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Innovative approaches to application of information technology in disease surveillance and prevention in Western Kenya

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Abstract

We describe an electronic injury surveillance system that provides data for improving patient care and monitoring injury incidence and distribution patterns. Patients with injuries visiting a rural Kenyan primary care center were enrolled consecutively over 14 months. Injury information was added onto an existing medical record database that captures data for each patient visit. A new injury data encounter form and entry screen were created that included geographical coordinates of the injury site. These coordinates were obtained using a handheld global positioning system (GPS) device, and data were downloaded to the database and linked to each patient. We created digital maps of injury spatial distribution using geography information systems (GIS) software and correlated injury type and location with patients' clinical data. A computerized medical record system, complemented by GIS technology and an injury-specific component, presents a valuable tool for injury surveillance, epidemiology, prevention and control for communities served by a specific health facility.

Keywords: Electronic medical record; Geography information system; Injury surveillance

1. Introduction

Injuries constitute a major cause of mortality and morbidity worldwide. In 1998, 5.8 million deaths, corresponding to 97.9 per 100,000 population, and many more cases of disability resulted from injuries [1]. Injuries are responsible for about five percent of the total mortality globally, with an estimated annual economic direct cost of around 500 billion US dollars. The World Health Organization (WHO) estimates that 16% of the global disease burden is attributed to injuries [1]. Five of the top ten causes of death in the world for persons aged 15–44 years are injury-related: motor vehicle crashes, interpersonal violence, self-inflicted harm and drowning [1,2]. Most types of injuries occur more frequently among people in the middle and low-income countries and account for over 80% of all injury-related deaths [3].

The mortality data normally derived from vital registries represent fewer than 1% of all injured patients [4] and are thus just the tip of the iceberg [5]. Moreover, for each death from injury there are more than 300 injuries that result in hospitalization or treatment in emergency departments or other health care facilities [5,6]. In middle- and low-income countries, limited information is available for the vast majority of non-fatal injuries concerning their magnitude, risk factors and consequences.

Lack of comprehensive data on injuries has been recognized as a major impediment to safety promotion and injury control efforts in many developing countries [7,8]. When injury data have been collected, this has been done in large hospital-based studies. Like other countries in East Africa,

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in Kenya documentation of injuries is generally poor. For example, a recent study in Nairobi showed that more than 70% of the records of patients with road traffic injuries were inaccurate and incomplete in many data elements [9]. Whereas most hospitals and health centers in Kenya keep inpatient records for treatment and financial purposes, there are no systems to ensure accurate and complete recording, proper storage, easy retrieval, analysis and reporting of inpatient data. Outpatient or emergency room records tend to be even worse, as patients often lack unique identifiers and are normally given a new record number on each visit. Notes and treatment records are often written in free text, by hand, on pieces of paper (or booklets which patients carry home) and are often not maintained in a single file. In addition, there is no standard for the information content of such notes, which are normally sketchy and contain only a record of the diagnosis (nature of injury) and treatment. Thus, collecting even the most basic morbidity statistics is problematic. Consequently, injury morbidity data reported by hospitals grossly underestimate the true number and magnitude of nonfatal injuries and are generally biased towards more severe injuries requiring hospitalization. There is a need to develop an improved outpatient-based injury recording and reporting system to facilitate better understanding of the problem both at the local and national levels.

Outpatient health centers are a natural point of departure for public health studies of injury, in particular in areas where no other identification exists for injury sufferers besides health center records. Medical record systems that consistently collect clinical data can form the backbone on which injury data are collected. In this report we outline such a pilot project designed to address a number of these issues. The Mosoriot Electronic Injury Surveillance System (MEISS) integrates data describing the location, predisposing factors, coincidental findings, and outcomes specific to each injury event, including geographic coordinates, into an existing electronic medical record system [10–13]. As such, MEISS represents the first step in using an existing electronic clinical record system in a developing country to assess a specific important clinical problem—in this case, injury prevention—and drive prevention and control efforts.

