Epidemic preparedness: why is there a need to accelerate the development of diagnostics?

Rosanna W Peeling, Maurine Murtagh, Piero L Olliaro

Global epidemics of infectious diseases are increasing in frequency and severity. Diagnostics are needed for rapid identification of the cause of the epidemic to facilitate effective control and prevention. Lessons learned from the recent Ebola virus and Zika virus epidemics are that delay in developing the right diagnostic for the right population at the right time has been a costly barrier to disease control and prevention. We believe that it is possible to accelerate and optimise diagnostic development through a five-pronged strategy: by doing a global landscape analysis of diagnostic availability worldwide; through strategic partnerships for accelerating test development, in particular with vaccine companies to identify novel diagnostic targets; by creating and sharing repositories of data, reagents, and well characterised specimens for advancing the development process; by involving key public and private stakeholders, including appropriate regulatory bodies and policy makers, to ensure rapid access for researchers to diagnostics; and last, by fostering an enabling environment for research and access to diagnostics in the countries that need them. The need is great, but not insurmountable and innovative and faster development pathways are urgently required to address current shortfalls.

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Introduction

Epidemics of infectious diseases are increasing in frequency and severity, and are a global health security threat.[1,2] Diagnostics are needed to detect the cause of epidemics and facilitate effective control and prevention.[3] Diagnostic tests typically take 2–5 years to develop and 5–10 years to undergo evaluations, regulatory approval, and policy and guideline development, before procurement and rollout can be initiated. These timelines are far too long for diagnostics to be developed and deployed during outbreaks. Innovative solutions to accelerate this pathway are urgently needed as an integral part of epidemic preparedness.

During the Ebola virus and Zika virus epidemics, the WHO prequalification programme and the US Food and Drug Administration (FDA) offered the WHO Emergency Use Assessment and Listing Procedure (EUAL) and the FDA Emergency Use Authorization (EUA),[4] respectively, to accelerate regulatory review and approval for diagnostics needed to respond to the emergency. Although these efforts are welcome, on closer examination, the root cause of the lack of effective diagnostic tools for epidemic preparedness lies in barriers upstream of diagnostic test approval processes. In this Personal View, we examine these barriers to diagnostic development in response to outbreaks, using Zika virus, dengue virus, and chikungunya virus infections, and suggest innovative solutions for epidemic preparedness.

Diagnostics for outbreak preparedness: current needs

Pathogens of epidemic potential include both bacteria and viruses. Although strengthening diagnostic capacity for bacterial diseases is important especially in under-resourced settings, these pathogens cause outbreaks that tend to be smaller and more localised than viruses. A number of these viruses share symptoms, geographical distribution, and vectors. For Zika, dengue, and chikungunya viruses, despite some differentiating symptoms, clinical manifestations and relevant epidemiological exposure alone are generally not reliable indicators of any of these infections.[5,6] Therefore, a definitive diagnosis requires dedicated testing methods, which depend on the infection timeline as illustrated for arbovirus infections generally (figure).

During the acute phase of an arbovirus infection (generally the first 5–6 days), direct test detection methods using viral isolation or detection of viral RNA in plasma or sera by nucleic acid amplification tests (NAATs) or tests to detect viral antigens are recommended; after the period of viraemia serological testing, such as IgM ELISAs and immunofluorescence assays, are recommended.[6] The kinetics of infection and recommended testing algorithm are similar for dengue virus, chikungunya virus, and Zika virus.[6]

