The Electronic Trauma Health Record: Design and Usability of a Novel Tablet-Based Tool for Trauma Care and Injury Surveillance in Low Resource Settings

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BACKGROUND: Ninety percent of global trauma deaths occur in under-resourced or remote environments, with little or no capacity for injury surveillance. We hypothesized that emerging electronic and web-based technologies could enable design of a tablet-based application, the electronic Trauma Health Record (eTHR), used by front-line clinicians to inform trauma care and acquire injury surveillance data for injury control and health policy development.

STUDY DESIGN: The study was conducted in 3 phases: 1. Design of an electronic application capable of supporting clinical care and injury surveillance; 2. Preliminary feasibility testing of eTHR in a low-resource, high-volume trauma center; and 3. Qualitative usability testing with 22 trauma clinicians from a spectrum of high- and low-resource and urban and remote settings including Vancouver General Hospital, Whitehorse General Hospital, British Columbia Mobile Medical Unit, and Groote Schuur Hospital in Cape Town, South Africa.

RESULTS: The eTHR was designed with 3 key sections (admission note, operative note, discharge summary), and 3 key capabilities (clinical checklist creation, injury severity scoring, wireless data transfer to electronic registries). Clinician-driven registry data collection proved to be feasible, with some limitations, in a busy South African trauma center. In pilot testing at a level I trauma center in Cape Town, use of eTHR as a clinical tool allowed for creation of a real-time, self-populating trauma database. Usability assessments with traumatologists in various settings revealed the need for unique eTHR adaptations according to environments of intended use. In all settings, eTHR was found to be user-friendly and have ready appeal for frontline clinicians.

CONCLUSIONS: The eTHR has potential to be used as an electronic medical record, guiding clinical care while providing data for injury surveillance, without significantly hindering hospital workflow in various health-care settings. (J Am Coll Surg 2014;218:41–50. © 2014 by the American College of Surgeons)

Trauma is among the greatest global public health challenges of our time. Each year, 5 million people die, and another 100 million lives are devastated, often permanently, from the consequences of injury.[1-3] Globally, injury accounts for as many deaths as HIV, malaria, and tuberculosis combined.[1] Injury is the leading cause of death of young people, and therefore, the leading cause of loss of human potential. The global health community has been slow to recognize injury as a priority, yet injury has been estimated to be responsible for 12% of the global burden of disease.[3-5] The world's poorest populations shoulder much of this burden with the fewest resources to devote to injury control: more than 90% of injury deaths occur in low- and middle-income countries (LMICs).[6-8] This is perhaps public health's biggest

Disclosure Information: Nothing to disclose.

The University of British Columbia (UBC) Branch for International Surgery, the UBC Clinical Investigator Program, and the Vancouver Trauma Research and Education Fund provided research grants in support of this project.

This work won the First Place Award—Clinical Research at the American College of Surgeons Committee on Trauma Annual Conference, San Diego, CA, March 2013.

Received August 1, 2013; Revised September 5, 2013; Accepted October 1, 2013.

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Published by Elsevier Inc.

ISSN 1072-7515/13/$36.00
http://dx.doi.org/10.1016/j.jamcollsurg.2013.10.001

Abbreviations and Acronyms

eTHR = electronic Trauma Health Record
GSH = Groote Schuur Hospital
LMIC = low- and middle-income countries

opportunity—implementation of effective systems of injury control and trauma care in LMICs has the potential to save millions of lives every year.[7-14]

In North America, trauma systems have developed as a public health approach to injury control. Trauma systems have been conceptualized as resting on a public health framework encompassing 3 key activities: assessment of injury data, policy development based on these data, and ongoing assurance of quality of care through data-driven performance evaluation.[13,15,16] Each of these pursuits is fundamentally dependent on injury surveillance—the systematic collection and analysis of data. The central role of injury surveillance in injury control is reflected in the World Health Organization (WHO) *Guidelines for Essential Trauma* Care.[17] A key first step for emerging trauma systems will be to establish a foundation of injury data on which to base effective strategies for injury prevention and accessible and effective acute trauma care and rehabilitation.[15,16] Unfortunately, trauma surveillance is largely absent in LMICs because of cost and complexity.[17-20] Where it does exist, it is rudimentary, poorly developed, and incomplete.[20-24]

Advances in, and the widespread availability of, powerful, mobile information technology (mHealth) tools may have the potential to bridge this surveillance gap, and, in so doing, to create intriguing possibilities for global trauma systems development and injury control. We hypothesized that a tablet computer-based electronic Trauma Health Record (eTHR), designed for clinical use by trauma care providers and with the capacity to organize and securely upload data to a concurrent trauma registry, could potentially provide a means for high quality clinical care and injury surveillance in low-resource settings.

In this article, we describe the design process, initial field-testing, and initial usability testing of a novel tablet-based electronic "app" with capabilities to support both clinical care and trauma surveillance in low-resource settings.

