

# Controlling the last known cluster of Ebola Virus Disease

Before the latest localised outbreak, Liberia was declared free of Ebola in May. This is the fascinating story of how transmission was finally terminated

As one of the three West African countries highly affected by the 2014–2015 Ebola Virus Disease (EVD) epidemic, Liberia reported approximately 10 000 cases.<sup>1</sup> The Ebola epidemic in Liberia was marked by intense urban transmission, multiple community outbreaks with source cases occurring in patients coming from the urban areas, and outbreaks in healthcare facilities (HCFs).<sup>2,3</sup> This report, based on data from routine case investigations and contact tracing, describes efforts to stop the last known chain of EVD transmission in Liberia. The index patient became ill on 29<sup>th</sup> December 2014, and the last of 21 associated cases was in a patient admitted into an EVD treatment unit (ETU) on 18<sup>th</sup> February 2015. The chain of transmission was stopped because of early detection of new cases; identification, monitoring, and support of contacts in acceptable settings; effective triage within the healthcare system; and rapid isolation of symptomatic contacts. In addition, a ‘sector’ approach, which divided Montserrado County into geographic units, facilitated the ability of response teams to rapidly respond to community needs. In the final stages of the outbreak, intensive coordination among partners and engagement of community leaders were needed to stop transmission in densely populated Montserrado County. A companion report describes the efforts to enhance infection prevention and control efforts in HCFs.<sup>4</sup> After 19<sup>th</sup> February, no additional clusters of EVD cases have been detected in Liberia.\* On 9<sup>th</sup> May, the World Health Organization (WHO) declared the end of the EVD outbreak in Liberia.

## Evolution of the cluster

The index patient in this cluster was a woman aged 50 years who became ill on 29<sup>th</sup> December 2014, in a community near St. Paul River Bridge in Montserrado County (Monrovia). After seeking care from an herbalist in her community, the patient presented to an HCF on 4<sup>th</sup> January with high fever, red eyes, and cough. EVD was suspected, but she refused referral to an ETU and was sent home with antibiotics and antipyretics. On 5<sup>th</sup> January, she was admitted to an ETU and died later that

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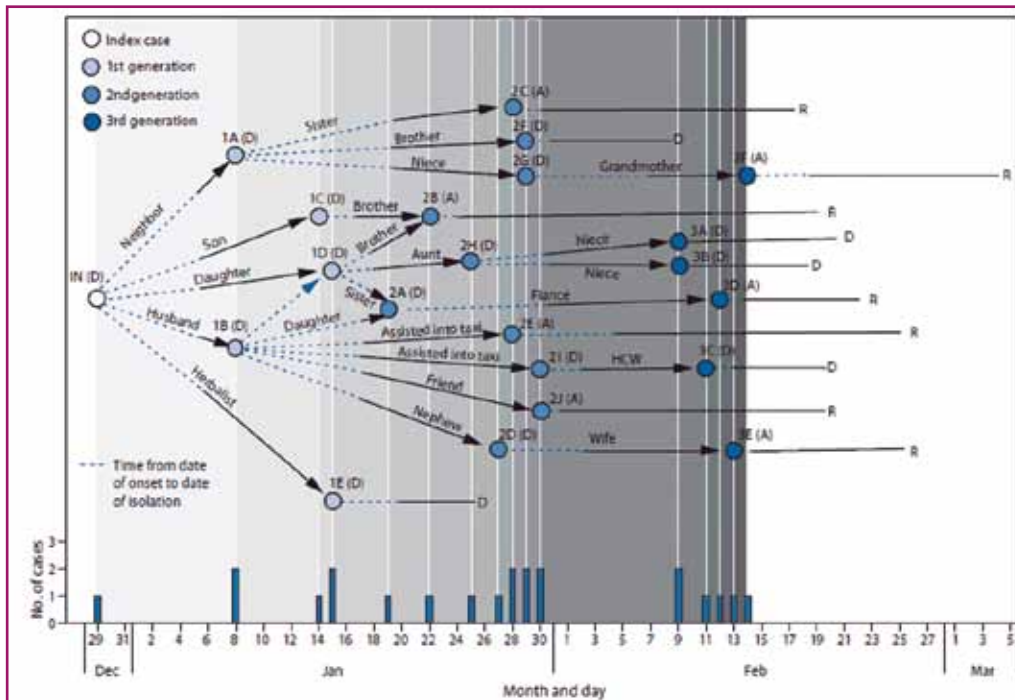
Tolbert Nyenswah, Mosoka Fallah, Sonpon Sieh, Karsor Kollie, Moses Badio, Alvin Gray, Priscilla Dilah, Marnijina Shannon, and Stanley Duwor, all from the Ministry of Health and Social Welfare, Liberia; Chikwe Ihekweazu, Thierry Cordier-Lasalle, Shivam A. Shinde, Esther Hamblion, Gloria Davies-Wayne, Murugan Ratnesh, and Christopher Dye, all from the World Health Organization; Jonathan S. Yoder, Peter McElroy, Brooke Hoots, Athalia Christie, John Vertefeuille, Sonja J. Olsen, A. Scott Laney, Joyce J. Neal, Thomas R. Navin, Stewart Coulter, Paran Pordell, Terrence Lo, Carl Kinkade, and Frank Mahoney, all from the Centers for Disease Control and Prevention.