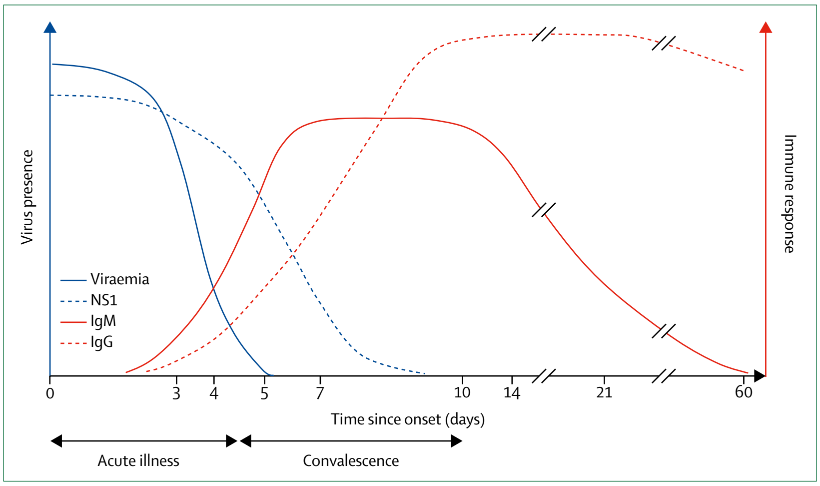

Figure: **Time course of an arboviral infection and related diagnostic approaches**
Detection of virus via viral RNA with RT-PCR or NASBA, or via viral antigens such as positivity for NS1. Detection of immune response to the virus quantified via serological assays, such as ELISA. NASBA=nucleic acid sequence-based amplification. NS1=non-structural protein 1.

	Required operational characteristic	Required diagnostic tests	Comments
Surveillance and alerts	High-throughput assays for population-based surveys; specimens that are easy to collect and transport	IgM tests for routine arbovirus surveillance; alerts are created when increased number of IgM-positive reports or unusually high IgM titres are observed	IgM antibodies can persist for 5–6 months
Case detection to identify cause of outbreak	Detect virus or antigen in acute infection (days 0–5 after onset of symptoms); high sensitivity and specificity; easy to use at point of care; affordable	Confirmed cases: virus isolation, NAAT, antigen detection, or IgM or IgG seroconversion. Probable cases: IgM-positive or elevated IgG titre	Onset of illness for dengue virus and chikungunya virus can be defined by the appearance of fever, but for Zika virus infection it is often ill defined; what test to use depends on when patients seek care
Surveys to assess extent of outbreak to inform control	Incidence and prevalence estimates to assess the extent of the outbreak and where the hotspots are	Can use surveillance tools but high specificity required	..
Research	To improve the understanding of the pathogenesis; to monitor the effectiveness of interventions	Can use a combination of case detection and surveillance tools	..

NAAT=nucleic acid amplification test.

Table 1: **Use-case categories of diagnostic tests in arboviral disease outbreaks**

More generally, diagnostic tests needed for arboviral and other infections with outbreak potential must be suited to their intended purpose and to the settings where they will be used. To be fit for purpose, the product specifications for each use case need to be based on a range of factors, including the pathogen, the host response to infection and pathogenesis, and health system considerations such as when and where the patients present for care. We summarise below the four use-case categories of diagnostic tools required for epidemic preparedness of arboviruses (table 1).

Diagnostic tools can be used as part of a surveillance programme to alert health authorities to the possible emergence of an outbreak. For arboviruses, high-throughput immunoassays detecting IgM antibodies are customarily used. Although antibodies are not ideal markers of active infection for surveillance purposes because they can persist for 5–6 months, an outbreak alert can be created when increased numbers of IgM-positive reports or unusually high IgM titres are observed in the population.

Case detection can be used to identify the cause of an outbreak; tests must be highly sensitive and specific in detecting the virus directly through virus isolation or its nucleic acid or antigen in the acute phase of infection. Infection can also be diagnosed retrospectively through seroconversion of IgM or a four-fold increase in IgG between the acute and convalescent serum samples collected 14 days or more apart. In a retrospective study of dengue infections,[7] a combination of IgM and either NAAT or antigen detection tests has proved effective in extending the window of detection of acute infection.

Surveys can also be used to assess the extent of an outbreak, inform control strategies, and to identify hotspots. High-throughput, ideally highly specific, tests that can be used across populations are required.