METHODS

Phase 1: Creation of the electronic Trauma Health Record

After a period of close and systematic observation of clinical work flow at one of the world's busiest trauma units (Groote Schuur Hospital [GSH], Cape Town, South Africa), and in consultation with South African injury prevention experts and trauma surgeons, a paper-based admission note (Trauma Admission Record) was designed. The Trauma Admission Record was intended to serve as a clinical charting form, but also contained standardized fields relevant to injury prevention, injury severity scoring, and diagnostic and therapeutic classification.[25] Close to 10,000 of these forms were completed and collected by GSH trauma physicians.[26] Their experiences and observations guided the conversion of this paper record into electronic form (Fig. 1).

The specific capabilities of the eTHR were defined by a consensus of trauma surgeons, surgical residents, trauma managers, nurses, data ethnographers, and medical software designers. The consensus panel reviewed key trauma systems resources[16-19] before initiating design. Essential considerations during the development process included a high degree of usability by clinicians, no clinical workflow hindrance, adoption of the Advanced Trauma Life Support Course as an organizational foundation of the electronic form, integration of "smart" safety checklists and evidence-based practice guidelines, easy printability of a legible paper form, and capability to instantly and securely upload data to a concurrent electronic trauma registry (Table 1). The eTHR was then equipped with 3 key modules: the Trauma Admission Record (demographics, mechanism, and diagnoses), the Operative Note (key interventions), and the Discharge Summary (key outcomes).

The eTHR was designed as a downloadable, multiplatform, web-based application, initially for use on the iPad (Apple Computers). The user interface was built using the jQuery Mobile 1.0 Framework and was designed to save and update data in a MySQL database through asynchronous javascript requests sent over Secure Socket Layer (SSL) encryption. Data transfer, with 128-bit encryption, was designed to enable synchronous or intermittent upload of data to dedicated, secured servers within a host site.

Phase 2: electronic Trauma Health Record preliminary pilot in a low-resource center

A functioning eTHR prototype underwent a 4-week pilot test in the trauma unit at Groote Schuur Hospital (GSH), Cape Town's major trauma referral center. No comprehensive injury surveillance system was in operation there. Fifty complex trauma patients who met criteria to be seen by GSH trauma staff in the trauma unit's resuscitation area had both a paper admission note and a deidentified eTHR admission note completed concurrently by GSH trauma staff and the research team. Criteria for

