REVIEW ARTICLE

How can health systems be strengthened to control and prevent an Ebola outbreak? A narrative review

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The emergence and re-emergence of infectious diseases are now more than ever considered threats to public health systems. There have been over 20 outbreaks of Ebola in the past 40 years. Only recently, the World Health Organization has declared a public health emergency of international concern (PHEIC) in West Africa, with a projected estimate of 1.2 million deaths expected in the next 6 months. Ebola virus is a highly virulent pathogen, often fatal in humans and non-human primates. Ebola is now a great priority for global health security and often becomes fatal if left untreated. This study employed a narrative review. Three major databases – MEDLINE, EMBASE, and Global Health – were searched using both 'text-words' and 'thesaurus terms'. Evidence shows that low- and middle-income countries (LMICs) are not coping well with the current challenges of Ebola, not only because they have poor and fragile systems but also because there are poor infectious disease surveillance and response systems in place. The identification of potential cases is problematic, particularly in the aspects of contact tracing, infection control, and prevention, prior to the diagnosis of the case. This review therefore aims to examine whether LMICs' health systems would be able to control and manage Ebola in future and identifies two key elements of health systems strengthening that are needed to ensure the robustness of the health system to respond effectively.

Keywords: *Ebola virus*; *outbreak*; *prevention*; *control*; *health system*; *low- and middle-income countries*

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The emergence and re-emergence of infectious, zoonotic, high-risk diseases are now more than ever considered threats to public health systems (1–3). The most profound consequences of the recent outbreak of Ebola virus disease (EVD) were felt in Western Africa due to the failure of today's health governance (4). Rid and Emanuel (5) argue that global response mechanisms were relatively poor as a consequence of poor infrastructure, fragmented health systems, and inadequate experimental treatments. This paper addresses an overarching research question: What have been the weaknesses of primary healthcare systems in low- and middle-income countries (LMICs), and how might they be strengthened to ensure better control and prevention of Ebola outbreaks in future?

Methods

This study utilised a narrative review of the papers focusing on EVD and health systems in relation to control and prevention in the primary healthcare context. Petticrew and Roberts (6, p. 39) argued that narrative review refers to 'a systematic review that synthesises the individual studies narratively' (rather than by means of a meta-analysis). This involves systematically extracting, checking, and narratively summarising information on their methods and results relating to a specific research question to provide 'informative and evidence-based' answers. The Institute of Medicine (7, p. 82), however, alerts the narrative reviewer to the danger of incorrect conclusions, and ultimately wrong decisions or recommendations if they 'fail to acknowledge or address the risk of reporting biases, neglect to appraise the quality of individual studies included in the review, and (they) are subject to errors during the data extraction and analysis'.

Three major electronic databases (MEDLINE, EMBASE, and Global Health) were searched using both 'text-words' and 'thesaurus terms', focusing on Ebola and

1

health systems in LMICs. These databases were considered the best known, having international coverage of over 80 countries and about 15,000 journals indexed, alongside their vast resources capturing the fields of medicine, international health, and related disciplines.

The disease

Ebola virus is a highly virulent pathogen. It is an RNA virus and member of the filovirus family, one of four families of viruses which can cause viral haemorrhagic fever, a severe multisystem syndrome which is often fatal in humans and non-human primates. The incubation period varies between 1 and 21 days; however, patients are not considered infectious until they develop symptoms (8). During outbreaks, the risk of person-to-person transmission through contact with body fluids from infected patients is very high, particularly during the late stage of the disease (9) and touching cadavers has been shown to be a significant risk factor associated with developing EVD (10–12). Indeed, in Guinea, during the 2014 EVD outbreak, 60% of cases were found to be linked to traditional burials (13).

Despite the severity of the symptoms, a 56% survival rate may be seen in the present outbreak, but considerably higher rates have been seen in previous outbreaks; for example, in Uganda, the case fatality rate for Bundibugyo strain infections was only 25% and in Europe it was only 22%, mainly due to proper intensive care with appropriate supportive therapy (14–16).

