Adapting the mobile laboratory to the changing needs of the Ebolavirus epidemic

Timothy J. J. Inglis

School of Pathology and Laboratory Medicine, University of Western Australia, Crawley, Western Australia 6009, Australia

The current Ebolavirus disease (EVD) epidemic in West Africa has now been running for >1 year and has been an international health emergency for >6 months. As the weekly number of new cases falls, the World Health Organization is preparing its response to the final stages of the epidemic. The final totals will exceed 20,000 cases and 8000 deaths. An ability to adapt disease countermeasures including laboratory support to the changing epidemiology of EVD has become a matter of urgency. This article considers the planning, development and modification of a flexible microbiology laboratory response, and describes logistic and operational considerations for clinical and public health microbiologists.

No battle was ever won according to plan, but no battle was ever won without one.

[Dwight D. Eisenhower]

Introduction

These are challenging times for clinical microbiology and infectious diseases. The first signs of a fall in the number of new Ebolavirus disease (EVD) cases came after almost 1 year of sustained international effort in the three West African countries where high-level transmission persisted. The current West African EVD epidemic defied conventional public health wisdom and continues to provoke debate over the best methods of containment. Over 4000 EVD cases occurred in West Africa during the first 6 months of the epidemic and >2000 of these died from the infection (WHO Ebola Response Team, 2014). As of 1 February 2015, cumulative totals of 21,724 cases and 8641 deaths had been reported (World Health Organization, 2014a), but the World Health Organization (WHO) noted that these figures were likely to underestimate the full scale of the epidemic. Health care workers caring for patients with EVD had to cope in poorly resourced conditions and featured prominently amongst the early casualties (Forrester et al., 2014). Developed countries with substantial clinical service, laboratory support and disease control capacity were quick to offer assistance. The Institut Pasteur in Lyon confirmed the presence of Ebolavirus (EBOV) in clinical specimens from Guinea in March 2014, and the Centers for Disease Control (CDC) promptly dispatched epidemiologists to support national governments and the WHO outbreak response effort (Dixon et al., 2014). Contributions from European, North American and Asian countries via government and non-government organizations rapidly expanded the international response. By June 2014, the WHO media centre was able to report that field laboratories were being set up to support disease control efforts in the three countries at the centre of the epidemic (World Health Organization, 2014b). By August, teams from other African nations were active in the battle against West African EVD. Notable amongst these was a field laboratory team from the South African Centre for Communicable Diseases that deployed to Sierra Leone to assist disease control specialists (National Institute of Communicable Diseases, 2014). Despite international assistance, the epidemic continued to break out in new locations, cross land boundaries and cause a steady attrition of local health workers. The escalating numbers and continued high mortality led the WHO Director-General to take the unusual step of declaring the West Africa EBOV epidemic an international health emergency and call for international cooperation on EVD control in an address to the United Nations on 25 September 2014 (Director-General, World Health Organization, 2014). Government reticence was countered in professional circles by advocacy for deployment of subject matter experts to meet humanitarian and international assistance obligations, and provide fair access to the benefits of research (Rid & Emanuel, 2014).

This complex, dynamic environment there were competing claims on limited disease treatment and control resources. Médecins Sans Frontières was quick to develop in-country experience managing EVD patients, and turned down offers of government funding, insisting that specialist expertise was more valuable than dollars. Microbiology laboratory support lagged behind field epidemiology and became a limiting factor in disease control efforts (Kelly, 2014). After revising and implementing viral haemorrhagic fever plans to counter the anticipated threat of EVD in returning international travellers, we joined the growing body of support for a proactive deployable laboratory response and prepared

Abbreviations: CDC, Centers for Disease Control; MAP, Military Appreciation Process; WHO, World Health Organization.
to assist our public health colleagues who at that point were already working in the epidemic zone (Inglis, 2014).

