecologic study describing the burden of trauma seen at a Level I trauma center, using real-time data collected by the eTHR on consecutive patients during a 12-month study period. The study was conducted from October 1, 2010, to September 30, 2011, at Groote Schuur Hospital, Cape Town, South Africa. Data analysis was performed from October 15, 2011, to January 15, 2013.

MAIN OUTCOMES AND MEASURES The primary outcome of part 1 was data field competition rates of pertinent trauma registry items obtained through electronic or paper documentation. The main measures of part 2 were to identify risk factors to trauma in Cape Town and quality indicators recommended for trauma system evaluation at Groote Schuur Hospital.

RESULTS The 41 physicians included in the study found the electronic patient documentation to be more efficient and preferable. A total of 11 612 trauma presentations were accurately documented and promptly analyzed. Fields relevant to injury surveillance in the eTHR (n = 11 612) had statistically significant higher completion rates compared with paper records (n = 9236) (for all comparisons, $P < .001$). The eTHR successfully captured quality indicators recommended for trauma system evaluation which were previously challenging to collect in a timely and accurate manner. Of the 11 612 patient admissions over the study period, injury location was captured 11 075 times (95.4%), injury mechanism 11 135 times (95.9%), systolic blood pressure 11 106 times (95.6%), and Glasgow Coma Scale 11 140 times (95.9%). These fields were successfully captured with statistically higher rates than previous paper documentation. Epidemiologic analysis confirmed a heavy burden of violence-related injury (51.8% of all injuries) and motor vehicle crash injuries (14.3% of all injuries). Mapping analysis demonstrated clusters of injuries originating mainly from vulnerable and low-income neighborhoods and their respective referring trauma facilities, Mitchell's Plain Hospital (734 [10.1%]), Guguletu Community Health Center (654 [9.0%]), and New Somerset Hospital (400 [5.5%]).

CONCLUSIONS AND RELEVANCE Accurate capture and simultaneous analysis of trauma data in low-resource trauma settings are feasible through the integration of surveillance into clinical workflow and the timely analysis of electronic data.

JAMA Surg. 2018;153(5):e180087. doi:10.1001/jamasurg.2018.0087
Published online March 14, 2018.

Supplemental content

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Trauma systems reduce injury mortality rates by 15% to 20% through improvements in timeliness and quality of care.[1-5] Increased universal implementation of trauma systems has the potential to save 1.9 million lives each year.[1,5-7] The development of global trauma systems capacity is one of the most significant opportunities in global public health.[2,4,8,9] The success of modern trauma systems is rooted in the introduction and maturation of trauma databases.[2,8,10-12] These trauma registries collect credible data to drive advances in all areas of injury control and are used continuously to inform the performance of trauma systems.[6,9,13-15]

Although significant advancements in injury control and outcomes have been made in high-income countries through the introduction and maturation of trauma systems, low- and middle-income countries (LMICs) continue to struggle with developing organized systems of trauma care.[2,10-12,16] One of the challenges of building trauma systems—the establishment of conventional trauma registries—has proven difficult because of data collection costs, large hospital admission volumes, and limited public health personnel.[9,17,18] As a result, trauma registries have been largely absent in LMICs.[2,10-12,19-23]

Point-of-care digital technology for clinical data collection may represent one solution toward establishing trauma registries in LMICs.[4] Smartphones, tablets, and computers are now almost universally available, and using these tools to bypass time-consuming and costly medical records reviews, manual database creation, and analysis could be a key to streamlining surveillance capabilities in low-resource centers. To date, however, there has been little documentation of the effectiveness of digital platforms for point-of-care clinical documentation and injury surveillance.[22-26]

An electronic trauma health record (eTHR) has been developed and validated as an injury surveillance tool for LMICs. The eTHR is a cross-platform mobile application used by frontline trauma clinicians to capture initial assessment, resuscitation, operative, and discharge data as part of standard clinical documentation.[22] Data captured by the eTHR are instantly reorganized to generate printable admission records, operative notes, and discharge summaries. More importantly, the eTHR formats and simultaneously uploads data to a concurrent electronic trauma registry, thereby creating clinician-entered injury surveillance systems. The eTHR thus functions as a clinical document and a concurrent injury registry with the potential to drive policy development and clinical quality improvements if successfully implemented.[22]

The eTHR has previously been piloted as a surveillance and research tool in both high- and low-resource centers globally using trained research personnel.[22] The next phase of this tool's development is the full incorporation and use by trauma care physicians in high-volume, underresourced trauma units. To our knowledge, this study is the first assessment of any electronic clinical tool used concurrently as an electronic injury surveillance system in LMICs with clinicians as the principal source of data acquisition.