Research to assess the effect of control interventions is needed, as is the need to improve knowledge of the pathogen and its pathogenesis through a combination of surveillance and case detection tests. The absence of Zika virus-specific immunoassays to identify infection incidence or prevalence in pregnant women prevented researchers from doing population-based studies to assess the risk of microcephaly and other neurological disorders in neonates born to women infected during pregnancy. Having population-based tools also allows assessing the effect of any control interventions.

As to the settings where tests for outbreaks will be used, health system considerations are important. In low-resource settings, sophisticated molecular assays and high-throughput immunoassays can be used in central reference laboratories; but at lower levels of the health-care systems, such as regional laboratories and district hospitals, tests have to be appropriate to the technical competency of the test users—typically lay health providers rather than laboratory technicians—and to environmental demands of the tests, such as high temperatures, humidity, and dust.

Ideally, the infectious disease community would have diagnostics available for use in outbreaks, including dengue virus, Zika virus, and chikungunya virus, that meet the ASSURED criteria (ie, affordable by those at risk of infection, sensitive, specific, user-friendly, rapid, equipment-free, and deliverable to those who need it),[8] and could confirm a diagnosis across the entire temporal spectrum of the infection from onset to convalescence and be able to reliably distinguish the target infection from other infections. Unfortunately, such outbreak diagnostics are not available today. Therefore, the question is—in the context of outbreaks, where time is of the essence—how can the community most effectively make certain that the required tests are available at the right time for the right patient?

Accelerating test development before the next outbreak

Innovative approaches are needed to accelerate the development and deployment of assays before the next epidemic. Substantial progress can be made outside epidemics, but this progress requires a range of partners coming together. In the wake of the Ebola virus crisis in 2015, WHO initiated a call for open platform technologies as part of the Research and Development Blueprint to enable vaccines, therapeutics, diagnostics, and reagents to be rapidly developed, validated, and deployed in the event of an epidemic.[9] This initiative was highly welcome, but for diagnostics it is still in its infancy.

We propose a five-pronged strategy: landscape analysis of diagnostics available and in the development pipeline; partnerships for accelerating test development, in particular, working with vaccine companies to identify novel diagnostic targets; creating and sharing repositories of data, reagents, and well characterised specimens to facilitate development; involving key public and private stakeholders, including regulators and policy makers in the financing and epidemic preparedness process; and fostering a sustainable, durable, conducive environment for both research and development and access that does not just last the time of an outbreak, when there are demand and incentives, which cease to exist as soon as the epidemic is over—leaving an unfinished agenda for the next epidemic.

Diagnostic landscapes

Analyses of the diagnostic landscape can provide up-to-date knowledge of diagnostics available and in the pipeline, helping researchers and stakeholders to identify where gaps exist. Diagnostic landscapes should be done for key outbreak pathogens, whether viral or bacterial, as part of epidemic preparedness. They are an important first step in accelerating test development by targeting the scope of the needed diagnostics. For example, landscapes for dengue virus, Zika virus, and chikungunya virus can be accessed through the International Diagnostic Centre website.[10] Of the three diseases, the diagnostic landscape for dengue virus is the most robust, as these outbreaks have been occurring with regular intervals for decades. Despite being just a snapshot of a rapidly evolving area, the landscapes reflect important challenges in incentivising diagnostic test development and commercialisation outside of epidemic periods.

Sensitive and specific molecular tests for dengue virus exist, but many are not commercialised, their usefulness is limited to the short period of viraemia, and they are not affordable for many endemic countries. Isothermal amplification assays are promising in terms of affordability and ease of use, but commercialisation will depend on advance purchase commitments or analysis of market potential. Most NAATs for chikungunya virus are laboratory-developed, real-time PCR. Only one NAAT is commercially available outside of the USA but its performance has not been independently validated. This situation reflects the lack of attention to chikungunya virus outbreaks compared with dengue virus and Zika virus.