There have been over 20 outbreaks of EVD in the past 40 years in Africa, including Zaire in 1976, Sudan in 1976, Congo (DRC) in 1995, Uganda in 2000–2001, and Congo (ROC) in 2003. These have shown the importance of preparedness to deal with the situation (17, 18) in order to minimise human loss. In 2014, the outbreak of EVD in West Africa was declared as a public health emergency of international concern (PHEIC) by the World Health Organization (WHO), with a projected estimate of 1.2 million deaths (19, 20). As of 13 September 2015, there have been 28,220 reported confirmed, probable, and suspected cases of EVD (21). EVD, by nature, mostly affects economically deprived/poor countries where there is limited capacity to respond to the incidences of disease. This in turn impacts negatively on national infrastructure and disease management (22). Though there is some evidence of controlling and managing infectious disease using appropriate means, the controlling of diseases or infection using health systems intelligence is patchy.

Problem analysis

Zoonoses are defined as infectious diseases that are naturally transmitted between wild or domesticated vertebrate animals and humans (23, 24). More than 60% of human infections arise from zoonotic pathogens; they are responsible for billions of cases of human disease and millions of deaths annually and are considered to represent an increasing threat to global health (24). Although many zoonotic infections are stably established (enzootic) in animal populations and transmit from animals to people with little or no subsequent person-to-person transmission, some such as Ebola virus can spread efficiently within the human population leading to localised outbreaks (24). Statistics reveal that children and mothers who are poor and marginalised are particularly vulnerable to this disease (25), especially in developing nations where health and environment systems are fragile, fragmented, and non-responsive in meeting people's healthcare needs. It has been argued that the lack of strong public healthcare delivery systems has been a key factor in the failure to halt the development of the disease (26). Community ignorance due to poor education and knowledge, and ineffective primary care systems at the local levels, are likely to lead to the development of myths, stigma, and anxiety associated with EVD and its mode of transmission, constraining adoption of methods of protection and personal hygiene practices (27). Osungbade and Oni (28) claim that the control measures for EVD were undermined by several factors: lack of a clinically proven vaccine and virus-specific treatment, weak health systems including poor environment, and traditional socio-cultural beliefs and practices. Furthermore, healthcare professionals are not appropriately trained in how to manage cases during an outbreak situation, and the resources needed to prevent the spread of disease are unavailable (2). Demographic changes, changing human behaviour, political violence in civil war and ethnic conflicts, ignorance, and poor health infrastructure are considered as key determinants for exacerbating these problems (3, 29). These attributes would certainly create some challenges in disease identification, notification, and characterisation, as well as undermining collaborative endeavours for the access to and provision of disease surveillance and treatment (30).

Ebola is now a great priority for global health security (26, 31). The multiple challenges identified would require a range of interventions to halt an epidemic. LMICs are not coping with the current challenges of Ebola, not only because they have poor and fragile systems, but also because there are poor infectious surveillance and response systems in place. That has had an impact due to the poor epidemiological responses to emerging disease outbreaks, therefore community initiatives would be important for disease prevention, surveillance, and community-based treatment and support (32). Evidence shows that large-scale and coordinated efforts, both at national and international levels, contribute to supporting both affected and at-risk nations through developing response systems and strengthening health capacities (26, 33).

Identification of potential cases is always problematic in several LMICs, particularly with respect to contact tracing and infection control, as well as prevention prior to diagnosis. Several studies demonstrate that better disease

surveillance, improved education, improved knowledge-associated socio-ecological factors, and improved financial capacities would improve the local and national health system in terms of control measures (28, 34). Borchert et al. (35) claim that three important systems at the public health levels – laboratory systems, information systems, and networking and coordination systems – would be able to detect and then respond to health threats. In addition, developing some tools and approaches related to diagnostics and novel therapies, including vaccines, and implementing an early warning reporting system (EWARS), would certainly contribute to health system improvement (27).

Thus, poor health systems have significant impacts in terms of their ability to strengthen disease surveillance, patients' care (and isolation), infection control, developing incident management systems, and disease test/screening. It is, therefore, important to improve EVD care and support at both the individual and the systemic levels (31). In addition, WHO's capacity is important in playing a role in the development of new essential vaccines (4).

