Determination of true patient origin through motorcycle mapping: design and implementation of a community-defined geographic infrastructure surveillance tool in rural Sierra Leone

Edward J. M. Monk[a,*,1], Ka-Ping Yee[b], Rupert Allan[b] and Ivan B. Gayton[b]

[a]Nixon Memorial Methodist Hospital, Segbwema, Kailahun District, Sierra Leone; [b]Missing Maps, London, EC4A 1AB, UK

*Corresponding author: Telephone: +44 (0)27074046600; E-mail: ejmmonk@gmail.com
[1]Present address: C/O Médecins Sans Frontières UK, London EC4A 1AB, UK.

Background: Village-level geographic infrastructure data are often insufficient in low-resource settings, despite accurate patient origin determination being essential for surveillance and outbreak management. We detail a novel and seemingly reliable method for the determination of true patient origin with proof of concept in rural Sierra Leone.

Methods: Potential villages (n=2263), identified within a 7800 km^2 hospital catchment area from satellite imagery, were accessed by motorcycle and surveyed in person, capturing village name and community-defined section/chiefdom/district.

Results: A survey established 1740 inhabited villages and a village of origin determination tool (gazetteer) was produced. Recording the district/chiefdom/section/village at hospital registration allowed Global Positioning System patient origin determination in 2277/2344 (97.1%) attendances.

Conclusions: Our proof of concept reports a substantial and sustained record of true patient origin in a low-resource setting.

Keywords: contact tracing, epidemics, geographic information systems, maps, West Africa

Introduction

Surveillance and contact tracing is a fundamental component of health protection and outbreak management, often hindered in health care settings of low- to middle-income countries (LMICs) by a lack of pre-existing record of village-level geographic infrastructure.[1] One recent example is from the 2014–2016 West Africa Ebola outbreak, where phonetic record of village of origin at registration, paired with time, direction and method of travel, were not a reliable method to determine true patient origin, as villages often shared the same name and had multiple names with multiple spellings.[2] In June 2017, we found a similar phenomenon after interrogating patient records at Nixon Memorial Methodist Hospital, Segbwema, Kailahun District, Sierra Leone. We describe the design and implementation of an in-field method for the determination of true patient origin and demonstrate its feasibility through proof of concept in rural Sierra Leone.
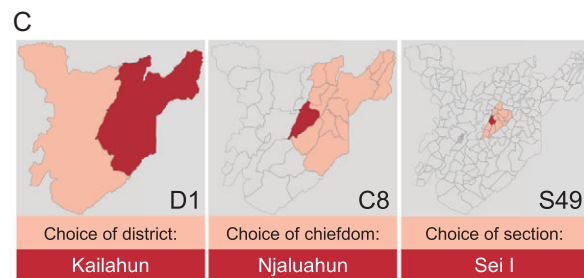
Materials and methods

Potential villages within the Nixon Memorial Methodist Hospital's catchment area (7800 km^2), spanning the districts of Kailahun and Kenema, were identified and digitalised from satellite imagery by mapping volunteers (Missing Maps and Humanitarian OpenStreetMap Team) to produce 2263 clusters of community dwellings (polygons).

Twelve community members were trained locally as surveyors (each for 2 d) and paired with experienced motorcycle riders. Recruitment criteria included smartphone ownership and test-survey ability; the surveyors' education level was rarely post-secondary schooling. Ground-level community member surveys were conducted at every polygon generated from satellite mapping, each representing a potential village. Survey tools OpenDataKit and OsmAnd were utilised. The design aimed to capture all names held by the community for each village and establish the community's definition of geographical country