Since the beginning of the Zika virus epidemic and as of April 30, 2017, 25 Zika virus-specific NAATs are available, of which one was developed by the US Centers for Disease Control and Prevention (CDC), but not commercialised. Seven are multiplex NAATs that have been commercialised for distinguishing among Zika virus, dengue virus, and chikungunya virus (table 2). Recently, the first NAAT Zika virus test was approved by the US FDA to screen blood donor samples.[11]

Antigen detection assays provide a more affordable means of identifying a pathogen compared with NAATs. Antigens can typically be detected for longer periods in a patient's blood than viral nucleic acid. Non-structure protein 1 (NS1) antigen tests for dengue virus, available as laboratory-based immunoassays or rapid diagnostic tests, are highly specific but tend to be less sensitive than NAATs. They can be used to confirm acute infection at point of care. A few commercial NS1 assays for dengue virus have been evaluated and found to have acceptable performance.[12–14] NS1 assays for Zika virus are in development.

The most widely used IgM assay for dengue virus infection is the Dengue IgM Capture ELISA (MAC-ELISA), a laboratory-based test developed by the US CDC. Because IgM antibodies persist for 5–6 months, a positive IgM test result is only suggestive of an acute infection. Other limitations include the inability to determine dengue virus serotype and potential antibody cross-reactivity with other flaviviruses. Combining an NS1 antigen test with an IgM test has shown to diagnose more than 90% of acute dengue virus infections using a single blood specimen taken in the first 7 days after onset of symptoms.[7] Although showing good performance, these combined assays will require additional studies.[15] There are many commercially available ELISAs for the detection of chikungunya IgM antibodies, and at least two rapid diagnostic tests. Studies have reported that some ELISAs showed poor or inconsistent performance.[16,17]

For more on **landscapes for dengue virus, Zika virus, and chikungunya virus** see http://www.idc-dx.org

Few serological tests exist for Zika virus IgM and IgG, but their usefulness is confounded by extensive cross-reactivity with other flaviviruses, in particular dengue virus. Plaque reduction neutralisation tests are not always able to resolve this cross-reactivity.[18] Eight immunoassays to detect Zika virus IgM antibodies have been developed and commercialised, only three of which received EUA approval, two have Conformité Européenne (CE) in-vitro diagnostic marking, but none received EUAL approval, and there have been no peer-reviewed publications of their performance (table 3).

The ability to distinguish among Zika virus, dengue virus, and chikungunya virus infections is important for patient management, and multiplex assays–including rapid diagnostic tests–have been developed or are in development for this purpose (table 3).

In summary, the landscapes show that, while several molecular assays generally have been developed for dengue virus, chikungunya virus, and Zika virus, few are