The exact impact of EVD is still unknown, but it has clearly left a great burden on health systems as well as threatening the sustainability of health programmes, besides which insecurity, civil strife, and political instability might lead to displacement of populations (36, 37). Since 2014, Guinea has recorded a significant decline (over 31%) in outpatient visits to hospitals due to the combination of EVD with other diseases (38). Child health services were affected the most, as the evidence reveals that cases of diarrhoea and acute respiratory infection among under-5 children decreased significantly by about 60%, mainly due to adverse effects [reduced hours, service closures, loss of health workers (10% of the deaths) and service suspensions] on service access and utilisation. Iyengar et al. (39) argue that the outbreak has developed a profound risk of escalating the mortality and morbidity of maternal and newborn patients; for example, in Liberia, a 9–14% reduction in antenatal visits, and the proportion of deliveries utilising the healthcare facilities has dropped by 9–33%, so it is important to prioritise maternal and newborn survival issues in such humanitarian crises.

Strategic options

Hewlett et al. (40) argue that there must be an adequate understanding of local people's socio-political and economic situations, as well as psychological insight into how health service users, health practitioners, and the local people may respond to a biological crisis to ensure that response efforts bring appropriate strategies to minimise such suffering (41). Similarly, appropriate measures to protect healthcare professionals physically and emotionally, and to train them to provide appropriate, safe clinical care, are essential. In addition, providing education and training support to healthcare professionals on disease control and surveillance, and generating awareness of veterinary public health (2) are necessary to reduce the risk of contracting disease, as the vast majority of transmissions of Ebola during an outbreak such as the current one are person-to-person (25). Recent experiences have thrown up a substantial research agenda. This would focus on building up an Ebola isolation unit, strengthening disease surveillance, and identifying and examining the source of the outbreak, so as to introduce prevention and control measures (42).

The WHO (43) representation of health systems encompasses both organisations and people, together with their actions, directed towards meeting people's healthcare needs through design and delivery of responsive and financially fair systems. These thereby offer the best or most efficient care using available human and material resources. Ebola cannot be eradicated, but it can be managed. Robust health systems – enhancing and strengthening capacity to develop constant surveillance and outbreak verification within the public health infrastructure – are an essential step to the control and management of current and future Ebola virus outbreaks (44).

As we have seen in relation to HIV/AIDS and cholera, outbreaks place particular stress on those public health systems that are least able to cope with them. Senior managerial capacity is diminished as front-line staff are infected. Additionally, the ability to undertake efficient and effective supervision of district-level management and front-line staff is compromised. These staff will themselves be already facing extraordinary demands on their capacity and capability to deal directly with the outbreak at the local level. If management systems are already weak in general, in the event of an Ebola outbreak they will be stretched beyond their breaking point. While external support will understandably be directed towards providing additional resource for the immediate management of the outbreak, it is important that longer term support is also provided to ensure that local health systems are strengthened and better prepared for a future outbreak or threat of an outbreak. In Antoun and Reich's (45) view, health systems should be reformed in such a way that they seek to 'improve performance, advance equity, and resolve challenges'. In addition, bringing the system into focus through a systems-thinking lens, that is, designing/evaluating system-level interventions with system-wide effects, assessing the main effects within the contextual paradigms and involving multi-disciplinary and multiple stakeholders, would help to understand the situations better in terms of knowing not only what works, but what works for whom under what circumstances (46).

Better systems thinking would make health systems-strengthening investments and interventions effective, as it would bring an opportunity for interaction between the actors and components of the systems. Similarly, other prevention measures are

1. restriction of the movement of persons and goods from epidemic-affected areas and coordination for the effective combating of epidemic outbreaks in the future (47);
2. engaging with key community members – decreasing stigma, fear, and demoralising perceptions (48);
3. adopting a multi-disciplinary approach, including case identification and management, infection control, and social mobilisation, as well as understanding of local contexts to develop and adapt prevention messages and control measures (49); and
4. establishing intersectoral as well as trans-disciplinary surveillance response systems through EWARS, adequate collaboration, funding, participation from wider stakeholders, research innovation for vaccine development and pursuing global health initiatives to establish surveillance systems with EWARS, including research–action interventions (27).

At the broader level, an holistic approach is clearly needed, 'understanding [. . .] the nature of public health systems and the shifts from a medical paradigm to a more holistic paradigm' (50), encompassing human ecology, socio-economic, political, environmental and policy agendas, with appropriate division of responsibilities locally, nationally, and globally through interdisciplinary collaboration (2, 51). Kim-Farley (52) argues that 'only through worldwide concerted action will the effort to control infectious disease be effective'. Additionally, trained/qualified healthcare professionals with adequate supplies of personal protective equipment, and the development of standard operating procedures, are needed (33). It is equally important to set up permanent testing/disease surveillance facilities in under-served areas – the sort of places that would be able to run a qRT-PCR block, ELISAs, and rapid diagnostic tests at point of care (53), as well as basic immunohistochemistry with enough generators and technology to be able to store supplies. Third, community-based strategies emphasising prevention, treatment, response, and recovery are paramount. Building up health infrastructure is the sensible long-term solution for managing Ebola, and is a necessary response to the combination of rapid population growth and a decaying health system in several African countries. In addition, positive thinking towards Ebola patients/survivors, and exploring appropriate community supports (education, counselling and psycho-social supports) are critical to minimise potential anxiety, myths, and stigma (32).