2. Methods

2.1. Study setting

The Mosoriot Rural Health Centre (MRHC) is funded by the Kenyan Ministry of Health and is located 25 km southwest of Eldoret, the fifth largest city in Kenya with a population of approximately 400,000. The MRHC provides outpatient and limited inpatient health care services to the surrounding population of approximately 40,000 people and is a rural health-training center for nurses, community health workers, public heath technicians and traditional birth attendants. A range of primary care preventive and curative services are provided there, including general medicine, maternal child health and family planning, HIV and sexually transmitted infections, and health education. Due to limited inpatient facilities, patients can stay in the ward for up to 24 h, while follow-up services are offered for special cases such as sexually transmitted diseases. Mosoriot is one of the sentinel surveillance sites in Kenya for anonymous screening for HIV infection. An HIV treatment clinic was established in 2001, attended by physicians from Indiana University and Moi University Faculty of the Health Sciences [14].

2.2. The Mosoriot Medical Record System (MMRS)

The Mosoriot Medical Record System (MMRS) is an electronic medical record system supporting a primary care health center in rural Kenya. Implemented in 2001, it was the first ambulatory Electronic Medical Record (EMR) system in sub-Saharan Africa. Its conceptualization, design, initial development and implementation have been reported in detail elsewhere [11–13]. Briefly, the system is built on a Microsoft Access (Redmont, WA) relational database and is comprised of a Registration Module, a paper encounter form, a Data Entry module, a Reporting Module, and a Data Dictionary.

Patients are registered into the MMRS and given a plastic card with their name and MMRS number, which they are expected to bring with them at all subsequent visits in order to access their information. If a previously registered patient does not have his or her card, the MMRS registration system provides a name lookup option. Public health surveys in the villages served by the Mosoriot health center have shown that more than 90% of households can produce the ID cards for family members. [Personal communication, M.V. Otsyula, August 2003] Moreover, the MMRS has a lookup capability on the check-in screen, and the registration fields (first-Christian, middle-Kenyan, and last-family name, mother's first name, birth date) uniquely identify Kenyans, so 100% of the time if patients cannot produce their plastic ID cards, the check-in clerks are able to identify them within the system and print a new card. This process addresses one of the central problems of paper-based systems, the lack of continuity of data from visit to visit.

The MMRS data model uses the patient and visit date as the unique identifiers of the visit, the basic unit of observation. All clinical, test, pharmacy, and financial data are captured on a 1-page encounter form and are thus linked to the patient visit. These data are then used to support clinical care management, quality improvement activities, and required monthly reporting to the Kenyan Ministry of Health. A time-motion study performed before and after implementing the MMRS demonstrated time savings for both patients and health care providers [11]. The existence of an electronic medical record system and a process of individual identification, in an area where limited or no means of legal identification exists, present a host of opportunities for implementing public health projects by integrating public health information with the existing EMR system.

2.3. Design and implementation of the injury surveillance system

2.3.1. Construction of a minimum injury dataset

A minimum injury data set, modeled on the International Classification of External Causes of Injuries (ICECI) [15] and WHO [16] guidelines, was modified to suit the clinical, public health and administrative needs of the health center. The data elements captured included the core, optional, and supplemental fields shown in Table 1.

Meetings and consultations were held with the health center's head clinical officer and nurse, the administrative officer, medical records personnel, other clinical officers and nurses in all clinics, to review the draft MEISS encounter form containing injury data elements. A final 1-page injury surveillance encounter form was thus created (Fig. 1).

2.3.2. Incorporation of the injury component into the MMRS: the MEISS

To incorporate the injury encounter form into the MMRS, the system data dictionary was expanded to include codes and descriptions of all injury-related diagnoses. Descriptions of terms in the data dictionary were in accordance with the 10th edition of the International Classification of Diseases (ICD-10).

The data entry interface of the MMRS database was designed with tabs that reflect the clinic visited (e.g., adult medicine or pediatrics) and services provided at the health center such as laboratory, X-rays, pharmacy, or treatment procedures. Each tab selects a sub-screen that contains all of the fields relevant to that site or activity. Using tabs also allows for easy expansion of the MMRS to include new components such as injury-specific data. A new sub-screen for injury data fields was built onto the core MMRS and a tab was created to link it with the other clinics and activities (Fig. 2).