	US FDA EUA approval	WHO EUAL approval	CE IVD marking	Independent review (validation)
Zika only assays				
TaqPath Zika virus kit (Thermo Fisher Scientific, Waltham, MA, USA)	Yes	..	..	No
RealStar Zika virus RT-PCR kit 1.0 (Altona-Diagnostics GmbH, Hamburg, Germany)	Yes	Yes	Yes	Yes
Zika ELITe MGB kit US (ELITechGroup Solutions, Puteaux, France)	Yes	..	..	No
Zika virus real-time RT-PCR kit (Liferiver/Shanghai ZJ Biotech, Shanghai, China)	..	Pipeline	..	No
Abbott RealTime Zika (Abbott Molecular, Chicago, IL, USA)	Yes	..	..	No
Zika virus RNA qualitative real-time RT-PCR (Focus Diagnostics, a subsidiary of Quest Diagnostics, Cypress, CA, USA)	Yes	..	..	No
Aptima Zika virus assay (Hologic, Marlborough, MA, USA)	Yes	..	..	No
Zika virus real-time RT-PCR test (Viracor-IBT Laboratories, Lee's Summit, MO, USA)	Yes	..	..	No
VERSANT Zika RNA 1.0 assay (kPCR) kit (Siemens Healthcare Diagnostics, Berkeley, CA, USA)	Yes	..	..	No
xMAP MultiFLEX Zika RNA assay (Luminex Corporation, Austin, TX, USA)	Yes	..	..	No
Sentosa SA ZIKV RT-PCR test (Vela Diagnostics US, Fairfield, NJ, USA)	Yes	..	Yes	No
Zika virus detection by RT-PCR test (ARUP Laboratories, Salt Lake City, UT, USA)	Yes	..	..	No
Gene-RADAR Zika virus test (Nanobiosym Diagnostics, Cambridge, MA, USA)	Yes	..	..	No
Genesig easy kit (Primerdesign, Liverpool, UK)	..	..	..	No
Detection kit for Zika virus RNA (PCR-Fluorescence Probing; DaAn Gene, Sun Yat-sen University, Guangzhou, China)	..	Pipeline	..	No
careGENE Zika virus RT-PCR kit (WELLS BIO, Seoul, South Korea)	..	Pipeline	..	No
Zika virus—single check (Genekam Biotechnology AG, Duisburg, Germany)	..	..	Yes	No
FTD Zika virus (Fast Track Diagnostics, Sliema, Malta)	..	..	Yes	No
Multiplex assays				
Trioplex real-time RT-PCR (Thermo Fisher Scientific, Waltham, MA, USA)	Yes	..	..	Yes
AccuPower ZIKV (DENV, CHIKV) multiplex real-time RT-PCR Kit (Bioneer, Daejeon, South Korea)	..	Yes	Yes	No
VIASURE Zika, Dengue & Chikungunya real-time PCR detection kit (Certest Biotec, Zaragoza, Spain)	..	..	..	No
FTD Zika/Dengue/Chik assay (Fast-Track Diagnostics, Sliema, Malta)	..	..	Yes	No
DiaPlexQ ZCD virus detection kit (SolGent, Daejeon, South Korea)	..	..	..	No
CII-ArboViroPlex rRT-PCR (Columbia University, New York, NY, USA)	Yes	..	..	No
TaqPath Zika virus triplex kit (ThermoFisher Scientific, Waltham, MA, USA)	..	..	..	No

FDA EUA=Food and Drug Administration Emergency Use Authorization. EUAL=Emergency Use Assessment and Listing Procedure. CE= Conformité Européenne. IVD=in-vitro diagnostic.

Table 2: **Commercially available molecular (nucleic acid detection) tests for the detection of Zika virus and for the simultaneous detection of Zika, dengue, and chikungunya viruses**

commercialised and many are only available at central laboratories. Not enough antigen or antibody assays, or both, are commercially available for each of the pathogens or for the pathogens combined. For tests that are available, their analytical performance has not been sufficiently validated. More commercially available, independently validated assays (molecular, antigen, and antibody) for use at or near point of care are urgently needed and are key for epidemic preparedness.

Partnerships for accelerating test development

Whatever the pathogens, the development of new test platforms and assays can be a long process, typically taking 2–5 years to develop and 5–10 years to undergo evaluations, regulatory approval, and policy and guideline development, before procurement and rollout can be initiated.[19] Rapid development and commer-cialisation of NAATs is possible because once a viral genome sequence is known it is relatively easy to select primers and probes for a unique region of the genome as a diagnostic target.

The development process for an antigen detection test takes longer. Identifying a suitable viral protein as a diagnostic target requires knowledge of the proteins expressed during the course of infection, their abundance, and ease of detection. Once the antigen is identified, high-avidity and highly specific monoclonal antibodies need to be generated so that they can be used as capture antibodies in the diagnostic assay. Usually this process requires cloning, expressing, and purifying the protein before injecting it into animals to produce monoclonal antibodies.