A
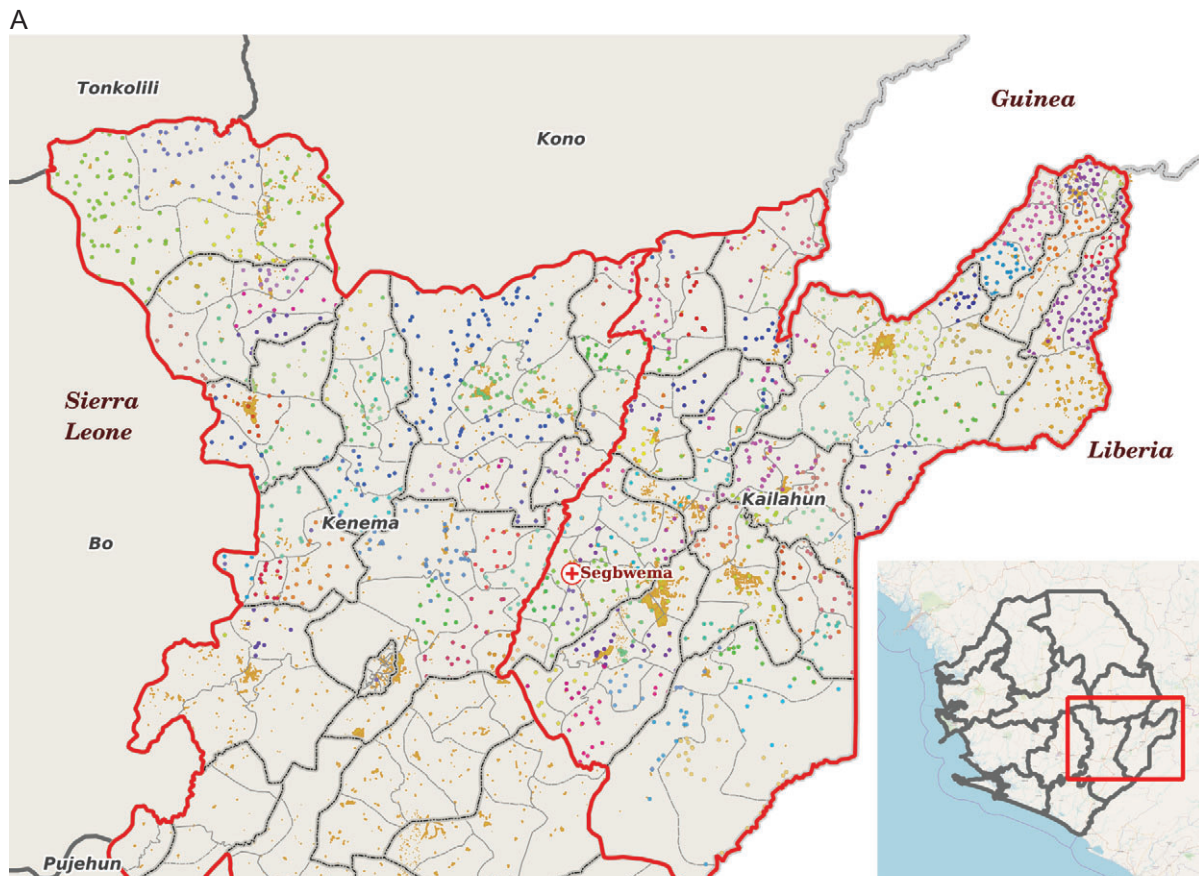
B

Page	Title	Question	Answer	Turn to...
Cover	START	What is your district?	North Atlantis	...page D1
			South Atlantis	...page D2
D1	North Atlantis	What is your chiefdom?	Highland	...page C1
D2	South Atlantis	What is your chiefdom?	Midland	...page C2
			Lowland	...page C3
C1	Highland	What is your section?	Rosewood	...page S1
			Greenwood	...page S2
C2	Midland	What is your section?	Lakewood	...page S3
			Rosewood	...page S4
C3	Lowland	What is your section?	Westwood	...page S5

C

		D1		C8		S49
Choice of district:			Choice of chiefdom:			Choice of section:
Kailahun			Njaluahun			Sei I

Page	Title	Question	Answer	Other names	Village chief	Coordinates	Unique sequence of responses from patient
S1	Rosewood	What is your village?	Newton		T Wilson	12.02, 29.83	*North Atlantis, Highland, Rosewood, Newton*
			Smallville	Littleville	P Baker	12.07, 29.74	*North Atlantis, Highland, Rosewood, Smallville*
			Redville		S Richards	12.05, 29.91	*North Atlantis, Highland, Rosewood, Redville*
S2	Greenwood	What is your village?	Springton		A Thomson	12.21, 28.32	*North Atlantis, Highland, Greenwood, Springton*
			Newton		N Barber	12.27, 28.71	*North Atlantis, Highland, Greenwood, Newton*
S3	Lakewood	What is your village?	Clifton		H Farmer	11.97, 27.72	*South Atlantis, Midland, Lakewood, Clifton*
			Eastville	Ostville	E Good	11.87, 27.46	*South Atlantis, Midland, Lakewood, Eastville*
			Newton		V Smith	11.79, 27.51	*South Atlantis, Midland, Lakewood, Newton*
			Rockton	Rocktown	C Knight	11.81, 27.62	*South Atlantis, Midland, Lakewood, Rockton*
			Stoneville		D Walker	11.88, 27.77	*South Atlantis, Midland, Lakewood, Stoneville*
S4	Rosewood	What is your village?	Summerville		J Black	11.82, 28.01	*South Atlantis, Midland, Rosewood, Summerville*
			Redville		M Waters	11.89, 28.04	*South Atlantis, Midland, Rosewood, Redville*
			Pineville		H Morgan	11.91, 28.07	*South Atlantis, Midland, Rosewood Pineville*
S5	Westwood	What is your village?	Stoneville		W Dean	12.35, 30.02	*South Atlantis, Lowland, Westwood, Stoneville*
			Grassville		S Stevens	12.44, 30.07	*South Atlantis, Lowland, Westwood, Grassville*