Table 1
Core and supplementary data collected as part of the minimum injury data set

Core	Unique Patient Identifier
	Age
	Gender
	Residence
	Mechanism or Cause of injury
	Activity or event being undertaken when the injury occurred
	Intent
	Nature of injury (diagnosis)
Supplementary	Place of occurrence of the injury
	Specific information on traffic injuries
	Type of road user
	Type of transportation
	Specific information on assaults
	Context or reasons for the assault
	Relationship of victim to assailant
	Specific information on self-inflicted injuries
	Precipitating factors
	ICD-10 code
	Estimate of injury severity
	Use of alcohol
	Patient disposition

2.3.3. Staff training

As in the initial phase of establishing the MMRS, the Mosoriot health center staff, mainly medical records clerks, nurses and clinical officers, were trained to record and enter injury data. The areas of training included definitions of data elements, recording data on the paper encounter forms and entering encounter form data into the computer. Although the current users and records clerks had previously had some basic training in data entry, more training was necessary on the expanded system to place emphasis on the new injury-related fields added to the system. The other health care providers were also trained on the new system to increase their awareness of the injury component of the MMRS. In particular, the clinical officers were trained on the use of the modified encounter forms, emphasizing the need for complete and consistent data entry. For this purpose, a detailed protocol using standardized definitions and codes was developed, and sufficient copies of injury surveillance encounter forms were made available.

With regard to the GIS component of the project, three hand-held devices for capturing geographical coordinates were purchased. Two research assistants were recruited and trained in the operation of the equipment. Bicycles and cellular phones were provided to facilitate transportation to injury sites and maintain 24-hour communication with the principal investigator (PI). The PI (WO) monitored all aspects of data collection and verified the accuracy of GPS measurements. He also visited and took digital photographs of motor vehicle accident locations to show environmental features that may have contributed to occurrence of the crash.

2.3.4. Geography information system techniques to describe spatial distribution of injuries

Using location descriptions stored in the MMRS, the assistants visited *every injury incident location* for each patient treated at Mosoriot health center during the period of the study. The location data captured by GPS were entered into the MEISS database and linked to the corresponding patient information. ArcView desktop GIS software (ESRI, Redlands, CA) was used to create maps and charts displaying the geographic distribution of locations of injuries and their relationships with environmental and demographic parameters.

2.4. Statistical analysis

Comparisons of continuous measures were performed with the Mann–Whitney two-sample test. Associations

Record #:……………………# ER Registry **Date**: ……………… **Arrival Time**: …..:….. am/pm
First Name : ………………………………….…**Middle Name**…………………………. **Last Name**…………………………………..…
Date of Birth: __/__/__ **Age:** __ __ years **Sex:** 1. □ Male 2 □ Female
Father's Name…………………………………. **Mother's Name**……………………………………………………………………….
District……………………… **Location**………………………...**Sub-Location** ………………………… **Village**…………………………
Occupation :……………………………………. **Reason for visit:** 1. □ Injury 2. □ Illness 3. □ Preventive Care (MCH/FP)

Date of Injury: (dd/mm/yy) __/__/__/ **Time of Injury**____:____ am/pm
Exact place where injury occurred: (*Name of street/road, village, farm, estate, building or house number*)
………..
Intent:
1. □ Unintentional (accidental, RTA) 2. □ Intentional (assault, violence) 3. □ Self-inflicted (suicide, attempted suicide)
4. □ Legal intervention (police, security personnel) 98. □ Other …………………99. □ Don't know

Place: *Where were you when you got injured?*
1. □ Home
2. □ Street/Road
3. □ School/ Educational area
4. □ Industry/ Construction area
5. □ Farm
6. □ Commercial area/office/shop/hotel
7. □ Sports/athletics area
98. □ Other ………………………
99. □ Don't know