**Expeditionary microbiology**

The Centers for Disease Control website (CDC, 2014) lists the EBOV tests employed in their high-level-security laboratories. Whilst full operational details of their field laboratory protocols have yet to be published, heavy reliance has clearly been placed on real-time PCR assays for the Zaire ebolavirus (Nyenswah et al., 2014). The European Mobile Laboratory deployed a team of scientists to Guinea (World Health Organization, 2014c), where they developed local diagnostic capability including EBOV field PCR assays. These and a growing number of other groups strengthen local pathology laboratory services with field laboratories at treatment centres and national laboratories, where other febrile illness such as malaria, dengue, enteric fever and other tropical infections feature in the differential diagnosis of EVD (Schoepp et al., 2014).

No matter how comprehensive the test repertoire, deployed laboratories face a choice of operating as a fixed, centralized laboratory with high test throughput or as a more flexible, mobile laboratory able to relocate as the epidemiology changes. With a home base in specialized central laboratories, expatriate field laboratory staff bring a bias towards centralized services. However, the ability to take laboratory services closer to a newly infected population can be advantageous. We demonstrated this effect when deploying a molecular laboratory to a military field hospital in Queensland during the influenza A/H1N1/09 pandemic (Inglis et al., 2011), and have repeated these field laboratory deployments over the last 6 years (Inglis, 2013). Close proximity of a reliable laboratory assay for an emerging viral infection acts as a trigger for early treatment and decisive disease control measures (Grolla et al., 2012). In our hands, the deployable laboratory payload has steadily decreased (Inglis, 2013) due to improvements in thermocyclers and nucleic acid amplification technology that enable reliable operation under austere environmental conditions, including from out of a vehicle (Inglis et al., 2013).

**Just-in-time planning for emerging infectious diseases**

Carefully argued, scientifically based health intelligence is a necessary step towards planning a field laboratory deployment. We use a systematic approach to integration of the microbiological features of a newly emergent infectious disease with its other characteristics in order to establish a series of priorities for the laboratory, clinical and public health response (Inglis, 2007). A rapid escalation in case load also demands just-in-time planning skills to deliver effective medical countermeasures. For this we use a logistic planning method resembling the widely used Military Appreciation Process (MAP) to develop a laboratory logistics plan.

---

**Fig. 1.** MAP adapted to mobilization of deployable laboratory support to an emerging infectious disease response. Communicable disease intelligence preparation informs all stages of MAP and here relies on the causality criteria described previously (Inglis, 2007). Mission analysis includes the stated purpose, method, intended end state and time appreciation. Course of action development seeks to design several distinctive options without pre-judging their overall suitability. This call is made at the course-of-action assessment stage and scores the relative benefits of each option. The best overall option can then draw from strengths of other options to deliver a set of instructions on how to implement the best plan.
(Inglis et al., 2008). The MAP is less familiar in public health circles, where planning methods often rely on a slowly consultative, design ethos (Walker, 2010) and is explained in outline in Fig. 1.

Starting with a foundation of health intelligence, the MAP then takes mission analysis as its first step. This comprises a clear statement of the purpose, method and intended end-state of the proposed laboratory deployment. It is evident from the WHO Director-General that this was to strengthen EVD control measures through deployment of specialist health workers in order to bring the EVD epidemic under control. The implied laboratory mission was and continues to be support for EVD control and treatment by deploying additional field laboratory capability to deliver timely and accurate EVD confirmation. As in any time-critical activity, the timeline is an important part of mission analysis and is generally calculated backwards from the stated objective. A failure to bring the EVD epidemic under control in its first few months clearly led to its continued expansion and persistence, and permitted changes in its epidemiology through continued EVD mutation (Gire et al., 2014). Whilst the original worst-case scenario of an estimated 550 000–1 400 000 cases by 20 January 2015 has not been realized, continuing intervention is needed to eliminate transmission before a second year passes. The time available for further planning revisions needs to include deployment of newly focussed mobile laboratory teams and all the logistic stages of that process. Miscalculation of logistic timelines causes delays to operational deployment, loss of coordination with staff already in location and a possible loss of perishable mission-critical supplies such as laboratory reagents.