This study was designed as proof of concept that it is feasible for clinicians to capture accurate and useful data with mobile digital devices at the point of acute trauma care. The objectives of this study were 3-fold: (1) to assess the association between a mobile digital platform designed for clinical documentation in acute trauma care and clinical workflow and user satisfaction at a busy level 1 trauma center, (2) to compare the quality of the electronic data captured with previous paper-based injury surveillance, and (3) to determine whether clinician-entered data could be used to provide the first near real-time epidemiologic description of trauma in an underresourced South African trauma center.

Key Points

Question Can injury surveillance simultaneous with clinical documentation using mobile technology in a South African trauma center be performed without workflow hindrance?

Findings In this quality improvement study, 11 612 trauma presentations were accurately documented and promptly analyzed electronically with statistically significant greater accuracy, completion, and efficiency compared with a paper-based surveillance predecessor. Clinician-entered data into mobile devices have provided real-time epidemiologic description of trauma in a major South African city.

Meaning In low-resource centers, electronic injury surveillance can successfully capture quality indicators recommended for trauma system evaluation through clinician-entered data using mobile devices.

Methods

The pilot site selected for this study was the level I trauma center at Groote Schuur Hospital (GSH), Cape Town, South Africa. Groote Schuur Hospital is 1 of 2 government-funded, academic, tertiary referral trauma hospitals for the city of Cape Town and one of the world's busiest trauma centers. The study was conducted in 2 parts: (1) the preimplementation and postimplementation phase evaluated physician satisfaction, time to completion, and quality of data collected when comparing paper vs electronic trauma charting; and (2) the ecologic study provided a description of the burden of trauma seen at GSH from eTHR data collection on consecutive trauma patients during a 12-month period. After a review of the eTHR data handling, privacy, and safety measures, the University of Cape Town's Research Ethics Board granted full ethics approval for this project.[22]

All hospital-staff participants provided verbal consent for the survey and their responses were confidential. All data were deidentified.

Preimplementation and Postimplementation Study

Workflow and clinical documentation in the trauma unit were observed and measured over a 2-week period prior to the implementation of the eTHR. The eTHR was implemented after this observation period, replacing the traditional paper admission notes, operative notes, and discharge summaries. Two weeks following eTHR implementation, the research team measured trauma team workflow and clinical documentation processes for an additional 2-week period. Accuracy and completeness of eTHR data were assessed at the end of this trial

period and then again 1 year after implementation. The 1-year data were compared with a previous audit of 12 months of paper admission records done at GSH in 2011.[12]

Inclusion Criteria

Admission records were collected for analysis on "red" patients, defined as requiring full trauma team activation at GSH. Activation criteria included Glasgow Coma Scale value lower than 13; systolic blood pressure lower than 90 mm Hg; airway compromise; respiratory rate less than 10 or more than 30 breaths/min; gunshot wound to the head, neck, chest, and/or abdomen; stab wound to the neck or precordium; major extremity vascular injury; traumatic amputation; or cardiac arrest. "Yellow" patients (to be seen within 1 hour) and "green" patients (nonurgent care) were not included in this analysis. Operative notes were collected from procedures performed emergently by the trauma service. These cases are designated as red cases when an operating theater is required immediately or orange cases when an operating theater is required within 2 hours. Discharge summaries were reviewed for patients admitted under the trauma service at GSH and then discharged during the study period. A total of 150 admission records, operative notes, and discharge summaries were reviewed in the paper and electronic formats.

Statistical Analysis

Admission Records

Field completion rates for data points relevant to injury surveillance were compared between the eTHR admission note and its paper predecessor, the trauma admission record, using a Pearson χ^2 test. The mean time to complete the documentation of red resuscitation patients using the trauma admission record compared with the eTHR was also recorded and compared using a 2-tailed, paired *t* test. The GSH trauma physicians were unaware that their paper or electronic documents were being audited for completion rates and that their time to completion of these forms was measured.

Operative Notes and Discharge Summaries

Previous paper operative notes and discharge summaries of GSH are narrative documents. These were compared with the eTHR operative and discharge modules that contain a combination of dropdown menus and multiselect options similar to the admission record in addition to traditional narrative text boxes. Field completion rates of pertinent aspects of each record were nevertheless collected and analyzed using a Pearson χ^2 test. The mean time for completion of these documents was also collected without the physicians' awareness and compared using a *t* test. **Table 1** summarizes the key data fields collected in these 3 modules.