day. A postmortem swab of oral fluids tested positive for EVD by polymerase chain reaction. Her family reported no known contact with other EVD patients, although other EVD cases had been reported in the same neighbourhood. In addition, before her illness, the woman had travelled to Grand Cape Mount County, where EVD transmission was ongoing.

Over the following 7 weeks, 21 additional persons with laboratory-confirmed EVD were linked to this case: 11 family members, six neighbours, two community members, one healthcare worker, and an herbalist (Figure 1). These cases occurred in three generations, all epidemiologically linked to the index case. The time interval from onset of illness to admission to an ETU decreased with each generation of cases. Twenty patients (including the index patient) received treatment at an ETU, including 13 patients who died. The two associated EVD-infected persons who did not seek care in an ETU died in the community. Five first-generation patients were admitted to an ETU on average 6.0 days (range = 2–11 days) after illness onset. Ten second-generation patients averaged 4.7 days (range = 1–11 days) from symptom onset to ETU admission or death in the community. The six third-generation patients averaged 1.5 days (range = 0–4 days) from symptom onset to ETU admission (Table 1). The case-fatality rates among the successive generations were 100%, 60%, and 50%, respectively. Probable transmission for 18 of the cases (86%) occurred within 1 kilometer of St. Paul River Bridge in Montserrado County, whereas transmission for three cases occurred near Red Light, 15 kilometers southeast of St. Paul River Bridge (Figure 2).

Five patients worked in an HCF, three as cleaners (1A, 2C, and 3D) and two as healthcare providers (3A and 3C). However, the cleaners and one health care provider (3A) had significant household exposures with persons with confirmed EVD that could account for their infection (Figure 1). One patient (1B) travelled to Red Light while symptomatic, became incapacitated in the community, and exposed two persons (2E and 2I) who assisted him into a taxi. One of these men later exposed patient 3C, a healthcare provider working in Red Light.

According to information provided by patients or their family during case investigations, several symptomatic patients sought care in counties outside of Montserrado to conceal their illness or obtain more affordable medical care. Patient 2A travelled from Montserrado to Bomi County to seek care at an ETU; 2G travelled to Bomi County to access an affordable appendectomy, but was turned back at a county checkpoint; 2H travelled from Montserrado to Lofa County and was transported by ambulance to an ETU in Bomi; and 2D,



Abbreviations: D = dead; A = alive; R = recovered.

\* In this transmission network diagram, date of onset of Ebola symptoms of confirmed cases (dot) is followed by a period of infectiousness (dotted line); time from date of isolation or safe burial to onset of the next generation case (black arrow); and time from date of isolation or safe burial to final disposition (solid black line). Dot colour represents generation. Cases are identified by a two character abbreviation: generation number and sequential lettering based on onset date. Survival status is indicated after each case abbreviation.

Figure 1: Transmission diagram for the last known cluster of Ebola Virus Disease cases (N=22) - Liberia, 29<sup>th</sup> December 2014 - 5<sup>th</sup> March 2015\*

to avoid detection, travelled to Margibi County under a different name, sought care twice from a non-ETU HCF, and died there in the community (Figure 1). His wife (3E) resided in Margibi County and became infected while caring for him. At least eight patients sought care at non-ETU HCFs before their EVD diagnosis in nine facilities in Montserrado County and one in Margibi County, exposing a total of 166 healthcare workers.<sup>4</sup>

In several instances, challenges with HCF triage contributed to missing patients with suspect or probable EVD. One patient (1A) tested positive for malaria and was sent home from an HCF. One initially afebrile patient (2G), with clinical symptoms consistent with appendicitis or pelvic inflammatory disease, received care at two clinics and was hospitalised at a third facility for 7 days before being transferred to an ETU. A symptomatic, high-risk contact (3C) under daily monitoring, presented for care at an ETU but was sent home despite a history of exposure to body fluids of a confirmed EVD patient because his temperature was <math>100.4^{\circ}\text{F}</math> (<math>38.0^{\circ}\text{C}</math>). Two days later, he presented with symptoms at the non-ETU HCF where he worked and was sent to an ETU, where EVD was confirmed.