Synthesising the strategic options outlined above would suggest four broad domains within which specific problems are encountered. The first is the wider social and economic context within which outbreaks of Ebola have occurred. The second is the lack of vaccines and virus-specific treatments. The third is the nexus of systemic weaknesses in the healthcare delivery system. The fourth is the absence of meaningful community engagement. Of these four domains, the first may be the most important for achieving long-term sustainable impact, but is the domain least amenable to intervention during the course of a particular episode. The second domain will be considered briefly below. However, it is the third and fourth domains, which we see as being inextricably linked, which offer the best prospects for medium-term intervention, thereby strengthening the capability of the health system to respond more effectively to any future outbreak.

Vaccines and therapies

Prior to the EVD outbreak in West Africa, progress in developing effective vaccines and therapies had been slow, in part due to the low numbers of cases associated with EVD outbreaks. Since the recent outbreak, progress has been accelerated and a number of therapies have been tested in clinical trials; however, none to date have successfully demonstrated a significant therapeutic effect (27). Additionally, as noted by Tully et al. (54), current treatments are expensive, production can be difficult to scale up, none are suitable for use prophylactically, and all require supervision from already overstretched front-line workers in overstretched Ebola treatment centres.

Perhaps more usefully, development of an effective vaccine should offer long-term, preferably lifelong, protection for an individual as well as protection for unvaccinated individuals in the community through herd immunity. To expedite the development of a suitable vaccine, international consortia have been formed to accelerate collaborative multisite trials of two candidate Ebola virus vaccines: cAd3-EBOZ and rVSV-EBOV, while a third vaccine, a combination prime-boost vaccination regimen of Ad26- and MVA-EBOV entered a Phase I trial (54). Crucially, ethical and regulatory approvals for these trials were prioritised to reduce the time taken to initiate clinical trials. Henao-Restrepo et al. (55) report on the interim analysis of a trial of rVSV-ZEBOV in Guinea, West Africa. The VSV-EBOV vaccine consists of a vesicular stomatitis virus genetically engineered to express Ebola glycoproteins; and the vaccine variant known as rVSV-ZEBOV specifically expresses glycoproteins of the Zaire Ebola virus or ZEBOV. The trial, involving 7651 people, indicated that rVSV-ZEBOV might be highly efficacious and safe in preventing EVD, and is most likely effective at the population level when delivered during an EVD outbreak *via* a ring vaccination strategy – a similar strategy to that used in the final stages of the smallpox eradication campaign (56). However, a number of adverse events were reported during the study and safety assessment is ongoing. It is also unclear at this stage how a wide-scale immunisation programme would be funded or implemented within LMICs in the future.

Health system strengthening

The literature identifies a number of discrete areas of systemic weakness: training of healthcare professionals; poor infection surveillance and response systems; infection control; contact tracing; laboratory systems; information systems; networking and coordination systems; and community ignorance and absence of community engagement. A strategy of health systems strengthening would address these through two closely connected strategic developments. The first would be the decentralisation of systemic planning and management, and the second would be an enhanced agenda of community engagement.

Decentralisation allows for more responsive decision-making (57). This is particularly critical when a system is in crisis mode. The most effective deployment of local resources is a matter best determined closest to the point of impact. Reassignment, or the co-option of *ad hoc* local resources, should not be contingent on higher level authorisation. Appropriate training programmes, designed in accord with national and regional guidelines but tailored to the local circumstance, will ensure that valuable knowledge (both of disease-specific issues and of the operation of general management and disease response systems) is most effectively disseminated.