User Satisfaction

A 9-part questionnaire evaluating the end user's experience with the eTHR and its level of usability was administered to the hospital staff directly involved in using the eTHR at GSH. The sample population consisted of a total of 41 surgery and emergency medicine registrars, medical officers, interns, and medical students. Statistical significance was set at $P < .05$. Statistical analysis was performed using SAS, version 2013 (SAS Institute Inc) and was conducted from October 15, 2011, to January 15, 2013.

Table 1. Data Fields Collected for Comparison of the 3 eTHR Modules With Paper Records

eTHR Module	Data Field
Admission record	Patient demographics (triage, sex, age) Prehospital details (injury date, injury time, referring hospital, arrival date, arrival time, arrival mode) Injury details (injury location, type, setting, mechanism) Admission vital signs (systolic BP, Glasgow Coma Scale, respiratory rate, heart rate, temperature) Physician's name
Operative note	Procedure date Resident performing operation Resident's role in operation WHO checklist completion Estimated blood loss Fluids and blood amounts given Packs remaining in situ if damage control operation Postoperative distention Future plans
Discharge summary	Date of admission Date of discharge Hospital length of stay ICU admission Complications Clavien-Dindo grade of complication Missed injuries

Abbreviations: BP, blood pressure; eTHR, electronic trauma health record; ICU, intensive care unit; WHO, World Health Organization.

Ecologic Study

A 12-month period after eTHR implementation was designated for an ecologic study to test the utility of digitally collected point-of-care data for clinical and health services research. During this period, the eTHR was used exclusively by trauma clinicians for clinical documentation of all red, yellow, and green patients. No chart reviews were performed to complete or add additional data to the registry for the purpose of this study. Reporting for this ecologic study used only preprogrammed analytics and data visualization strategies to highlight the automatic output of the platform.

The eTHR was designed with audit filters to evaluate the process and quality of care. The process of care at GSH was described through the evaluation of operating room wait times for trauma patients booked as red, orange, and yellow cases, with expected operating room wait times of 0, 2, and 6 hours, respectively. The quality of trauma care was evaluated through systematic, point-of-care capture and grading of complications prior to discharge from the trauma service. Finally, the eTHR geographic data were mapped using geographic information science techniques to generate insights on injury hot spots and flow of trauma patients throughout Cape Town.

Results

Preimplementation and Postimplementation Study

Admission Records, Operative Notes, and Discharge Summaries

When the 9236 paper admission records were compared with the 11 612 eTHR admission records, all studied fields for the admission records, operative notes, and discharge summaries

Table 2. 12-Month Data Comparison of Paper and 11 612 Electronic Field Completion Rates

Admission Records	Completion Rate, No. (%)	
	Paper[a]	eTHR
Date of birth	311 (3.4)	11 469 (98.8)
Sex	9059 (98.1)	11 590 (99.8)
Prehospital		
Injury date	8755 (94.8)	11 477 (98.8)
Arrival date	8621 (93.3)	11 612 (100)
Arrival mode	7859 (85.1)	10 133 (87.3)
From scene/transfer	0	8421 (72.5)
Injury details		
Geolocation	7606 (82.4)	11 075 (95.4)
Setting	7004 (75.8)	10 344 (89.0)
Injury intentionality	7048 (76.3)	11 217 (96.6)
Mechanism	8441 (91.4)	11 135 (95.9)
Vital signs		
Systolic BP	7184 (77.8)	11 106 (95.6)
Heart rate	5962 (64.6)	10 914 (94.0)
Respiratory rate	6796 (73.6)	11 013 (94.8)
Temperature	2480 (26.9)	9236 (79.5)
Glasgow Coma Scale	7224 (78.2)	11 140 (95.9)

Abbreviations: BP, blood pressure; eTHR, electronic trauma health record.