Contact tracing identified 745 contacts for this cluster over the 6-week period, including the 166 healthcare workers from 10 HCFs.<sup>4</sup> During the response to this cluster, considerable efforts were made to address

the needs of high-risk contacts (e.g., those with documented exposure to body fluids of persons with confirmed EVD). In some instances, contacts agreed to home-based quarantine, and groups of contacts agreed to facility-based observation (i.e., direct daily symptom and temperature monitoring in an HCF), where they could be immediately isolated if symptoms developed, without risk of community transmission. Incomplete contact tracing contributed to the persistence of this cluster; only 15 (68%) of the cases were in persons listed as known contacts;

60% of first and second generation and 100% of third generation cases were in persons who were known contacts (Table 1). Several patients in the cluster denied EVD symptoms or exposure to persons with confirmed EVD when seeking care, reportedly because of fear of community stigma and apprehension of ETUs. At least one child (1D) was hidden from contact tracers when they visited. Persons who initially presented to non-ETU HCFs were less likely to be listed as contacts; two (25%) of eight persons who initially presented to non-ETUs were known contacts, compared with 13 (93%) of 14 who first presented for care at an ETU. Although guidance called for immediate isolation of symptomatic contacts, nine (75%) known contacts were isolated  $\geq 2$  days after symptom onset. The last confirmed case in this cluster (3F) was in a person admitted to an ETU on 18<sup>th</sup> February and discharged on 5<sup>th</sup> March. The last cluster-associated contacts who did not become ill exited monitoring on 11<sup>th</sup> March.

**Discussion**

This network of EVD transmission in Liberia illustrated numerous challenges that persisted throughout the epidemic: fear of stigmatisation in the community, delays in seeking treatment, inadequate triage in HCFs, lack of recognition of EVD cases, and incomplete identification and follow-up of some contacts. The motivations

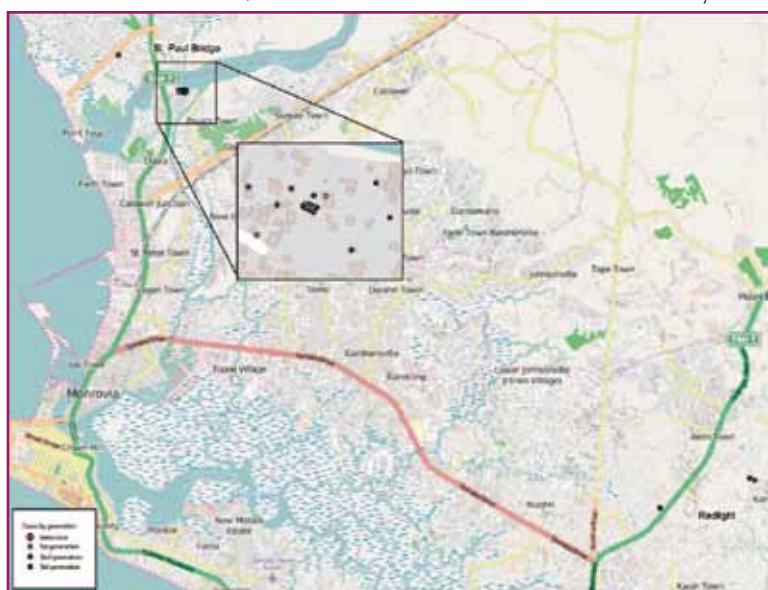
Characteristic	Transmission generation			
	Total (N=22)*	1st (n=5)	2nd (n=10)	3rd (n=6)
Average age (years) (range)	36 (10–60)	32 (10–60)	34 (13–55)	41 (24–58)
Average no. of symptomatic days in the community (range)	4.2 (0–11)	6 (2–11)	4.7 (1–11)	1.5 (0–4)
Female	12	2	5	4
Survived	7	0	4	3
<b>Transmission location</b>				
Montserrado County, Sector 2	18	5	8	4
Montserrado County, Sector 4	3	0	2	1
Margibi County	1	0	0	1
<b>Initially listed as contact</b>	15	3	6	6
<b>Visited non-ETU while symptomatic</b>	8	2	4	1
<b>Abbreviation:</b> ETU = Ebola treatment unit. * Includes index patient.				