Activity: *What were you doing when you got injured?*
1. □ Working -paid work
2. □ Working —unpaid work
3. □ Travelling
4. □ Studying
5. □ Sports/athletics
6. □ Leisure/playing
7. □ Vital activity- resting/ s sleeping/eating/drinking
98. □ Other…...................…
99. □ Don't know

Mechanism: *How was the injury caused?*
1. □ Traffic accident
2. □ Assault
3. □ Fall on same level/ tripped
4. □ Fall from height/ tree/roof/stairs
5. □ Blunt force/object
6. □ Fire/Hot fluid
7. □ Knife/sharp/ penetrating object
8. □ Strangulation
9. □ Drowning
10. □ Poisoning
11. □ Firearm/Gun
12. □ Machinery
13. □ Struck by or against object
98. □ Other ....
99. □ Don't know

Traffic injuries			Assaults		Self-inflicted
Type of User:	**Transport used:**	**Other Vehicle involved:**	**Relationship of victim to assailant**	**Context:** *(What was the reason?)*	**Precipitating factors:**
1. □ Pedestrian	1. □ Pedestrian	1. □ None	1. □ Spouse/ partner	1. □ Fight/quarrel	1.□ Family conflicts
2. □ Driver	2. □ Bicycle	2. □ Bicycle	2. □ Parents	2. □ Robbery	2.□ Physical problem/ disease or pregnancy
3. □ Passenger	3. □ Motorcycle	3. □ Motorcycle	3. □ Other relative	3. □ Sexual assault	3. □ Psychological/ Psychiatric condition
4. □ Motorcyclist	4. □ Car	4. □ Car	4. □ Friends	4. □ Drug-related	4. □ Financial
5. □ Bicyclist	5. □ Pick-up	5. □ Pick-up	5. □ Stranger	5. □ Other crimes	5. □ Death in family
98. □ Other.......	6. □ Truck/Lorry	6. □ Truck/Lorry	6. □ Police	6. □ Gang-related	6. □ Sexual or Physical Assault
99. □ Don't know	7. □ Bus	7. □ Bus	98. □ Other ……..	7. □ Political	98. □ Other……….
	8. □ Minibus/matatu	8. □ Minibus/matatu	99. □ Don't know	98. □ Other……….	99. □ Don't know
	9. □ Tractor	9. □ Tractor		99. □ Don't know	
	98. □ Other………	98. □ Other………			
	99. □ Don't know	99. □ Don't know			

Use of alcohol: 1. □ Suspected or evidence 2. □ Not suspected or no evidence 3. □ No information available
4. □ Not applicable (child, under 16 years)
Nature of injury:
1. □ Fracture 2. □ Sprain 3. □ Cut or open wound 4. □ Bruises, superficial wound
5. □ Haematoma/Swelling 6. □ Burn 7. □ Cerebral Concussion 8. □ Injury other organs
98. □ Other ....…….99. □ Don't know

Injury Severity: 1. □ No apparent injury 2. □ Superficial injury 3. □ Moderate (requires sutures) 4. □ Severe (requires surgery)

DIAGNOSIS: ………………………………………………………………………………… **ICD-10 CODE**……………………………..…
Patient Disposition: 1. □ Treated and sent home 2. □ Admitted 3. □ Referred to ………………hospital
4. □ Died 98. □ Other…………………… 99. □ Don't know
Patient notes:
………
………

Name of Clinician: ………………………………………………….**Date:** …………………………..

Fig. 1. Template of injury encounter form.

between categorical factors were assessed with the Fisher's exact test.

3. Results

As an illustration of the information obtained from MEISS, we provide here a small number of analyses produced with data collected with the system. We analyzed data collected from 11 November 2002 to 26 January, 2004, during which 597 patients with injuries presented to the Mosoriot health center for care. Of these, 374 (63%) were men. The median age was 25 years (1–81 years) and was not significantly different between men and women. The types of injuries are listed in Table 2. The most frequent cause of injury is assault with 220 cases (38.9%), followed by "struck by or against object" with 154 cases