[a] Total of 9236 paper-based admission records data (October 1, 2010-September 30, 2011).

were found to have statistically significant higher rates of completion when completed electronically compared with paper (for all comparisons, $P < .001$). Specifically, for the admission records age (76% vs 100%), sex (64% vs 100%), injury date (64% vs 100%), injury location (36% vs 100%), injury mechanism (68% vs 100%), and admission vital signs (68% vs 100%) had higher field completion rates. Similarly, the operative notes' data capture for estimated blood loss (32% vs 100%), World Health Organization checklist completion (12% vs 100%), postoperative disposition (4% vs 100%), future plans (16% vs 100%), discharge summaries' data capture for hospital length of stay (14% vs 100%), intensive care unit admission (68% vs 100%), complications (40% vs 100%), and missed injuries (20% vs 100%) were also found to have statistically significant higher completion rates. This is because of the eTHR's design with mandatory fields that are required to be completed within the modules before a PDF document could be generated and printed.

12-Month Comparison With Paper-Based Trauma Admission Record

Following eTHR's first year of introduction at GSH, 11 612 admission records were completed and input into the electronic trauma registry. These data were compared with 9236 paper admission records collected and analyzed from a 12-month period at GSH from October 1, 2010, to September 30, 2011.[12] **Table 2** and the eTable in the Supplement demonstrate completion rates of the eTHR data fields compared with their paper predecessor 1 year following the eTHR introduction. Similar to the 2-week postintroduction analysis, data field completion remained consistently high after 1 year and was more complete than the trauma admission record. The eTHR operative notes (n = 857) and discharge summaries (n = 5927) could not be compared with paper records because they were previously not captured in any GSH data registries. Nevertheless, these data fields also remained consistently high after 12 months.

Time Analysis

There were no clinically or statistically significant differences in the mean (SD) time to completion between the paper admission records and electronic charting (7.12 minutes [0.24 seconds] vs 7.28 minutes [0.25 seconds]), operative notes (6.44 minutes [0.43 seconds] vs 6.54 minutes [0.31 seconds]), and discharge summaries (14.15 minutes [0.35 seconds] vs 13.45 minutes [0.24 seconds]). With the paper system at GSH, however, secretarial clerks are required to create a paper folder for each newly arrived trauma patient, and this process was found to take a mean (SD) of 20 minutes (52 seconds). During this time, physicians were often waiting for folders before they could begin making their notes. With the eTHR, patient notes could be generated as soon as patient assessments were complete, bypassing this waiting period. When all of these times were combined, the eTHR was found to be a timelier means of documentation, both clinically and statistically.

User Satisfaction

The 41 end-user respondents preferred electronic (36 [87.8%]) over paper (5 [12.1%]) charting. The main motivators for this conversion were improved capabilities for injury surveillance (35 [85.3%]), ease of electronic charting (15 [36.6%]), and reduced time spent charting (5 [12.1%]). Overall, the eTHR was evaluated as easily adaptable to GSH's trauma service (36 [87.8%]), with an attractive user interface (34 [82%]), and was easy to use overall (31 [75.6%]). The main frustrations in user experience were printing the PDFs for the patient folders (28 [68.3%]) and connecting to Wi-Fi (24 [58.5%]).

Ecologic Study of the Burden of Trauma Seen at GSH

Patient Demographics

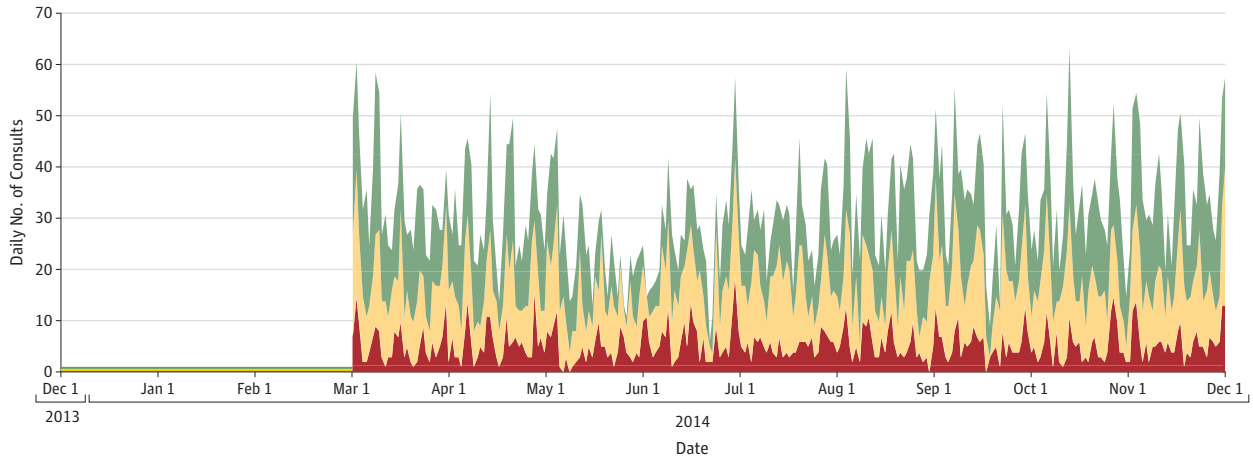
After the 12-month study period, 11 612 patients were registered into the electronic trauma registry created by the eTHR through simple clinical use of this tool. Following introduction of the eTHR, a continuous flow of self-populating real-time data became available at GSH where previously none had existed (**Figure 1**).