Decentralisation can strengthen the functioning of routine systems. Even when these are developed in keeping with quite stringent central requirements, decentralisation encourages better feedback and generates a deeper understanding of their underlying purpose. Decentralisation also frees the local healthcare system from log-jams that may occur at higher levels of the system. The experience of HIV/AIDS has taught us that one of the most debilitating impacts of an outbreak is the absence of senior officers at the higher levels of the system, which can lead to systemic paralysis throughout the system.

Decentralisation and enhanced community engagement go hand in hand. Recent experiences confirmed by the available literature inform us that trust is a critical factor in ensuring an effective community-level response. This is itself predicated on a genuine two-way dialogue which generates understanding – practitioner understanding of community knowledge, beliefs and views, and community understanding of the rationale for measures being implemented (50). In the context within which there is a strong motivation for family members to hide incidences, community knowledge is vital. This will be provided when community members feel that they can trust the response that disclosure will initiate. Full community engagement is also critical to the identification of *ad hoc* resources that may be co-optable at the local level.

Conclusion

Health systems strengthening does not offer a panacea. And health systems strengthening is most effective when it is implemented as part of a longer term strategy of health systems development. As countries move stutteringly into remission, it is paramount that the recent experience, particularly the aspect of disease surveillance and monitoring with community engagement, is thoroughly evaluated, that longer term lessons are learnt, and that measures are implemented that can lessen the impact of any future outbreaks and (we would argue) can make the local healthcare system more effective in its more normal day-to-day operation.

Conflict of interest and funding

References

1. Sobarzo A, Groseth A, Dolnik O, Becker S, Lutwama JJ, Yavelsky V, et al. Detection of *Sudan ebolavirus* (strain Gulu) epitopes that are targets of the humoral immune response in survivors. Int J Infect Dis 2010; 14: e461–2.
2. Kahn RE, Clouser DF, Richt JA. Emerging infections: a tribute to the one medicine, one health concept. Zoonoses Public Health 2009; 56: 407–28.
3. Goel NK, Gurpreet, Swami HM. How to deal with emerging and re-emerging infectious diseases globally? Internet J Bio Anthropol 2006; 1: 1. Available from: http://ispub.com/IJBA/1/1/6314 [cited 10 April 2015].
4. Dentico N. Ebola and the global governance of health. Recenti Prog Med 2014; 105: 405–6.
5. Rid A, Emanuel E. Ethical considerations of experimental interventions in the Ebola outbreak. Lancet 2014; 384: 1896–9.
6. Petticrew M, Roberts H. Systematic reviews in the social sciences: a practical guide. Oxford: Blackwell Publishing; 2006.
7. Institute of Medicine. Finding what works in healthcare: standards for systematic review. Washington, DC: National Academic Press; 2011.
8. Beeching NJ, Fenech M, Houlihan CF. Ebola virus disease. BMJ 2014; 349: g7348. doi: http://dx.doi.org/10.1136/bmj.g7348
9. Boardman A. Viral haemorrhagic fever. Prim Care Update Ob Gyns 2004; 10: 81–6.
10. Liu WB, Li ZX, Du Y, Cao GW. Ebola virus disease: from epidemiology to prophylaxis. Mil Med Res 2015; 2: 7. doi: http://dx.doi.org/10.1186/s40779-015-0035-4
11. Van Kerkhove MD, Bento AI, Mills HL, Ferguson NM, Donnelly CA. A review of epidemiological parameters from Ebola outbreaks to inform early public health decision-making. Sci Data 2015; 2: 150019. doi: http://dx.doi.org/10.1038/sdata.2015.19
12. Dowell SF, Mukunu R, Ksiazek TG, Khan AS, Rollin PE, Peters CJ. Transmission of Ebola hemorrhagic fever: a study of risk factors in family members, Kikwit, Democratic Republic of the Congo, 1995. Commission de Lutte contre les Epidémies à Kikwit. J Infect Dis 1999; 179(Suppl 1): S87–91.
13. Chan M. Ebola virus disease in West Africa–no early end to the outbreak. N Engl J Med 2014; 371: 1183–5. doi: http://dx.doi.org/10.1056/NEJMp1409859
14. Fletcher TE, Brooks TJ, Beeching NJ. Ebola and other viral haemorrhagic fevers be prepared, with new guidance featuring old and well established principles. BMJ 2014; 349: g5079.
15. Bausch DG, Sprecher AG, Jeffs B, Boumandouki P. Treatment of Marburg and Ebola haemorrhagic fevers: a strategy

for testing new drugs and vaccines under outbreak conditions. Antiviral Res 2008; 78: 150–61.