Table 1: Characteristics of patients with Ebola Virus Disease (EVD) in the last known cluster of EVD (N=22\*), by transmission generation - Liberia, January - February 2015.

for denying EVD symptoms and resisting treatment are complex, but include stigma, fear, and denial related to possible EVD infection, mistrust of ETUs, and low medical literacy. Despite the widespread availability of ETUs in Montserrado County, some persons opted for care at distant ETUs or care in non-ETU settings, where, consequently, large numbers of healthcare workers were exposed. Delayed treatment might have contributed to worse outcomes in the first two transmission generations compared with the last generation, when patients sought care more promptly. Triage systems did not fully prevent EVD patients from being admitted to HCFs rather than ETUs. Despite these challenges, the last cluster of EVD in Liberia was controlled because of successful implementation of known effective EVD control strategies, including early detection of new cases; identification, daily monitoring, and support of contacts in acceptable settings; effective triage within the healthcare system; and rapid isolation of symptomatic contacts.<sup>2,3</sup>

To improve case investigations and contact tracing, Montserrado County had coincidentally decentralised management of outbreak activities in the four geographic sectors. This decentralised, 'sector' approach might have reduced the risk for community transmission. Each geographic sector had multidisciplinary teams led by coordinators located in each sector to manage and coordinate outbreak response activities at the sector, zone, and block level. Sector teams were empowered to make decisions related to control activities locally, and this enabled flexible adaptation of accepted outbreak control principles to fit local circum-

stances. Strategies included the use of home-based and community quarantine and facility-based observation, with provision of basic needs and psychosocial support, active case-finding, and outreach to religious and community leaders to allay the fears of affected households and community members. Although decentralisation of sector management presented initial communication and coordination challenges, the enhanced sector-based efforts resulted in more complete contact tracing, more prompt isolation of symptomatic patients in the second and third generations of transmission, increased survival, and reduced transmission in the community.



\* N=21 for Montserrado County; one other case in this cluster of 22 cases occurred in Margibi County.

Figure 2: Ebola Virus Disease (EVD) cases (N=21) in the last known cluster of EVD, by location and transmission generation - Montserrado County,\* Liberia, January - February 2015.





Micrograph of Ebola Virus Disease transmission electron

As the threat of EVD wanes, much needed non-EVD health services are resuming in Liberia. However, comprehensive triage for EVD<sup>3</sup> and appropriate personal protective equipment (PPE) are crucial but cannot completely eliminate risk for EVD transmission at HCFs. At least eight cases in the cluster described in this report were in patients who sought care at non-ETU HCFs; six (75%) of these were not listed as contacts, highlighting the critical importance of comprehensive contact tracing. These eight patients were treated by HCFs despite the universal requirement of triage. At least four patients in this cluster did not have fever when presenting for care; some HCFs and contact tracers used lack of fever as a de facto indicator to rule out EVD (i.e., rather than completing a comprehensive triage), highlighting the limitations of temperature-based triage. Conversely, many non-EVD patients had illnesses that met the case definition but could not be tested without transfer to an ETU, where care for their non-EVD medical conditions would not be offered. Despite these challenges, only one of the exposed healthcare workers in this cluster became infected with EVD, and no additional transmission occurred in HCFs, possibly because of timely, targeted infection prevention and control training and provision of PPE.<sup>4</sup> Additionally, the most recent EVD patient was appropriately triaged to an ETU when she presented to a non-ETU HCF.<sup>5</sup>

In contrast to earlier in the EVD epidemic, sector-based intensified contact tracing and in-depth case investigation, widespread infection prevention and control efforts,<sup>3</sup> and coordination of case investigation and contact tracing activities between Montserrado and other counties<sup>6</sup> were key to stopping this final chain of EVD transmission. The risk for re-introduction of EVD into Liberia will remain high as long as transmission continues in the region. National efforts to strengthen surveillance, alert and response, border screening, and triage and

infection prevention and control in HCFs are high-priority activities in the government of Liberia's recovery plan.

\* Another single case occurred in a person who received a diagnosis of EVD on 20<sup>th</sup> March 2015, and was not connected to this cluster.<sup>5</sup>

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