Figure 2 illustrates the demographics of trauma patients at GSH. The age distribution of these patients was weighted toward people younger than 40 years (67.4%), with injuries seen predominantly among males (74.5%). As expected, higher rates of injuries were seen on weekends compared with weekdays. Of all patients, 28.8% were found to be using alcohol or drugs prior to sustaining their injuries.

Injury Mechanism and Motivation

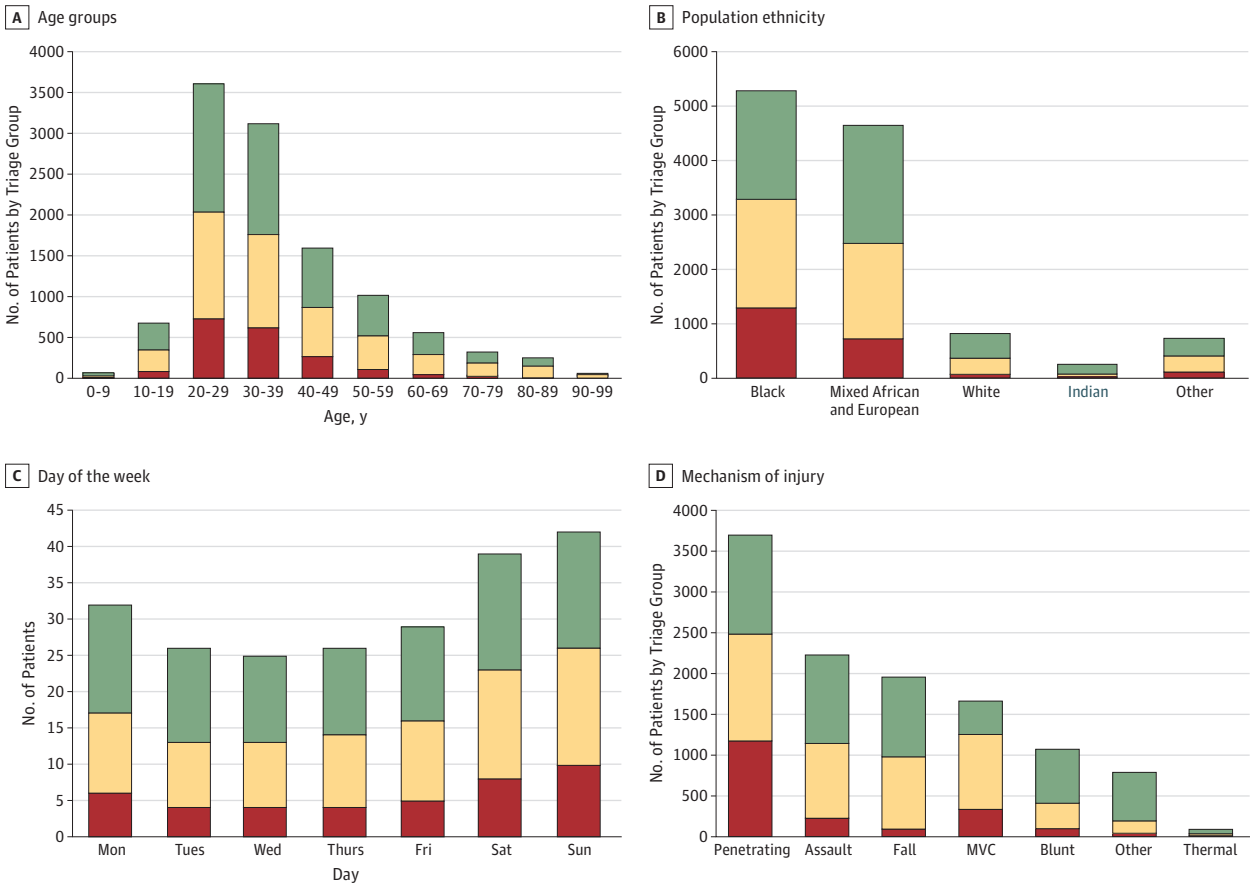
A total of 11 612 (51.8%) admissions to GSH during the study period for eTHR patients presenting to GSH sustained intentional injuries. Overall, the most common mechanisms of injury seen at GSH during the study period were penetrating