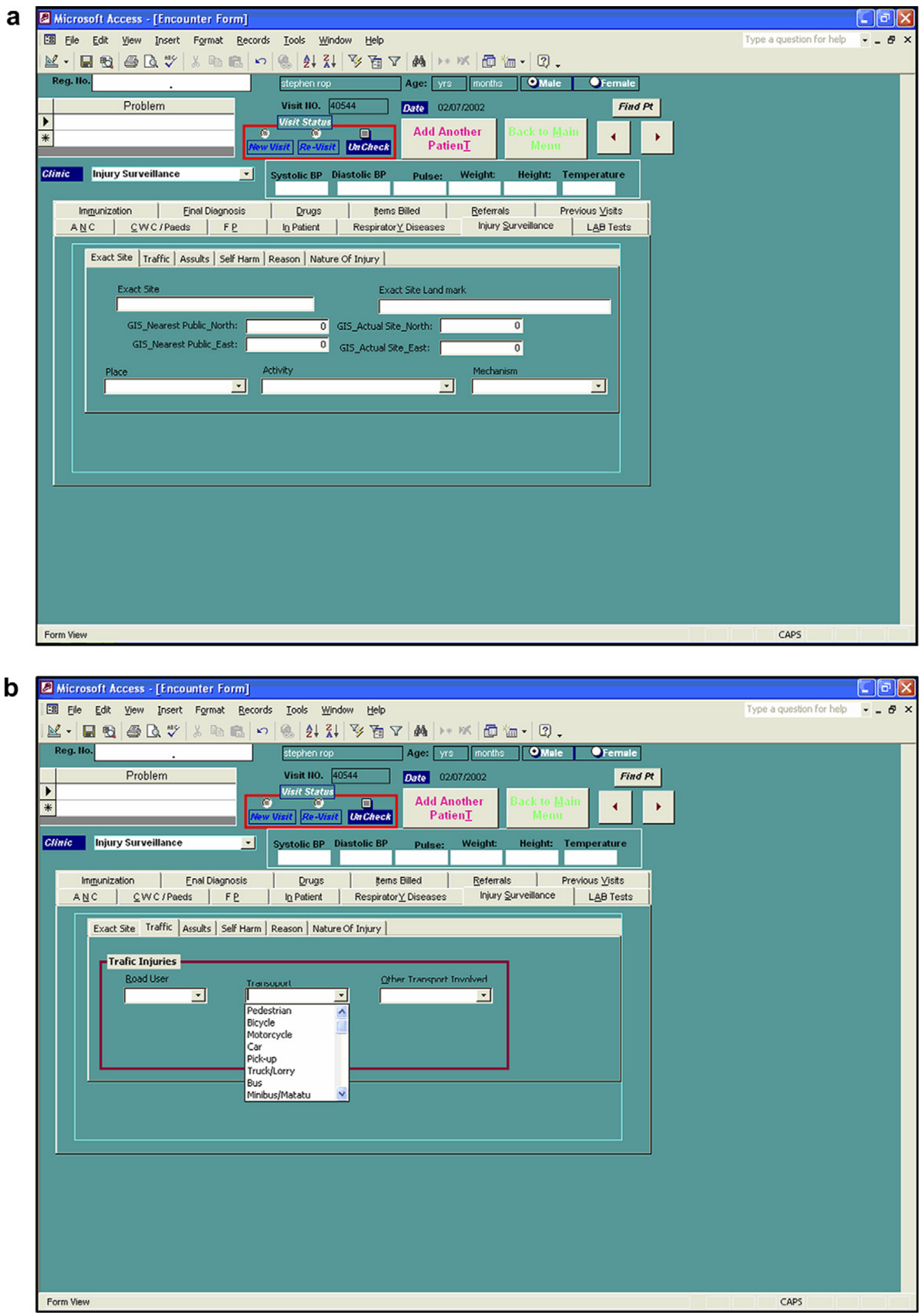

Fig. 2. The injury tab added to the Mosoriot Medical Record System. The sub-screen presented here shows the entry of the GPS coordinate for the exact location of the injury (a). Additional tabs (not shown) included coincidental information on the injury event such as the traffic injury shown here (b). Other such sub-screens included information gathered about injuries related to assaults, self-harm along with information about the reason and the nature of the injury.