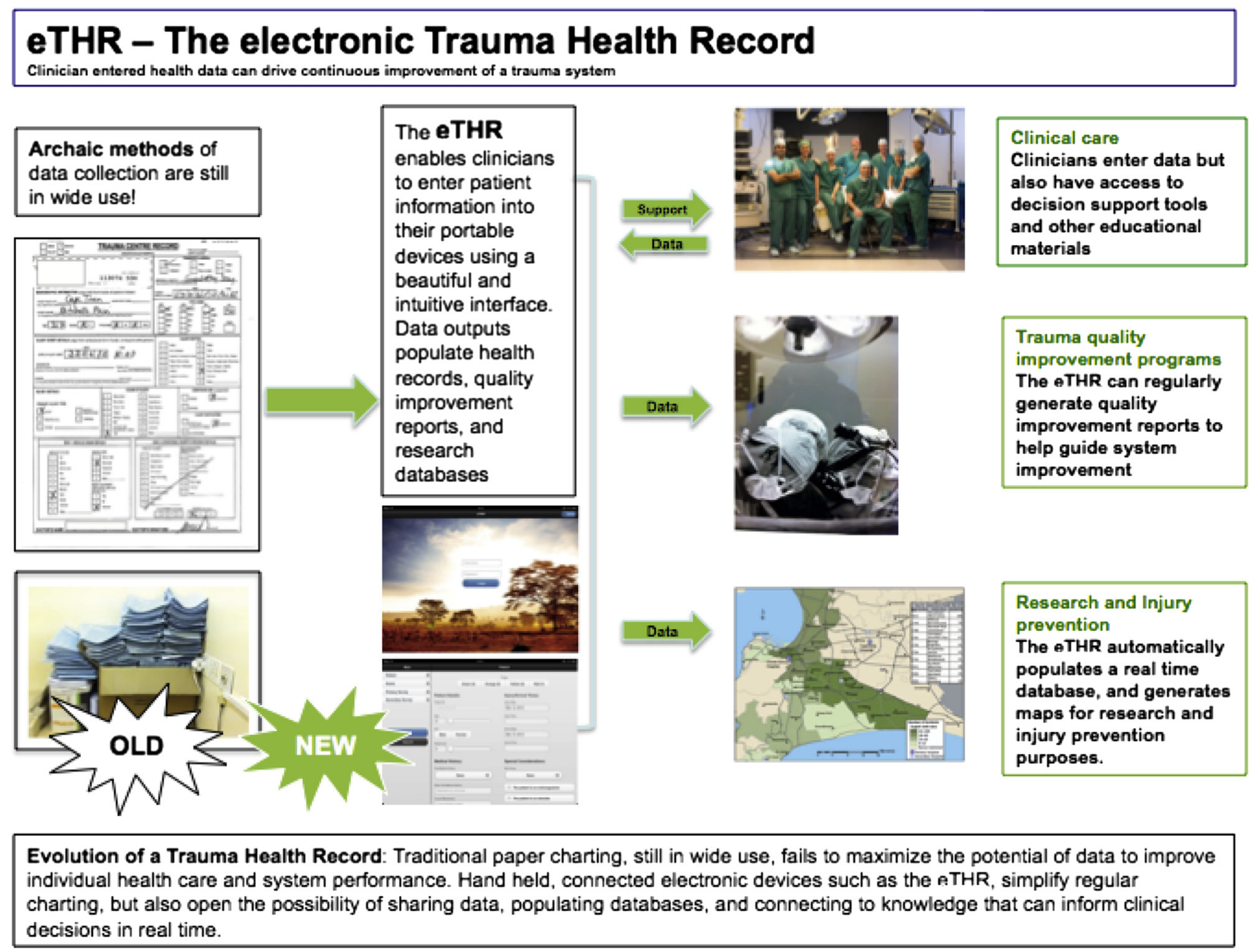

Figure 1. Conversion of a paper trauma admission record to an electronic trauma health record.

resuscitation room assessment were as follows: Glasgow Coma Scale score < 13, systolic blood pressure < 90 mmHg, airway compromise, respiratory rate <10 or >30 breaths per minute, flail chest, gunshot wound to head/neck/chest/abdomen, stab neck/precordium, major extremity vascular injury, traumatic amputation, traumatic cardiac arrest, facial burns, or at the physician's judgment. Connectivity to the eTHR server, speed and

Table 1. Key Considerations and Key Features of the Electronic Trauma Health Record

Key features of eTHR	3 Key modules
Highly user friendly for clinicians	Trauma admission record
No clinical workflow hindrance	Demographics
Capability to instantly and securely upload data to a concurrent electronic trauma registry	Mechanism
Integration of "smart" safety checklists and evidenced based best trauma practice guidelines	Diagnoses/treatment plan
Easy printability of a legible paper form for patient charting	Operative notes
Adoption of the Advanced Trauma Life Support Course	Key interventions
Modular to easily adopt eTHR to different environments and trauma centers	Complications
	Disposition
	Discharge summary
	Key outcomes
	Complications
	Follow-up plan

eTHR, electronic Trauma Health Record.

ease of use, user interface, pertinent data capture, and the ability to establish a seamless electronic trauma registry with this tool were tested during this pilot. Regular feedback from GSH trauma staff regarding necessary changes and alterations of data fields were obtained for improvements of the eTHR prototype.

Phase 3: electronic Trauma Health Record usability testing

Diverse heuristic usability testing using a "think out loud"[25] protocol, with trauma clinicians from a spectrum of high- and low-resource and urban and remote settings (the British Columbia Mobile Medical Unit, the Whitehorse General Hospital in the Yukon Territory, the Vancouver General Hospital, and the Groote Schuur Hospital in Cape Town, South Africa), was conducted using a hypothetical, standardized patient. A total of 22 traumatologists were surveyed at these 4 sites, with all interactions with the research team recorded and transcribed for analysis. The eTHR was assessed according to 3 broad heuristic categories well described within the ethnographic literature: Interface, Operation, and Interaction[26] (Table 2).

RESULTS

Phase 1: Creation of a modular electronic Trauma Health Record

The first of the eTHR's clinical modules, the Admission Record, was designed to capture patient information including demographics, past medical history, residential neighborhood, specifics about the scene of injury, injury mechanism, and use of drugs and alcohol. The eTHR was also designed to apply an individual patient's data to the automatic generation of a Revised Trauma Score (RTS) and an Injury Severity Score (ISS), allowing for future data standardization and performance evaluation.

The eTHR's Operative Note includes details of major surgical interventions. Principles of synoptic operative reporting, which ensure rapid and complete capture of operative data, were used in construction of the operative note.[27] The Discharge Summary was designed to capture patient complications and outcomes, data that allow clinicians to measure and improve trauma center performance.

The eTHR was designed with templates for patient assessment (primary and secondary survey), clinical practice guidelines for common severe injuries, and checklists based on the WHO Trauma Resuscitation Checklist[28] and the WHO Safe Surgery Safety Checklist.[28-30] These features are intended to be purely clinical tools that may increase clinical usability, while promoting complete and evidence-based patient care (Fig. 2).

In its current form, the eTHR is not designed to capture identifying data, but instead it assigns a specific number to each entered patient. Although the tablet computers and the app are password protected, no data reside on the tablet. Deidentified patient information is instantly updated to a secure server, which can be placed behind a hospital's own firewalls.