Similarly, antibody detection assays are usually developed by scanning the humoral antibody response to identify the most immunodominant epitopes, and

	US FDA EUA approval	WHO EUAL approval	CE IVD marking	Independent review (validation)
Zika only ELISAs				
ADVIA Centaur Zika test (Siemens Healthcare Diagnostics, Berkeley, CA, USA)	Yes	··	··	No
ZIKV detect IgM capture ELISA (InBios International, Seattle, WA, USA)	Yes	Pipeline	··	No
LIAISON XL Zika capture IgM assay (DiaSorin SpA, Saluggia, Italy)	Yes	··	··	No
NovaLisa Zika virus IgM µ-capture ELISA (NovaTec Immunodiagnostica GmbH, Dietzenbach, Germany)	··	Pipeline	Yes	No
Anti-Zika virus ELISA (IgM or IgG; EUROIMMUN, Lübeck, Germany)	··	Pipeline	Yes (RUO)	No
ZIKV IgG and IgM ELISA kit (DIA.PRO Diagnostic Bioprobes Srl, Sesto, Italy)	··	Pipeline	··	No
STANDARD E Zika IgM ELISA (SD Biosensor, Gyeonggi-do, South Korea)	··	Pipeline	··	No
RecombiLISA Zika IgM ELISA kit (CTK Biotech, San Diego, CA, USA)	··	Pipeline	··	No
Zika only rapid diagnostic tests				
STANDARD Q Zika IgM/IgG test (SD Biosensor, Gyeonggi-do, South Korea)	··	Pipeline	··	No
DPP Zika IgM assay system (Chembio Diagnostic Systems, Medford, NY, USA)	Yes	Pipeline	Yes	No
TELL ME FAST Zika virus IgG/IgM antibody rapid test (Biocan, Coquitlam, BC, Canada)	··	··	Yes	No
Multiplex immunoassays				
IIFT arbovirus fever mosaic 2 (IgG or IgM; EUROIMMUN AG, Lübeck, Germany)	··	Pipeline	Yes	No
recomLine Tropical Fever IgG; recomLineTropical Fever IgM MIKROGEN (Diagnostik, Dreieich, Germany)	··	··	Yes	No
Multiplex rapid diagnostic tests				
STANDARD Q Zika/Dengue Trio (SD Biosensor, Gyeonggi-do, South Korea)	··	Pipeline	··	No
TELL ME FAST Dengue, Chikungunya & Zika virus combo test (Biocan Diagnostics, Coquitlam, BC, Canada)	··	··	··	No

The Zika MAC-ELISA (US Centers for Disease Control and Prevention, Atlanta, GA, USA) is not included because it is not commercially available.[12] FDA EUA=Food and Drug Administration Emergency Use Authorization. EUAL=Emergency Use Assessment and Listing Procedure. CE= Conformité Européenne. IVD=in-vitro diagnostic. RUO=research use only.

Table 3: **Commercially available immunoassays for Zika virus and for the simultaneous detection of Zika, dengue, and chikungunya viruses**

then generating the protein target to capture the antibody of choice for the test. Selecting, characterising, and producing high-affinity antibodies in large volume takes months. Putting the assay together requires extensive optimisation before it can be evaluated on human samples. Their performance can only be ascertained against a NAAT reference standard in a large number of infected and uninfected individuals. This process can take more than 2–3 years if each developer has to seek sources of well characterised specimens and negotiate purchasing or partnering agreements. Strategic partnerships with vaccine companies searching for neutralising antibodies can accelerate the identification of diagnostic targets for antigen and antibody assays. The recent announcement of Coalition for Epidemic Preparedness and Innovations (CEPI) might provide the framework for such collaboration and partnerships between vaccine and diagnostic discovery.[20] Major stakeholders could facilitate and accelerate diagnostics development if they can agree on target product profiles. This development will need to consider the desired tests to set out the appropriate operational and performance characteristics needed for the test platform or assay, including minimal and optimal targets. For example, in 2014, WHO published a target product profile for a Zaire Ebola virus rapid test.[20]

Creating and sharing repositories of data, reagents, and well characterised specimens