Table 2
Frequency of various types of injuries

	Frequency	Percent	Cumulative percent
Traffic accident	33	6.1	6.1
Assault	209	38.8	44.9
Fall	62	11.5	56.4
Struck by object	154	28.6	85.0
Burn	32	5.9	90.9
Knife/sharp/penetration			
Object	3	0.6	91.5
Strangulation	1	0.2	91.7
Poisoning	6	1.1	92.8
Other	37	6.9	99.6
Don't know	2	0.4	100.0
Total[a]	539	100.0	

[a] Missing 59 records (9.7%) of all cases.

Table 3
Road accidents by type of user

	Frequency	Percent	Cumulative percent
Pedestrian	6	12.0	12.0
Driver	3	6.0	18.0
Passenger	19	38.0	56.0
Motorcyclist	4	8.0	64.0
Bicyclist	15	30.0	94.0
Other	2	4.0	98.0
Don't know	1	2.0	100.0
Total	50	100.0	

(28.7%) and fall 62 cases (11.3%). The type of traffic accidents is also listed in Table 3. The majority of traffic-related accidents involved bicyclists, pedestrians and passengers. The most common type of vehicle where a passenger was injured was a truck or a minivan. The majority of injuries treated at Mosoriot clinic were superficial, which is expected for an outpatient facility.

Out of the 379 injury cases involving an adult, alcohol use was suspected by the health care provider in 112 cases (29.6%) while it was not suspected in 267 cases (70.4%). Although injury severity was slightly lower for cases where alcohol use was not suspected, the difference was not statistically significant. However, alcohol use was significantly more likely among victims of assault (odds ratio 3.4%, 95% confidence interval 2.1–5.7, $p < 0.001$) (Table 4).

GIS analysis of injury location is presented in Figs. 3 and 4. In the former, the exact location and type of injury are shown along with the sublocations (Kenyan administrative area located hierarchically below district level) in the catchment area of Mosoriot Health center. In the latter, buffers of one, two and three kilometers around major roads have been drawn. The vast majority of injuries happen close to roads where population density is at its highest.

Table 4
Association of alcohol use and assault

Alcohol use	Assault		Total	*p*-value[a]
	No	Yes		
Suspected	36	67	103	<0.001
Not suspected	163	89	252	
Total	199	156	355	

[a] Fisher's exact test.

4. Discussion

The MEISS represents the first step in using an existing electronic clinical record system in a developing country to assess a specific important clinical problem—in this case, injuries—that can drive prevention and safety promotion efforts. It is significant because early experience with the system presented here shows that it can dramatically improve the content and quality of injury data as well as provide timely information for patient care, targeted interventions, public health education and research, and health service administration.

In this study we focused on the description of the MEISS, and the integration of data captured by an existing electronic medical record system, a global positioning system (GPS) and an additional public-health component containing information on predisposing factors, coincidental findings and outcomes specific to each injury event. Through a brief illustration of findings and analysis of data produced by the system, we showed how the EMR, GPS and public health components of the system worked seamlessly to provide important data that can be used to improve patient care and monitor injury incidence and distribution patterns. For example, mapping of sites of different types of injuries revealed that most injuries treated by this health center occur within a distance of 2 km of the rural road network. There is also some preliminary evidence of an inverse spatial relationship between high injury incidence and distance from the health center and correlation between injury density and population density (analyses not shown here). A more detailed review of the main study findings will be the object of a future publication.

Implementing EMRs in developing countries has its challenges. As the authors have described elsewhere [11–13,17], these challenges included infrastructure (e.g., an unreliable electricity grid), lack of a national identifier, lack of computer experience among clinic clerks, and a culture that relies on logbooks and registries rather than individual linked patient records. Overcoming these barriers required technology (e.g., solar-powered backup batteries) and a close collaboration between the developers and the clinic's administrators and clinicians. Once they embraced the MMRS as *their medical record*, the cultural and organizational barriers could be overcome by collaborative problem solving.