Phase 2: Preliminary field testing of functionality

Only the Admissions Record Module of the eTHR was tested in this preliminary examination because deidentified patients were not followed past primary resuscitation in the trauma bays. In order to complete the Operative Note and Discharge Summary modules, patients would

Table 2. Common Attributes of Usability of Electronic Health Records

Attribute	Description
Accomplishes the required goals of the software.	Software must contextually perform in a way the end users desire to aid in achieving the required task.
Provides valuable feedback of system status.	Software should always keep end user informed through appropriate feedback within reasonable time.
Consistency and standardization with program behaving in a familiar way.	Software platform should be predictable and easy to learn with minimal variation of words, situations, or actions meaning the same thing.
Helps users recognize, diagnose, and recover from errors.	Software error messages should be expressed in plain language (no codes), precisely indicate the problem, and constructively suggest a solution.
Esthetically pleasing, elegant, and minimalist design.	Software should not contain information that is irrelevant or rarely needed. Language should be easily understandable. Fonts, icons, and user interface must be visually appealing.
Recognition rather than recall.	Software should minimize the user's memory load by making objects, actions, and options visible. Instructions for use of the system should be visible or easily retrievable whenever appropriate.
Use of the program is efficient.	Software should speed up the interaction for the end user. Allow users to tailor frequent actions with minimal inputs, and decrease the time to perform the same task with previous methods.

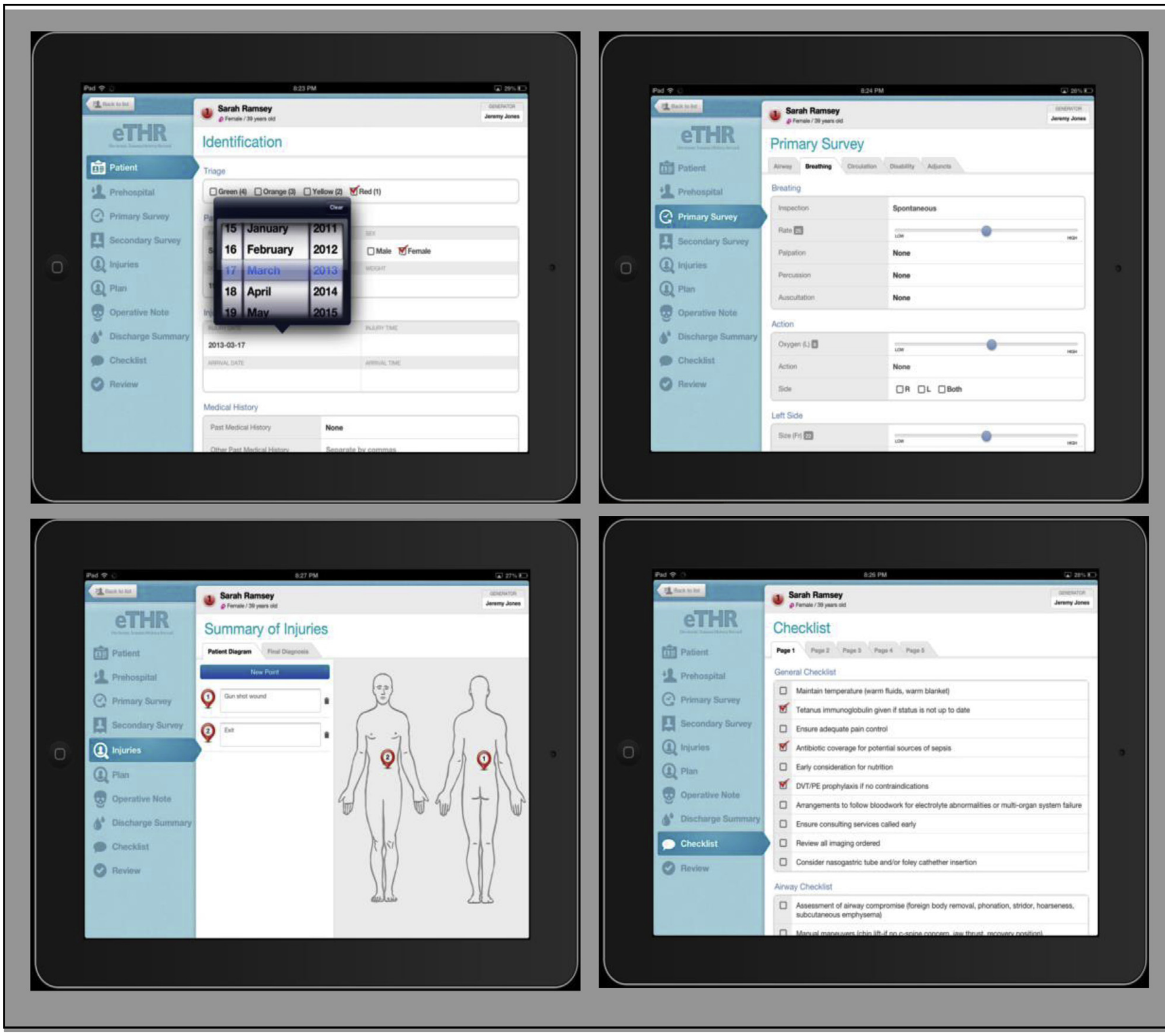

Figure 2. The electronic trauma health record (eTHR).

have required identification, which was beyond the scope of this pilot testing. Data capture was accurate and complete, and data fields were relevant to both clinical care and trauma surveillance. Secure data upload to a server proved successful, and a trauma registry based on the 50 patients was created.