Figure 1. Daily Number of Red, Yellow, and Green Trauma Patients Seen at Groote Schuur Hospital



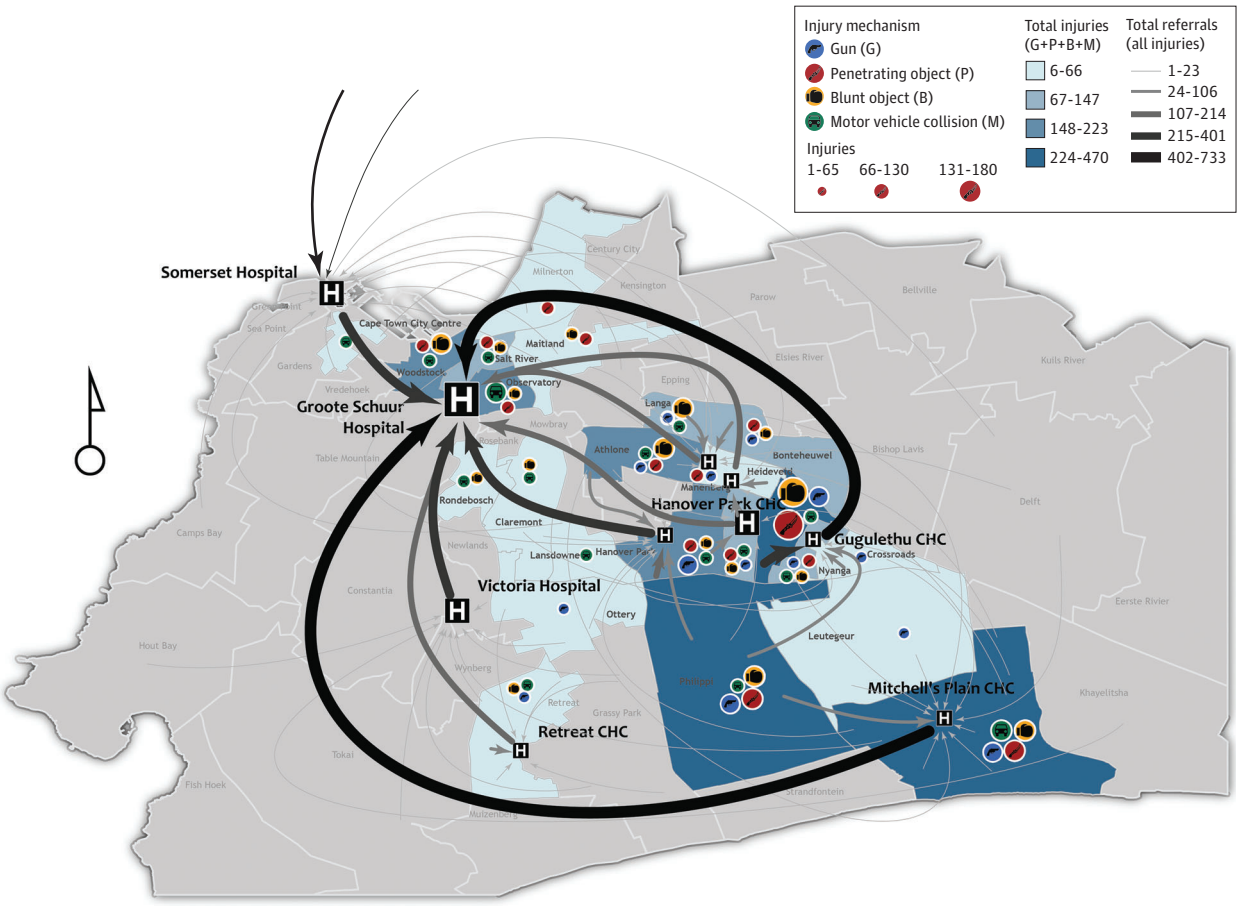
Implementation of the eTHR on March 1, 2014, enabled daily surveillance of trauma volumes. Red indicates that patients require full trauma team activation; yellow, patients need to be seen within 1 hour; and green, patients need nonurgent care.