Use of the MEISS had its own challenges. The clerks initially required a small financial incentive to complete the MEISS form, which took 5–10 min to complete, as it was part of a research project seen by the clinic personnel as

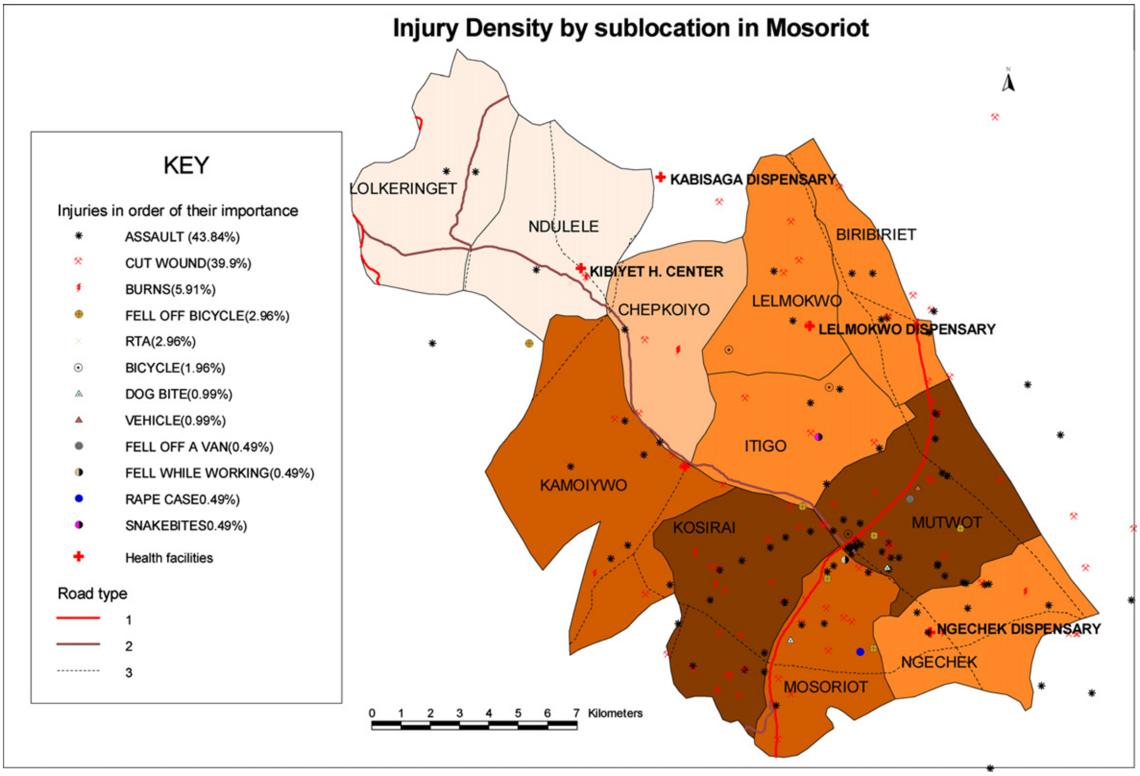

Fig. 3. Integration of the injury data collection into the Mosoriot Medical Record System.