The eTHR, which was extremely sought after by the trauma service residents, was uniformly found to be user friendly and intuitive, even in a busy clinical environment. Staff at GSH did not view the eTHR as a surveillance database but rather as a clinical tool. The trauma checklists and clinical practice guidelines were cited as particularly useful features for clinical care. All surveyed clinicians noted no hindrance to workflow with the use of the eTHR.

Two major issues arose with this preliminary testing. First, connection speeds to the eTHR server were found to be nearly 10 times longer than at test sites in Canada, where the app was developed. This delayed the loading of the eTHR modules and slowed the timeliness of clinical charting. Secondly, concerns over theft of the tablet devices arose, especially when staff would place the tablets in unsecured locations when called urgently to care for patients. No tablets were lost or stolen during this pilot, however.

Phase 3: Diverse usability testing of electronic Trauma Health Record operation

Usability assessments with 22 clinicians in various settings revealed the eTHR to be user-friendly, with ready appeal for frontline clinicians as a clinical tool. Few errors were made with data input into the eTHR, and when they were, the participant was able to quickly correct them. Participants became proficient in using the eTHR quickly, and charting time was reduced with using eTHR compared with paper predecessors. Usability testing identified the need for unique eTHR adaptations according to the environment of its intended use (Fig. 3). In a mobile medical unit at a mass gathering event (Abbotsford International Air Show), clinicians identified the need to expand eTHR beyond trauma, to include general admission categories and diagnoses common at these events (syncope, heat stroke, dehydration, myocardial ischemia). At the Whitehorse General Hospital, a small hospital in Northern Canada, limited Internet access revealed the need to redesign eTHR to have off-line capabilities as a native application. The busy trauma service at the Vancouver General Hospital identified the need to increase the amount of "dropdown" menus with prewritten options, thereby reducing charting time further compared with their standard paper documents. Finally, at the Groote Schuur Hospital in Cape Town, South Africa, eTHR was viewed as an essential clinical tool. Because many after-hours trauma resuscitations are performed by junior house staff, requests were made for additional clinical practice guidelines, trauma checklists, and "red-flag" identifiers.

DISCUSSION

New mobile information technologies have the potential to change the way the world confronts major issues in global health. In the age of information technology, opportunities for injury control are unprecedented, in terms of both capability and scale. Commercial wireless signals now cover more than 85% of the planet. Around 4 billion people own mobile phones, and almost two-thirds of them are in LMICs.[31] In Africa alone, there are at least 650 million cell phone subscribers, more than in the US or the EU, and that number is rising fast to a projected 1 billion by 2016.[32] In 2007, President Paul Kagame of Rwanda noted that in "10 short years, what was once an object of luxury and privilege, the mobile phone, has become a basic necessity in Africa."[32]

The promise of information technology has not been lost on the global public health community. In its 2011 publication, *mHealth for Development: The Opportunity for Mobile Technology for Health Care in the Developing World*, the WHO defined mHealth as the practice of public health and health care supported by mobile electronic devices, and it outlined opportunities and challenges for such technologies to shape emerging health care systems.[33] mHealth has since become a dynamic area of academic endeavor, and a focus of research funding and publication. Surprisingly, to date, very few investigators have explored potential applications of mHealth tools in injury control.

Figure 3. Diverse requirements will require ongoing electronic trauma health record (eTHR) redesign.

Certainly in trauma, mHealth tools have the potential to inform and standardize clinical practice, and to streamline and enhance injury surveillance, even in areas with little or no historic injury surveillance capacity. This is exciting because a key first step in the development of successful trauma systems is the systematic collection and analysis of injury data.[2,7,13,16,17] By defining the distribution and determinants of injury through surveillance, and by applying data to the reorganization of existing human and material resources, these trauma systems would have the chance to target effective prevention efforts, improve access to quality acute care, and, ultimately, to address glaring disparities in the burden of injury.

Currently, one of the major challenges to improved injury surveillance is its dependence on the painstaking and labor-intensive evaluation of patient records for manual abstraction and coding of demographic data, injury mechanisms, diagnoses, interventions, and outcomes.[34,35] Data abstraction must then be followed by the tedious task of organizing this information within a trauma registry for future analysis and interpretation.[34,35] These steps not only make systematic injury surveillance efforts costly and inefficient, but also often keep trauma databases months to years behind.[34] This is a vital opportunity for mHealth technologies, such as the eTHR.

Set-up and operating costs of eTHR may become a particularly attractive feature in LMICs, where the high costs of injury surveillance has previously been prohibitive. Although considerable investment has already gone into research and development, we anticipate that ultimate start-up and maintenance costs will be affordable in most LMICs. For example, in Cape Town, start-up costs have been related to customization of the application ($3,000), establishment of Wi-Fi connectivity ($1,500), purchase of tablet computers ($1,000), and purchase of wireless printers ($500). Training and troubleshooting requires some initial personnel costs (estimated at $1,000). Maintenance costs will be related to server fees ($100/month), data compilation, analysis and reporting ($3,000/year), and personnel for ongoing training and troubleshooting (estimated at $5,000/year). Overall annual costs are estimated to be approximately $10,000 to $15,000. Maintenance costs would, of course, be tailored to local needs and resources, and are expected to be highly flexible. The eventual development of advanced algorithms for automatic data analysis and reporting is expected to substantially reduce maintenance costs. It is anticipated that start-up and maintenance costs are expected to be similar in a spectrum of trauma systems.