16. Feldmann H, Geisbert TW. Ebola haemorrhagic fever. Lancet 2011; 377: 849–62.

17. Hewlett BL, Hewlett BS. Providing care and facing death: nursing during Ebola outbreaks in central Africa. J Transcult Nurs 2005; 16: 289–97.

18. Bres P. The epidemic of Ebola haemorrhagic fever in Sudan and Zaire, 1996: introductory notes. Bull World Health Organ 1978; 56: 245.

19. World Health Organization. WHO statement on the meeting of the International Health Regulations Emergency Committee regarding the 2014 Ebola outbreak in West Africa. Geneva: WHO; 2014. Available from: http://www.who.int/mediacentre/news/statements/2014/ebola-20140808/en/ [cited 7 October 2015].

20. WorldNetDaily. 1.2 million Ebola deaths projected in 6 months, 2014. Available from: http://www.wnd.com/2014/09/1-2-million-ebola-deaths-projected-in-6-months/#wyHds09yz2ufE7Km.99 [cited 10 April 2015].

21. World Health Organization. Ebola Situation Report. Geneva: WHO; 2015. Available from: http://apps.who.int/ebola/current-situation/ebola-situation-report-16-september-2015 [cited 21 September 2015].

22. Ghazanfar H, Orooj F, Abdullah MA, Ghazanfar A. Ebola, the killer virus. Infect Dis Poverty 2005; 4: 15.

23. World Health Organization. Neglected zoonotic diseases. Geneva: WHO; 2015. Available from: http://www.who.int/neglected_diseases/diseases/zoonoses/en/ [cited 6 October 2015].

24. Karesh WB, Dobson A, Lloyd-Smith JO, Lubroth J, Dixon MA, Bennett M, et al. Ecology of zoonoses: natural and unnatural histories. Lancet 2012; 380: 1936–45.

25. Souza MJ. One health: zoonoses in the exotic animal practice. Vet Clin North Am Exot Anim Pract 2011; 14: 421–6.

26. Shrivastava S, Shrivastava P, Ramasamy S. Ebola disease: an international public health emergency. Asian Pacific J Trop Dis 2015; 5: 4.

27. Tambo E, Ugwu EC, Ngogang J. Need of surveillance response systems to combat Ebola outbreaks and other emerging infectious diseases in African countries. Infect Dis Poverty 2014; 3: 29.

28. Osungbade KO, Oni AA. Outbreaks-of Ebola virus disease in the West African sub-region. Afr J Med Med Sci 2014; 43: 87–97.

29. World Health Organization. Ebola virus disease. Geneva: WHO; 2014.

30. Leditschke J, Rose T, Cordner S, Woodford N, Pollanen M. The development of a protocol for post-mortem management of Ebola virus disease in the setting of developed countries. Forensic Sci Med Pathol 2015; 11: 262–7.

31. Arwady MA, Bawo L, Hunter JC, Massaquoi M, Matanock A, Dahn B, et al. Evolution of Ebola virus disease from exotic infection to global health priority, Liberia, mid-2014. Emerg Infect Dis 2015; 21: 578–84.

32. Abramowitz SA, McLean KE, McKune SL, Bardosh KL, Fallah M, Monger J, et al. Community-centered responses to Ebola in urban Liberia: the view from below. PLoS Negl Trop Dis 2015; 9: e0003706.

33. Pathmanathan I, O'Connor K, Adams M, Rao C, Kilmarx P, Park B, et al. Rapid assessment of Ebola infection prevention and control needs – six districts, Sierra Leone, October 2014. MMWR Morb Mortal Wkly Rep 2014; 63: 1172–4.

34. Mirkovic K, Thwing J, Diack PA, Centers for Disease Control and Prevention. Importation and containment of Ebola virus disease – Senegal, August–September 2014. MMWR Morb Mortal Wkly Rep 2014; 63: 973–4.

35. Borchert J, Tappero J, Downing R, Shoemaker T, Behumbiize P, Aceng J, et al. Rapidly building global health security capacity – Uganda Demonstration Project, 2013. MMWR Morb Mortal Wkly Rep 2014; 63: 73–6.

36. Stanturf JA, Goodrick SL, Warren ML, Jr., Charnley S, Stegall CM. Social vulnerability and Ebola virus disease in rural Liberia. PLoS One 2015; 10: e0137208.