Figure 2. Demographics of the Trauma Patients Seen at Groote Schuur Hospital During the 12-Month Study Period



A, Patients grouped by age (A), race/ethnicity (B), presentation day of the week (C), and type of injury (D). MVC indicates motor vehicle crash; red indicates that patients require full trauma team activation; yellow, patients need to be seen within 1 hour; and green, patients need nonurgent care.

Figure 3. Trauma Hot Spots and Total Flow of Injured Patients to Groote Schuur Hospital During the 12-Month Study Period



CHC indicates community health center; MVC, motor vehicle crash.

intentional acts with guns, knives, and other sharp objects (3700 [31.9%]), followed by blunt assaults (2232 [19.2%]), falls (1928 [16.6%]), and motor vehicle crashes (1659 [14.3%]). When only the highest acuity red patients were examined, intentional penetrating injuries made up the majority of all injury mechanisms seen at GSH (1173 [59.5%]), followed by motor vehicle crashes (335 [17.0%]) and blunt assaults (225 [11.4%]) (Figure 2).

Process of Trauma Care: Operating Room Wait Times

Mean (SD) waiting times for booked trauma operations were evaluated. The operative notes generated on the eTHR reported that red, orange, and yellow cases were waiting 1.55 (0.94), 3.01 (0.95), and 4.17 (1.88) hours, respectively.

Outcomes of Trauma Care: Systematic Capturing of Complications

Prior to generating a discharge summary for a specific trauma patient, the eTHR requires that the clinician review and grade any complications and missed injuries for that patient. The most common complications for patients admitted to GSH's trauma department and entered into the eTHR were a retained hemothorax (14 [17.3%]), pneumonia (7 [8.6%]), and wound disruptions (7 [8.6%]).

Geographic Distribution of Injury

The main hot spots of injury in Cape Town were in the informal townships surrounding Cape Town. Over half of all the trauma patients seen at GSH were brought directly from the scene (4135 [56.8%]); the remainder of the patients were referrals from secondary hospitals and community health centers from these townships. The main referring hospitals were Mitchell's Plain Hospital (734 [10.1%]), Guguletu Community Health Center (654 [9.0%]), and New Somerset Hospital (400 [5.5%]). The location and flow of injured patients in the overall Cape Town trauma system as captured by the eTHR can be visualized using geographic information science techniques (**Figure 3**).

Discussion

Platform Usability

Currently, one of the major barriers to improving injury surveillance globally is the onerous and at times overwhelming task of systematically evaluating hospital records and patient documents to obtain pertinent injury information and organizing this information within a trauma registry for future

analysis and interpretation.[4,10,19,27-29] These impediments not only make injury surveillance efforts costly and inefficient, they often result in trauma databases lagging months behind.[1,20,21,23,26,30] With the creation of the eTHR, we have sought to shift the injury surveillance responsibilities from teams of data analysts that are not available in LMICs because of costs and limited resources to busy frontline clinicians. It is well known, however, that frontline clinicians are often reluctant to use surveillance tools that they view as burdensome, requiring large time investments without any immediate benefits to workflow or patient care.[10,11,22,29]

To address these concerns, the eTHR has been programmed with real clinical benefits. It can generate outputs in terms of an admission document, synoptic operative reports, and a prepopulated discharge summary. The eTHR therefore is able to fulfill the physicians' charting responsibilities while also seamlessly collecting data for injury surveillance purposes. Our preimplementation and postimplementation study suggests that the eTHR may be a more time-efficient means of patient documentation as a result of the heavy use of dropdown menus, multiselect and prepopulated fields, and minimal requirements for narrative-free text. The clinicians' responses in the survey on the eTHR were also positive. With our qualitative assessment, we found that the eTHR was perceived as a user-friendly clinical documentation tool.

Our study revealed that not only was workflow improved by the eTHR introduction, but also that the eTHR can generate a near-complete electronic trauma registry essentially in real time. Field completion rates of all epidemiologically pertinent injury surveillance data captured by eTHR were higher than paper documentation, which previously was found to have mean completion rates of less than 30%.[8] The rates of field completion continued to remain high even after our research support team had left Cape Town, suggesting that the eTHR may be a sustainable means of real-time injury surveillance in a low-resource trauma center where previously minimal data were available.