The next step is course-of-action development – the methodical description of a series of several distinct options, i.e. a highly mobile portable field laboratory, transportable variations or an expanded high-throughput laboratory with mobile components. These options will differ in more than scale and could have, for example, an attached treatment centre, in-house field epidemiology or dedicated transport. The case for and against each option should not be considered until the options have been described in detail. The final stage of the planning process is to choose the best course of action by comparing the feasibility, affordability, sustainability and distinctiveness of each one. The weaker features of the highest scoring option can be improved by including parts of the other options. A small, cohesive group activity can then move onto the execution stage where they develop a detailed set of instructions. A larger group will need to delegate the development of a subsidiary version of the MAP to their task-specific subgroups, who will clearly have less time to complete their specific plans.

**Bringing the plan to fruition**

Plans cannot address every eventuality in a complex, dynamic epidemic setting. Previous field laboratory deployments of the ‘Lab Without Walls’ have had to cope with a range of unexpected problems (Inglis, 2013), some of which have put project viability at risk. No assumptions can be made about access to higher-level maintenance, trouble-shooting support, data interpretation or reagent resupply. Sustainability of a field laboratory relies on maintenance and running repairs whilst deployed. The mission analysis phase may have made assumptions that do not hold up during preliminary field experience. News filtering back with returning early volunteers confirmed a need for self-sufficiency in many aspects of field work (Australian Broadcasting Corporation, 2014). Clear laboratory objectives, simple and consistent protocols, and robust assays may be more important than appeared from early planning. The tragic and unnecessary loss of health education specialists due to violence highlights the importance of physical security arrangements (BBC News, 2014), lack of which could make a mobile laboratory operation unworkable in remote locations. Even at this stage of the international epidemic response, placing mobile laboratory teams in the epidemic zone continues to challenge well-equipped multinational groups. The smaller, lighter and more flexible they are, the better their prospects of arriving on location with fully functional equipment and viable reagents. Larger field laboratories need to move in stages starting with a preparatory team, followed by a main body, then finishing off with back-up stores, equipment spares and other sustainment supplies. The precise configuration of the mobile laboratory team, its equipment, reagents and personal effects depends on their intended throughput, assay repertoire, means of transport and duration of operation. Long-term sustainability relies on a local capability-building component which places an extra demand on staff, equipment and reagents for the deployed laboratory. The main focus of the deployment therefore needs to be agreed before departure and should be reiterated during the deployment to avoid a subtle shift with time known as ‘mission creep’.

**Conclusion**

The EVD challenge in Western Australia was driven by a steady trickle of returning international travellers, most of whom are employed in the international resources sector. Some of these developed a febrile illness at or shortly after their return to Australia and required EVD laboratory tests. The long distances involved in medical evacuation within the state led us to consider the possible need to deploy an EVD diagnostic capability and quarantine specialists to remote communities or industrial sites in remote parts of Western Australia. This contingency was fed into the MAP whilst mobile field laboratory planning was already under way, illustrating the iterative nature of the planning process. With little modification to the emerging plan, we were able to develop a concept of operations based on existing commercial off-the-shelf equipment. We then operated the prototype mobile laboratory in a series of field trials. The mobile capability that emerged from a just-in-time planning process has wider application in the public health laboratory
response to more commonly encountered emerging infections, such as epidemic influenza and exotic arbovirus infection (Inglis et al., 2011). The adaptable nature of mobile laboratory planning and development makes our approach a candidate for a more generic laboratory response to other rapidly emerging infectious diseases. Inclusion of these planning, preparation and logistic skills in the public health laboratory repertoire prepare us for the next global infectious disease crisis.

Acknowledgements
The opinions expressed in this article are the personal views of the author and do not necessarily represent those of Western Australian or Australian Commonwealth government departments or their employees.

References