37. Okeibunor JC, Ota MC, Akanmori BD, Gumede N, Shaba K, Kouadio KI, et al. Polio eradication in the African region on course despite public health emergencies. Vaccine 2015; doi: http://dx.doi.org/10.1016/j.vaccine.2015.08.024

38. Barden-O'Fallon J, Barry MA, Brodish P, Hazerjian J. Rapid assessment of Ebola-related implications for reproductive, maternal, new born and child health service delivery and utilization in guinea. PLoS Curr 2015; doi: http://dx.doi.org/10.1371/currents.outbreaks.0b0ba06009dd091bc39ddb3c6d7b0826

39. Iyengar P, Kerber K, Howe CJ, Dahn B. Services for mothers and newborns during the Ebola outbreak in Liberia: the need for improvement in emergencies. PLoS Curr 2015; doi: http://dx.doi.org/10.1371/currents.outbreaks.4ba318308719ac86fbef91f8e56cb66f

40. Hewlett BS, Epelboin A, Hewlett BL, Formenty P. Medical anthropology and Ebola in Congo: cultural models and humanistic care. Bull Soc Pathol Exot 2005; 98: 230–6.

41. Hall RC, Hall RC, Chapman MJ. The 1995 Kirwit Ebola outbreak: lessons hospitals and physicians can apply to future viral epidemics. Gen Hosp Psychiatry 2008; 30: 446–52.

42. Bitekyerezo M, Kyobutungi C, Kizza R, Mugeni J, Munyarugero E, Tirowmwe F, et al. The outbreak and control of Ebola viral haemorrhagic fever in a Ugandan medical school. Trop Doct 2002; 32: 10–15.

43. Krause PR. Interim results from a phase 3 Ebola vaccine study in Guinea. Lancet 2015; 386: 831–5.

44. Krech R, Kieny M. The 2014 Ebola outbreak: ethical use of unregistered interventions. Bull World Health Organ 2014; 92: 622.

45. Antoun J, Reich M. Welcome to health systems & reform!. Health Systems Reform 2015; 1: 1.

46. Savigny D, Adam T. Systems thinking for health systems strengthening. Geneva: WHO; 2009.

47. Jalloh M. Analysing the economic consequences of an epidemic outbreak: experience from the 2014. Ebola outbreak in West Africa. J Nat Sci Res 2014; 4: 21.

48. Nyarko Y, Goldfrank L, Ogedegbe G, Soghoian S, de-Graft Aikins A, NYU-UG-KBTH. Preparing for Ebola Virus Disease in West African countries not yet affected: perspectives from Ghanaian health professionals. Global Health 2015; 11: 7.

49. Barboza P. Response to international health crises: Marburg haemorrhagic fever, Province of Uíge, Angola, 2005. Bull Épidémiol Hebd 2006; 7: 336–9.

50. Thunhurst C. Public health systems analysis – where the River Kabul meets the River Indus. Global Health 2013; 9: 39.

51. Simonsen L, Kane A, Lloyd J, Zaffran M, Kane M. Unsafe injections in the developing world and transmission of blood borne pathogens: a review. Bull World Health Organ 1999; 77: 789–800.

52. Kim-Farley R. Principles of infectious disease control. In: Detels R, Beaglehole R, Lansang M, Gulliford M, eds. Oxford textbook of public health. Oxford: Oxford University Press; 2009, pp. 1602–22.

53. Bhadelia N. Rapid diagnostics for Ebola in emergency settings. Lancet 2015; 386: 833–5.

54. Tully CM, Lambe T, Gilbert SC, Hill AV. Emergency Ebola response: a new approach to the rapid design and development of vaccines against emerging diseases. Lancet Infect Dis 2015; 15: 356–9.

55. Henao-Restrepo AM, Longini IM, Egger M, Dean NE, Edmunds WJ, Camacho A, et al. Efficacy and effectiveness of an rVSV-vectored vaccine expressing Ebola surface glycoprotein: interim results from the Guinea ring vaccination cluster-randomised trial. Lancet 2015; 386: 857–66.

56. Krause PR. Interim results from a phase 3 Ebola vaccine study in Guinea. Lancet 2015; 386: 831–5.

57. Regmi K. Decentralising health services: a global perspective. New York/Heidelberg/Dordrecht/London: Springer; 2014.