Figure 1. (**A**) Surveyed villages within the catchment area of Nixon Memorial Methodist Hospital (based in Segbwema, labelled). Clusters of villages of the same colour represent villages self-identifying to be within the same section, the lowest administrative division of the gazetteer. (**B**) Illustration of the gazetteer design, as if generated from data collected from the survey of 15 imaginary villages within a fictional country, Atlantis. The organisational hierarchy is that of Sierra Leone: villages within sections, sections within chiefdoms, chiefdoms within districts. The gazetteer guides the record keeper at the point of use through several steps of inquiry in order to establish a patient's true origin; the patient's sequence of responses uniquely identifies their true village (and thus geolocation) despite name duplication at the village and section level of the nested hierarchy. (**C**) An example of the geographical area covered by each level of the gazetteer, using Nixon Memorial Methodist Hospital's district (page D1), chiefdom (page C8) and section (page S49).

structure in which that village existed (section/chiefdom/district). Global Positioning System (GPS) coordinates were also captured during the survey (Figure 1).

A framework was developed from survey responses, organising villages within the established community-defined levels of geographical structure and providing a comprehensive list of chiefdoms within each district, sections within each chiefdom and villages within each section. A gazetteer (structured codex of all villages) was produced from this framework, providing a tool for patient origin enquiry at hospital registration through systematic record of a patient's district/chiefdom/section/village of origin. Survey responses offered a series of answers, based on this structure, unique to each village and linked to a GPS coordinate. The gazetteer was implemented at Nixon Memorial Methodist Hospital in August 2017.

Figure 1 includes an example of a gazetteer designed for 15 villages within five sections of three chiefdoms across two districts. Even with duplicity of names at both the section and village level, this gazetteer example allows GPS coordinate record of true patient origin as long as there is not duplicity within a single layer of the structure (e.g. two villages with the same name in the same section). The survey included the names of prominent community members (e.g. village chiefs/healthcare workers) to help distinguish between villages in such cases.

Results

The hospital's 7800 km^2 catchment area was covered in 102 working days (256 person working days) with an average of 8.8 polygons visited per surveyor per day. Of the 2263 polygons, 1740 (76.9%) were inhabited villages and the remainder were abandoned. Inhabited villages were at a density of 0.22 villages/km^2 and had a median dwelling count of 30 (interquartile range 15–108). There were 1396 distinct primary village names between the 1740 inhabited villages, with 514 villages (29.5%) sharing names; 1226 names (87.8%) were held by only one village, 96 (6.9%) by two villages, 33 (2.4%) by three villages and 41 (2.9%) by four or more villages. The survey revealed 481/1740 villages (27.6%) had village-level access to a water pump, 54/1740 (3.1%) had a market for at least 1 d of the week and 151/1740 (8.7%) a health care facility (primary health unit, hospital or 'other').

The final gazetteer organised the 1740 villages within the catchment area into a nested structure of 133 sections within 25 chiefdoms across the two districts. Between 1 August 2017 and 31 January 2019, 2277/2344 (97.1%) hospital attendances had district, chiefdom, section and village recorded and could be assigned to a GPS coordinate of origin. Record at the section level was available for 2324/2344 (99.1%) of attendances. Retrospective determination of patient origin could be achieved for patients that attended prior to gazetteer implementation, but only if their village of origin had a unique name and it was assumed they originated from within the catchment area.

Suburban patient locator tools have been developed and validated previously for clinic/hospital attendance but, to our knowledge, our method is the first reported for a large rural catchment area.[3] The demographic presenting to Nixon Memorial Methodist Hospital appeared to reflect that of the local population, but multiple factors across the catchment area comprised a barrier to health care access. Most importantly, these would have been enhanced with distance and poverty; poorer communities furthest from the hospital were more likely to use alternative health care facilities or traditional healers.[4] The gazetteer's potential utility, however, is by no means limited to Nixon Memorial Methodist Hospital; application could include health care and non-health care settings across the wider community.

Conclusions

Although GPS technology is widely available, accurate records of geographic community organisation are often lacking in LMIC settings. Where new technology replaces or advances existing systems, it is vital not to neglect gaps that remain or develop in basic infrastructures, especially as they are relied upon to a greater extent during periods of emergency and a key component of epidemic preparedness.[5] Our novel method for ensuring the recording of true patient origin builds a framework on which to map local units of interest through village-level surveys and develop community-defined strata of geographic organisation and infrastructure. Our proof of concept allows insights into scalability and reports ongoing success within a health care setting of relatively low resources 18 months after implementation.

References

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