Beyond providing an affordable means of injury surveillance, the central premise of the eTHR concept is that information technology tools can be applied to bypass the manual abstraction of injury surveillance data by creating a direct electronic connection from the clinical chart to a concurrent electronic trauma registry. The success of this premise is fundamentally dependent on the accuracy and completeness of clinician-entered data, and on the capacity of eTHR to code and standardize data into a usable format.

In an attempt to maximize the completeness of clinician-entered data, development of the eTHR prioritized usability of the electronic interface. An unusable app would defeat surveillance efforts at the outset. Features such as intuitive navigation, embedded clinical practice guidelines, checklists, red flags, and visual displays were attractive to trauma care providers and will likely improve usability. These features also have the welcome effect of making the eTHR a point of care educational tool, which can provide data and specific prompts to help to inform decisions at critical points during the course of resuscitation. Flexibility and adaptability of the app to the specific needs and health care capabilities of local environments may further improve usability. The eTHR can also be adapted to local public health contexts, such as by including functionality to generate local neighborhood injury maps for injury prevention purposes. Finally, the inherent usability and ubiquity of smart phones and tablet computers is also a powerful advantage of the eTHR and other apps. During the course of testing, we observed that app design became an iterative process, requiring constant interaction with the end users and perpetual modification of the app to further enhance usability.

In the design process of any electronic health record, once usability is confirmed, the accuracy, completeness, and initial formatting of the data must be considered. Our field and usability tests suggested that uploaded data were accurate. Limitation of free text and extensive use of drop down menus in the eTHR ensured some standardization of the data. Data can be further standardized and merged into scores (Revised Trauma Score [RTS], Kampala Trauma Score [KTS], Injury Severity Scores [ISS]) by mathematical algorithms embedded within the app. Clinicians were impressed by the automatic Revised Trauma Score calculator, which provided an instant estimate of survival probability once admission vital signs were entered. Early availability of prognostic scores for patients who are actively being resuscitated would represent a significant advance over North American injury scoring, in which data collection and entry by analysts are often required before these scores are available. Even more importantly, injury scoring can create the unprecedented possibility of comparing adjusted outcomes to national or international norms.

Additional factors for the high usability we observed in the study may have been related to the slow and deliberate transition from a standardized paper-based Trauma Admission Record to the eTHR, consistency between the paper and electronic forms, and a strong culture supporting quality trauma care at the GSH Trauma Unit and other test sites. Training during the transition period and attention to staff buy-in was a consistently high priority. All of these considerations are widely supported in the electronic health records literature.[36,37]

Data security and confidentiality are central priorities in eTHR implementation and in mHealth in general. Because the eTHR has the potential to be used in a diversity of health care environments, standard and location-specific security features must be specified. In the eTHR's current version, no data are stored on the iPad or tablet computer, and wirelessly uploaded data are deidentified and encrypted for storage on a cloud server. However, a privacy impact assessment at the Vancouver General Hospital and an ethics review at the University of Cape Town both emphasized the need to maintain patient identifiers in the database to avoid confusion of records or maintenance of multiple records. Future iterations of eTHR will be adaptable to local hospital firewalls and other local safety and security requirements.

We believe that the electronic registries, automatically populated by use of the eTHR, will be immediately relevant to audits of quality of care, based on standard indicators of trauma system process and outcomes (Fig. 4). The registries will create case series of traumatic events and will profile population-based cohorts of injured patients for research and health policy analyses. As in previous studies, data can be mapped to identify vulnerable populations, evolving patterns of injury, and risk factors associated with traumatic injuries,[38-40] however, eTHR will allow this to occur in real time.

Future research in this area should describe processes for successful adaptation of mHealth tools into diverse trauma environments through iterative testing and perpetual redesign of the apps. Further work needs to be done on data standardization, analysis, reporting, and, of course, data security. Finally, the cost and cost effectiveness of implementation of mHealth tools in