Data Usability and Reporting

Data captured by the eTHR were found to be of relevance to both clinical and epidemiologic approaches to injury control. From a clinical standpoint, the eTHR was successful in assisting frontline trauma teams to capture audit filters and complications (including those from the Trauma Quality Improvement Program) to inform performance improvement efforts.[20] Furthermore, the eTHR is able to compile clinician-entered data into prognostic scores, including the Kampala Trauma Score, Revised Trauma Score, and Injury Severity Score, enabling future risk-adjusted comparisons of oucomes.[16,27,31]

From an epidemiologic standpoint, eTHR data confirmed the previously observed but poorly quantified observation that the largest demographic group for trauma in Cape Town is young males, who have high rates of gun and knife violence.[8,12] Motor vehicle crashes were also noted to contribute significantly to the burden of trauma. With the addition of geographic information systems techniques, hot spots of injury were found to occur in low socioeconomic neighborhoods and among vulnerable population groups. Concurrent identification of injury hot spots and the flow of patients in the Cape Town trauma system can be visualized for what we believe to be the first time, thereby generating insights about injury prevention and trauma systems organization.

Limitations

Several limitations were identified during the study period with the eTHR. The eTHR is a web-based application requiring reliable and continuous Wi-Fi signal. When the Wi-Fi connection is lost, clinical documentation would revert to traditional paper means, thereby not capturing data for these patients in the electronic trauma database. As Cape Town represents a relatively better-resourced environment than most other contexts in Africa, issues related to Wi-Fi connectivity would be amplified with eTHR dissemination to trauma centers with greater resource restrictions. In response, a Wi-Fi–independent version of the eTHR has been designed to avoid this specific issue.

In addition, Cape Town represents a unique setting where a certain degree of organized system of data management, although more inefficient than the eTHR, previously existed. Having an existing system reflects a somewhat abnormal setting for eTHR's preliminary implementation site and will likely lead to new challenges before successful introduction more austere environments.

Finally, our results are not entirely reflective of a complete population-based study of the overall burden of trauma in Cape Town. The eTHR is currently implemented in only 1 of 2 level I referral trauma centers in Cape Town. We are optimistic that, with time, the flexibility and ease of implementation of the eTHR platform will promote its use across Cape Town's inclusive trauma system and trauma sites. This expansion would make transfer of clinical data and institutional comparisons seamless while strengthening existing networks. Of course the limitations of the missing data, in particular complications and missed injuries, must be further addressed and data capture improved within these fields.

Conclusions

Advances in information technology in health care, particularly the emergence of mobile digital platforms, have the potential to bridge the gap between clinical documentation and injury surveillance and, in doing so, change the way that many countries approach injury control. Migrating data collection to an electronic tablet system marks a departure from conventional data collection done by trained data abstractors. While there is an inherent risk in entrusting data collection to busy frontline clinicians, putting clinicians at the center of the surveillance effort creates numerous appealing possibilities. This study demonstrates that the use of a mobile digital platform by trauma teams at the front lines of trauma care is feasible, does not hinder workflow, generates useful clinical notes, and populates an electronic trauma registry with standardized and complete data in real time. It does so at relatively low cost and can therefore create rich data environments, with unprecedented opportunities for analysis and data visualization, even in low resource settings.

ARTICLE INFORMATION

Accepted for Publication: December 14, 2017.

Published Online: March 14, 2018. doi:10.1001/jamasurg.2018.0087

Author Contributions: Drs Zargaran and Hameed had full access to all of the data in the study and take responsibility for the integrity of the data and the accuracy of the data analysis.
Study concept and design: Zargaran, Spence, Nicol, Schuurman, Navsaria, Ramsey, Hameed.
Acquisition, analysis, or interpretation of data: Zargaran, Spence, Adolph, Nicol, Schuurman, Hameed.
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Critical revision of the manuscript for important intellectual content: Zargaran, Adolph, Nicol, Schuurman, Navsaria, Ramsey, Hameed.
Statistical analysis: Zargaran, Spence.
Administrative, technical, or material support: Zargaran, Nicol, Navsaria, Ramsey, Hameed.
Study supervision: Zargaran, Nicol, Hameed.

Conflict of Interest Disclosures: Dr Hameed is a founder at T6 Health Systems. No other conflicts are reported.

Funding/Support: This project was supported financially by research grant S5 0383-01 from Grand Challenges Canada.

Role of the Funder/Sponsor: Grand Challenges of Canada had no role in the design and conduct of the study; collection, management, analysis, and interpretation of the data; preparation, review, or approval of the manuscript; and decision to submit the manuscript for publication.

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