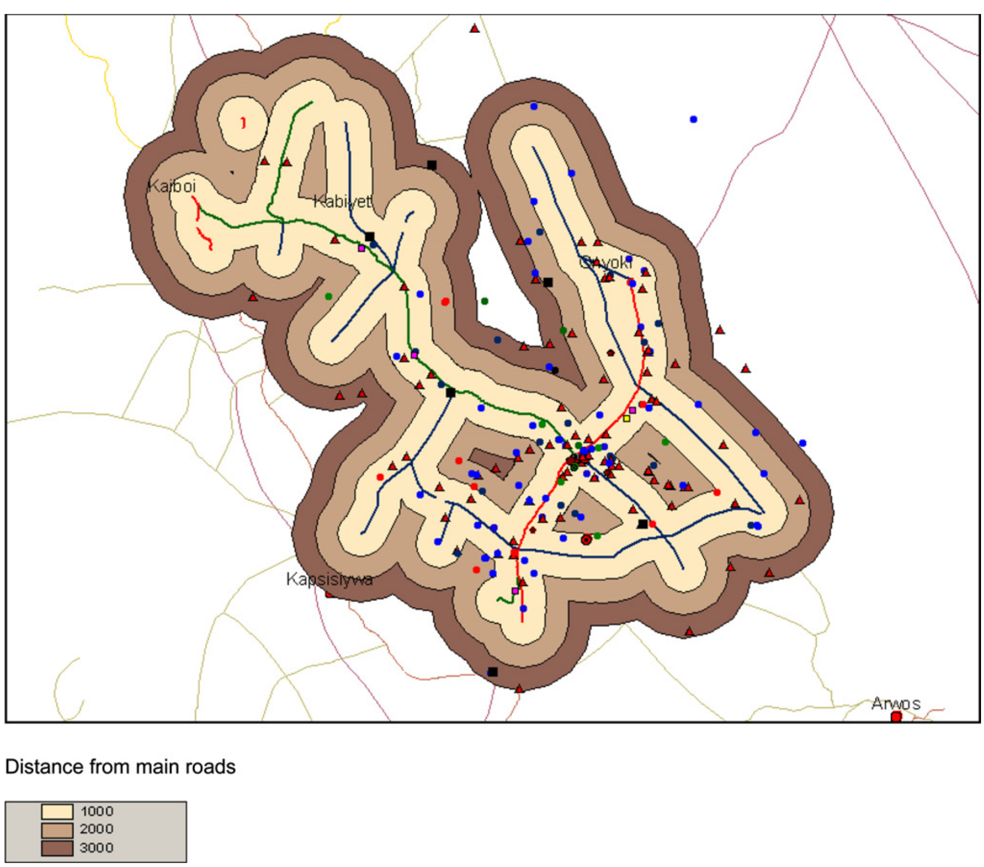

Fig. 4. Location of injury events in relation to major road arteries.

being separate from their assigned clinical activities. The research assistant had to use descriptive data on the location of an injury to find the spot on which to make the GPS recording. This required multiple iterations of the data collected on location in order to make it sufficiently descriptive.

The study demonstrates that using existing patient data systematically captured by and stored in a computerized medical record system, along with coincidental findings and spatial location analyzed by GIS, can identify areas of clustering of particular injuries, and can be used for targeting local injury prevention and control efforts. The results illustrate the potential for integration of electronic health record systems and GIS technology for public health functions. Although a small number of studies have reported the use of a similar approach in the surveillance of specific injuries [18–21], this is, to our knowledge, the first such study conducted in a developing country where the burden and consequences of injuries are the greatest. This report presents an example of how a simple and inexpensive computerized medical record system can be established and used, in combination with GIS technology and injury-specific data, to generate accurate and timely information for patient care, monitor distribution patterns and develop targeted interventions for injuries in a defined rural community in Kenya.

The combination of EMRs and GPS could have important uses in clinical care in developing countries. In particular, GPS is going to have a major role in the expanding network of HIV clinics that are being run through a collaboration between Indiana University in the U.S. and Moi University in Kenya. [22] Specifically, GPS will enhance outreach to those who are lost to follow-up, which is a major problem in developing countries where poverty and lack of transportation result in missed visits which, among patients treated with anti-AIDS drugs, can lead to HIV being resistant to these drugs. This GPS tracking system is necessary because Kenyan homes lack street addresses and the dirt roads to their homes are complex and constantly changing. Also, a home-based care program will use GPS to not only track HIV/AIDS patients but also look for geographic clusters of problems (e.g. diarrhea) and risk factors (e.g., contaminated wells). This will be facilitated by direct download of GPS data to the next generation of the MMRS [23] that is supporting the network of 17 urban and rural HIV/AIDS clinics maintained by the Indiana/Moi University collaboration [21]. This marriage of and EMR to GPS can facilitate the interaction of clinical medicine and public health approaches to battling the conditions causing extensive morbidity, mortality, and reduced life expectancy that afflicts the developing world.

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