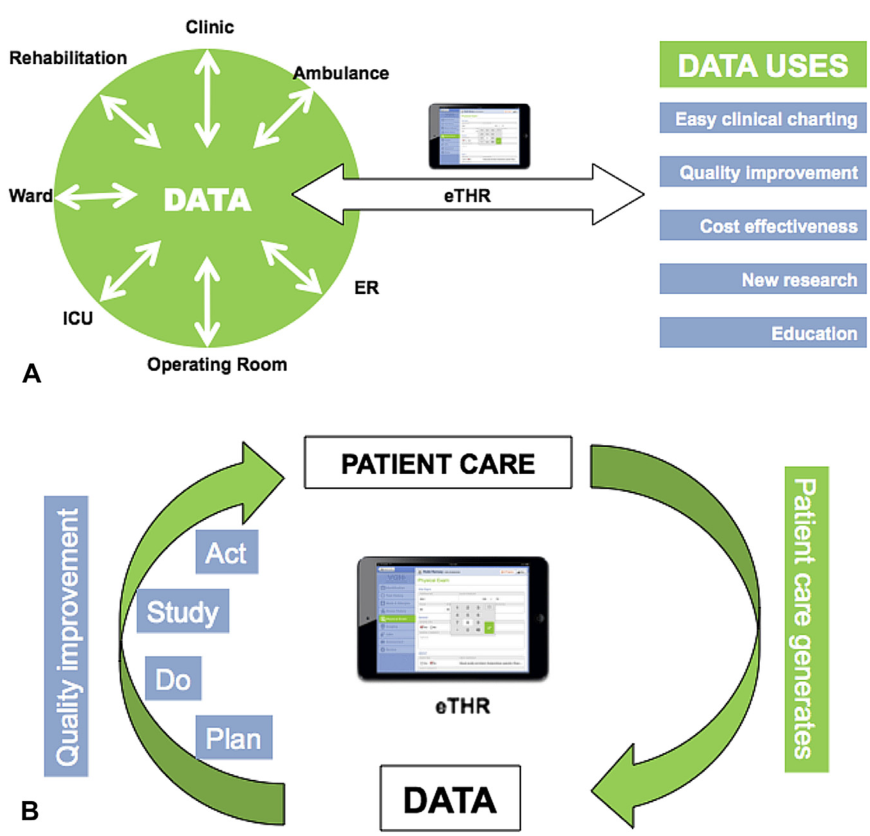

Figure 4. (A) Data flow and (B) applications.

LMICs is a critical research priority, and will ultimately determine how successfully mHealth can be integrated into the development of trauma systems around the world.

CONCLUSIONS

Technologies involving mHealth, such as the eTHR, may enable trauma clinicians to use low-cost, familiar devices to guide care, and to seamlessly gather pertinent trauma data with minimal or no disturbance of workflow and with little additional training. The data collected can then be wirelessly and securely uploaded to an electronic trauma registry for use by both injury prevention and trauma quality improvement programs. Ultimately, we believe that for mHealth tools such as the eTHR to affect global injury control, they should not be viewed as apps in isolation, but rather as organizational frameworks for clinical trauma care that promote best practices, and as platforms for basic injury surveillance. Our study suggests that such tools can provide these functions, and thereby support the emergence of increasingly sophisticated trauma systems around the world. Mobile technologies may soon become a basic necessity for global injury control.

Author Contributions

Study conception and design: Zargaran, Schuurman, Nicol, Matzopoulos, Cinnamon, Taulu, Ricker, Brown, Navsaria, Hameed

Acquisition of data: Zargaran, Nicol, Ricker, Brown, Navsaria, Hameed

Analysis and interpretation of data: Zargaran, Schuurman, Ricker, Hameed

Drafting of manuscript: Zargaran, Navsaria, Hameed

Critical revision: Zargaran, Schuurman, Ricker, Navsaria, Hameed

Acknowledgment: The authors thank Dr Mark Cicero, Dr Taha Bandukwala, and Mr Kuhan Perampaladas at 3BC Inc (www.3bcinc.com) and Dr Damon Ramsay at InputHealth Inc for providing technical expertise in the development and refinement of eTHR.