Creating and sharing repositories of data, reagents, and specimens for advancing the test development process is required. Once companies commence development of a new diagnostic assay, the need for well characterised clinical specimens becomes an important factor. The key barrier in the diagnostic crisis for epidemic-prone diseases is the paucity of well characterised, ethically obtained, standardised clinical specimens and their relevant meta-data from confirmed cases during different stages of the disease. These reference materials underpin the entire process of bringing a test into use. The inability to obtain such materials can greatly delay product development, test optimisation, clinical validation, and production introduction, adoption, and uptake. Goncalves and colleagues' call for a coordinated network of selected, quality-assured laboratories to be organised in advance of outbreaks,[21] so that once an outbreak occurs, they are ready to conduct clinical validation studies. Strategies and protocols are required in coordination with regulatory authorities.[22] A virtual biobank has been developed, as part of the Europe Union (EU)-funded consortium ZikaPLAN, for this purpose.[20] Specimens from a network of Good Clinical Practice-Good Clinical Laboratory Practice (GCP-GCLP) compliant evaluation sites will be used under a strict code of governance to facilitate test development and evaluation, and for research. During the Zika virus outbreak, the US CDC and the European Virus Archive made strains and specimens available but only on a limited scale. This act led to many companies paying high prices for specimens from sources without assurance of the quality of the characterisation. Proactive efforts to develop mechanisms for greater reagent availability and sharing of reagents such as antigens, monoclonal antibodies, reference and clinical materials, and standardised protocols are urgently needed.

Involving key stakeholders

It is imperative to involve key stakeholders throughout the process of test development for outbreak pathogens, including developers, regulators, researchers, implementers, funders, users (public and private health providers), and beneficiaries. Although organisations involved in vaccine delivery such as GAVI, the Vaccine Alliance and CEPI support ongoing efforts to address outbreak response, financing, and market sustainability, none of these organisations provide similar support for diagnostic development.[21] The Foundation for Innovative New Diagnostics (FIND) and other public and private stakeholders are advocating for a Global Forum for Diagnostic Preparedness.[23]

Fostering an enabling and sustainable environment

Fostering an enabling and sustainable environment for both research and access that does not just last the time of an outbreak is required. For example, from February, 2016 (ie, when the Zika virus emergency was declared), to September, 2017, the US FDA granted EUA status to 19 requests for Zika virus diagnostics. As of February, 2018, 18 active EUAs remain (tables 2, 3);[5] of these diagnostics, only one molecular test for use in blood screening has subsequently achieved full-standard in-vitro diagnostic status.[11] Clearly, the agenda is unfinished.

Creating an ongoing enabling environment for the public and private sectors to work together is essential, especially as the development of new diagnostics to the point of validation and regulatory approval is but part of a longer process towards implementation, uptake, and access. Additional challenges remain for companies in scaling up and marketing a new diagnostic, whereas in-country barriers include budget constraints and overall health systems weaknesses, typically including supply chain, training, and quality assurance.

To ensure funding and continued attention for diagnostic preparedness, we suggest that this diagnostic strategy be incorporated into countries' efforts to build integrated health and laboratory systems towards the attainment of the Sustainable Development Goals of leaving no one behind. This will achieve the dual purpose of fast tracking the development, validation, and access of diagnostics for diseases of outbreak potential, and of using this strategy to develop diagnostics of public health importance to strengthen health system and improve health outcomes in between epidemics.[24,25]

Conclusion

The public sector should provide the directional perspective to these developments, a role that the Special Programme for Research and Training has traditionally had for drugs and diagnostics. This approach would involve a sequence of actions starting with designing the right products all the way to putting them into use, including convening consultations to design relevant target product profiles; creating funding opportunities for target discovery, including partnering with vaccine companies to identify novel diagnostic targets; setting up a virtual biobank of laboratories and clinical evaluation sites for rapidly validating the targets with well characterised specimens, so that interested companies can develop kits; do multicentre evaluations on the performance and operational characteristics of the test kit; and, if the results are satisfactory, facilitate its review by regional regulatory harmonisation bodies to streamline it into use. The need is there; innovative approaches can be framed to address these needs.

Contributors

All authors contributed equally to the writing of this paper.

Declaration of interests

PLO is a staff member of WHO at the time of the writing. The opinions expressed in this paper are those of the authors, and do not necessarily reflect the opinions and views of WHO. RWP and MM declare no competing interests.

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