REFERENCES

1. World Health Organization. 10 facts on injuries and violence. Geneva: World Health Organization; 2008. Available at: http://www.who.int/features/factfiles/injuries/en/index.html. Accessed October 20, 2013.
2. Mock C, Quansah R, Krishnan R, et al. Strengthening the prevention and care of injuries worldwide. Lancet 2004;363:2172–2179.
3. Peden M, Krug EG, McGee K. Injury: A Leading Cause of the Global Burden of Disease, 2000. Geneva: World Health Organization, Department of Injuries and Violence Prevention, Noncommunicable Diseases and Mental Health Cluster; 2003.
4. Krug E, Sharma GK, Lozano R. The global burden of injuries. Am J Public Health 2000;90:523–526.
5. Mathers C, Fat DM, Boerma JT, World Health Organization. The global burden of disease 2004 update. Geneva, Switzerland: World Health Organization. 2008; Available at: http://site.ebrary.com/id/10266345. Accessed October 20, 2013.
6. Hofman K, Primack A, Keusch G, Hrynkow S. Addressing the growing burden of trauma and injury in low- and middle-income countries. Am J Public Health 2005;95:13–17.
7. Mock CN, Jurkovich GJ, Nii-Amon D, et al. Trauma mortality patterns in three nations at different economic levels: Implications for global trauma system development. J Trauma 1998;44:804–812.
8. World Health Organization. (2010). Injuries and Violence: The Facts. Available at: http://whqlibdoc.who.int/publications/2010/9789241599375_eng.pdf.
9. Mann NC, Mullins RJ, MacKenzie EJ, et al. Systematic review of published evidence regarding trauma system effectiveness. J Trauma 1999;47:25–33.
10. Peden M, McGee K, Krug E, eds. Injury: A Leading Cause of the Global Burden of Disease, 2000. Geneva: World Health Organization.
11. Joshipura M, Mock C, Goosen J, Peden M. Essential trauma care: strengthening trauma systems round the world. Injury 2004;35:841–845.
12. MacKenzie EJ, Rivara FP, Jurkovich GJ, et al. A national evaluation of the effect of trauma-center care on mortality. N Engl J Med 2006;354:366–378.
13. Mock C, Joshipura M, Arreola-Risa C, Quansah R. An estimate of the number of lives that could be saved through improvements in trauma care globally. World J Surg 2012;36:959–963.
14. Gruen RL, Mann NC. Population-based research assessing the effectiveness of trauma systems. J Trauma 1999;47:59–66.
15. Mock CN, Jurkovich GJ. Trauma system development in the United States. Trauma Quaterly 1999;14:197–210.
16. American College of Surgeons, Committee on Trauma. Resources for Optimal Care of the Injured Patient 2006. Chicago: American College of Surgeons; 2006.
17. WHO (2004). Guidelines for Essential Trauma Care. Geneva: World Health Organization.
18. MacLeod J, Kobusingye O, Frost C, et al. A comparison of the Kampala Trauma Score (KTS) with the Revised Trauma Score (RTS) Injury Severity Score (ISS) and the TRISS method in a Uganda Trauma Registry. Eur J Trauma 2003;29:392–398.
19. Baker S, O'Neill B, Haddon W, Long W. The injury severity score: a method for describing patients with multiple injuries and evaluating emergency care. J Trauma 1974;14:187–196.
20. World Health Organization. Electronic Health Records: Manual for Developing Countries. Geneva: WHO; 2006.
21. Farmer PE, Kim JY. Surgery and global health: a view from beyond the OR. World J Surg 2008;32:533–536.
22. Nwomeh BC, Lowell W, Kable R, et al. History and development of trauma registry: lessons from developed to developing countries. World J Emerg Surg 2006;1:32.
23. Schuurman N, Cinnamon J, Matzopolous R, et al. Collecting injury surveillance data in low- and middle-income

countries: The Cape Town Trauma Registry pilot. Global Public Health 2011;6:874−889.

24. Nicol A, Knowlton L, Schuurman N, et al. Trauma system access in Cape Town, South Africa: an analysis of 9,236 consecutive trauma center admissions. JAMA Surg 2013; in press.
25. Lewis CH. Using The “Thinking Aloud” Method In Cognitive Interface Design. (Technical Report RC-9265). 1982: IBM.
26. Nielsen J. Heuristic evaluation. In: Nielsen J, Mack RL, eds. Usability Inspection Methods. New York, NY: John Wiley & Sons; 1994.
27. Gur I, Gur D, Recaberan J. The computerized synoptic operative report. a novel tool in surgical residency. Arch Surg 2011;2221−2225.
28. World Health Organization. Surgical Safety Checklist. World Health Organization; 2009, Available from: http://whqlibdoc.who.int/publications/2009/9789241598590_eng_Checklist.pdf. Accessed February 16, 2012.
29. World Health Organization. Guidelines for Trauma Quality Improvements Programmes; 2009. Available at: http://www.who.int/violence_injury_prevention/services/traumacare/traumaguidelines/en.
30. Haynes AB, Weiser TG, Berry WR, et al. A surgical safety checklist to reduce morbidity and mortality in a global population. N Engl J Med 2009;360:491−499.
31. Lee A. mHealth: a revolution or a fad. Harvard College Global Health Review 2012. Available at: http://www.hcs.harvard.edu/hghr/online/mhealth.
32. World Health Organization. mHealth: New Horizons for Health Through Mobile Technologies. 2011. Available at: http://www.who.int/goe/publications/goe_mhealth_web.pdf. Accessed October 20, 2013.
33. Vital Wave Consulting. mHealth for Development. The opportunity for mobile technology for health care in the developing world. Washington, DC and Berkshire, UK: UN Foundation-Vodafone Foundation Partnership; 2012.
34. Odero W, Rotich J, Yiannoutsos CT, et al. Innovative approaches to application of information technology in disease surveillance and prevention in Western Kenya. J Biomed Inform 2007;40:390−397.
35. Cinnamon J, Schuurman N. Injury surveillance in low-resource settings using Geospatial and Social Web technologies. Int J Health Geographics 2010;9.
36. Nielsen J, Mack RL. Usability Inspection Methods. New York: Wiley; 1994.
37. Neuman WL. Survey research. In: Social Research Methods: Qualitative and Quantitative Approaches. Boston: Pearson Education, Inc; 2006.
38. Hameed SM, Bell N, Schuurman N. Analyzing the effects of place on injury: Does the choice of geographic scale and zone matter? Open Medicine 2010;4:171−180.
39. Laupland KB, Karmali S, Kirkpatrick AW, et al. Distribution and determinants of critical illness among status Aboriginal Canadians. A population-based assessment. J Crit Care 2006;21:243−247.
40. Laupland KB, Kortbeek JB, Findlay C, Hameed SM. A population-based assessment of major trauma in a large Canadian region. Am J Surg 2005;189:571−576.